# Master of Technology
# (Structural Engineering)

## CURRICULUM

## (Effective from 2024 - 25 Onwards)


**DEPARTMENT OF CIVIL ENGINEERING**
**NATIONAL INSTITUTE OF TECHNOLOGY**
**TIRUCHIRAPPALLI - 620 015, INDIA.**

### *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 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*

**PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)**

| | |
|---|---|
| **PEO 1** | Graduates of the Programme will contribute to the development of new materials, design and construction of structures that are sustainable |
| **PEO 2** | Graduates of the Programme, as part of an organization or as Entrepreneurs, will continue to learn to harness evolving technologies |
| **PEO 3** | Graduates of the Programme will be professional Structural Engineers, Teaching Professionals and engage in R&D works with ethical and societal responsibility. |

**PROGRAMME OUTCOMES (POs)**

| | |
|---|---|
| **PO1** | An ability to independently carry out research /investigation and development work to solve practical problems |
| **PO2** | An ability to write and present a substantial technical report/document |
| **PO3** | Students should be able to demonstrate a degree of mastery over Structural Engineering. The mastery should be at a level higher than the requirements in the bachelor program of Civil Engineering |

## CURRICULUM STRUCTURE

## M. Tech. (STRUCTURAL ENGINEERING)

| Components | Number of Courses | Credits | Total Credits |
|---|---|---|---|
| Programme Core (PC) | 3 / Semester (6 in 1st Year) | 24 | **42** |
| Programme Elective (PE)* | 3 / Semester (6 in 1st Year) | 18 | |
| Essential Laboratory Requirements (ELR) | 3 in 1st Year | 6 | **6** |
| Internship/Industrial Training/ Academic Attachment (I/A) | 1 | 2 | **2** |
| Open Elective (OE) / Online Course (OC)#@ | 2 (I – IV Semester) | 6 | **6** |
| Project Phase-I | 1 | 12 | **12** |
| Project Phase-II | 1 | 12 | **12** |
| **Total** | **20** | **80** | **80** |

**Note:**

* ***ONLINE COURSES EQUIVALENT TO PROGRAMME ELECTIVES (Optional):*** *Out of 6 programme electives, students have the option to study two online courses (Maximum of 1 per semester in the 1st year of Study) equivalent to programme elective courses through NPTEL / Swayam.*

\# ***OPEN ELECTIVES (OE) / ONLINE COURSE (OC) (Compulsory):*** *Students must complete 6 credits between I and IV semester either through online courses of their choice from NPTEL / Swayam (discipline electives / other electives) or through open electives offered by the PG programmes of the institute other than Structural Engineering*

@ ***MICROCREDITS (Optional):*** *Students may opt 3 courses of 1 credit (4-week duration) each as microcredits or 2 courses (2 credits (8-week duration) & 1 credit (4-week duration) instead of 1 OE/OC.*

# CURRICULUM

## SEMESTER I

| Code | Course of Study | Credit |
|---|---|---|
| MA624 | Applied Mathematics for Structural Engineering | 4 |
| CE651 | Theory of Elasticity and Plasticity | 4 |
| CE653 | Advanced Reinforced Concrete Design | 4 |
| | Programme Elective I | 3 |
| | Programme Elective II | 3 |
| | Programme Elective III / Online (NPTEL) | 3 |
| CE655 | Structural Engineering Laboratory | 2 |
| CE657 | Computational Laboratory for Structural Engineers | 2 |
| | | **25** |

## SEMESTER II

| Code | Course of Study | Credit |
|---|---|---|
| CE652 | Structural Dynamics | 4 |
| CE654 | Finite Element Analysis of Structural Members | 4 |
| CE656 | Advanced Design of Metal Structures | 4 |
| | Programme Elective IV | 3 |
| | Programme Elective V | 3 |
| | Programme Elective VI / Online (NPTEL) | 3 |
| CE658 | Structural Design Studio | 2 |
| | | **23** |

## SUMMER TERM (evaluation in the III semester)

| Code | Course of Study | Credit |
|---|---|---|
| CE659 | Internship / Industrial Training / Academic Attachment (I/A) (8 weeks) | 2 |

## SEMESTER III

| Code | Course of Study | Credit |
|---|---|---|
| CE697 | Project Work (Phase I) | 12 |

## SEMESTER IV

| Code | Course of Study | Credit |
|---|---|---|
| CE698 | Project Work (Phase II) | 12 |

## OPEN ELECTIVES (OE) / ONLINE COURSE (OC)

| Code | Course of Study | Credit |
|---|---|---|
| | # (To be completed between I to IV semester) | 6 |

**PROGRAMME ELECTIVES**

| Sl. No. | Code | Course of Study | Credit |
|---|---|---|---|
| 1. | CE661 | Matrix Methods of Structural Analysis | 3 |
| 2. | CE662 | Non - Linear Analysis | 3 |
| 3. | CE663 | Reliability analysis of structures | 3 |
| 4. | CE664 | Stochastic Processes in Structural Mechanics | 3 |
| 5. | CE665 | Structural Optimization | 3 |
| 6. | CE666 | Failure Analysis of Structures | 3 |
| 7. | CE667 | Forensic Engineering and Rehabilitation of Structures | 3 |
| 8. | CE668 | Fracture Mechanics | 3 |
| 9. | CE669 | Advanced Steel and Concrete Composite Structures | 3 |
| 10. | CE670 | Design of Metal Structures II | 3 |
| 11. | CE671 | Design of Thin-walled Steel Structures | 3 |
| 12. | CE672 | Stability of Structures | 3 |
| 13. | CE673 | Theory of Plates and Shells | 3 |
| 14. | CE674 | Analysis and Design of Tall Buildings | 3 |
| 15. | CE675 | Design of Offshore Structures | 3 |
| 16. | CE676 | Seismic Design of Structures | 3 |
| 17. | CE677 | Wind Effects on Structures | 3 |
| 18. | CE678 | Advanced Concrete Technology | 3 |
| 19. | CE679 | Prefabricated Structures | 3 |
| 20. | CE680 | Prestressed Concrete Structures | 3 |
| 21. | CE681 | Smart Structures and Applications | 3 |
| 22. | CE682 | Special Concrete | 3 |
| 23. | CE683 | Structures in Disaster Prone Areas | 3 |
| 24. | CE684 | Design of Boiler Structures | 3 |
| 25. | CE685 | Design of Bridges | 3 |
| 26. | CE686 | Façade design and engineering | 3 |
| 27. | CE687 | Design of Structures for Accidental Loads | 3 |
| 28. | CE688 | Green building Design | 3 |
| 29. | CE689 | Hydraulic Structures | 3 |
| 30. | CE690 | Structures for Power Plants | 3 |
| 31. | CE691 | Soil Structure Interaction | 3 |
| 32. | CE692 | Seismic Design of Steel Structures | 3 |
| 33. | CE693 | Introduction to 3D printing technology | 3 |
| 34. | CE694 | Modelling, Simulation and Computer Applications | 3 |
| 35. | CE695 | Random Vibrations | 3 |
| 36. | CE696 | Uncertainty Modeling, Analysis and Quantification | 3 |

**OPEN ELECTIVES (OE) (Courses from Programme Electives, that will be Open Electives for other PG Specialization, if it is offered as Programme Elective for the respective specialization)**

| Sl. No. | Code | Course of Study | Credit |
|---|---|---|---|
| 1. | CE665 | Structural Optimization | 3 |
| 2. | CE678 | Advanced Concrete Technology | 3 |

| | | | |
|---|---|---|---|
| 3. | CE685 | Design of Bridges | 3 |
| 4. | CE688 | Green building Design | 3 |
| 5. | CE691 | Soil Structure Interaction | 3 |
| 6. | CE693 | Introduction to 3D printing technology | 3 |
| 7. | CE694 | Modelling, Simulation and Computer Applications | 3 |
| 8. | CE696 | Uncertainty Modeling, Analysis and Quantification | 3 |

***(For OE courses refer the curriculum of other PG specializations)***

**MICROCREDITS (MC) [Students can opt 3 courses of 1 credit (4-week duration) each as microcredits or 2 courses (2 credits (8-week duration) & 1 credit (4-week duration) instead of 1 OE/OC]**

| Sl. No. | Code | Course of Study | Credit |
|---|---|---|---|
| 1. | | Equivalent to Online Course (May be completed between Semester I to Semester IV) | 3 |

**Electives [Choices]**

1. **Program Elective (PE) Courses**

**Option 1:**

| Semester | No. of Programme Electives | No. of Online Programme Electives | Credits for Programme Elective Courses |
|---|---|---|---|
| I | 3 | 0 | 9 |
| II | 3 | 0 | 9 |

**Option 2:**

| Semester | No. of Programme Electives | No. of Online Programme Electives | Credits for Programme Elective Courses |
|---|---|---|---|
| I | 2 | 1 | 9 |
| II | 3 | 0 | 9 |

**Option 3:**

| Semester | No. of Programme Electives | No. of Online Programme Electives | Credits for Programme Elective Courses |
|---|---|---|---|
| I | 3 | 0 | 9 |
| II | 2 | 1 | 9 |

**Option 4:**

| Semester | No. of Programme Electives | No. of Online Programme Electives | Credits for Programme Elective Courses |
|---|---|---|---|
| I | 2 | 1 | 9 |
| II | 2 | 1 | 9 |

## 2. Online Courses (OC) / Open Elective (OE) Courses

**Option 1:**

| Semester | No. of Open Elective Courses | No. of online Courses | | |
|---|---|---|---|---|
| | | 3 Credit courses | 2 credit courses | 1 credit course |
| I - IV | - | 2 | - | - |
| | - | 1 | 1 | 1 |
| | - | 1 | - | 1+1+1 |

**Option 2:**

| Semester | No. of Open elective Courses | No. of online Courses | | |
|---|---|---|---|---|
| | | 3 credit courses | 2 credit courses | 1 credit course |
| I - IV | 1 | 1 | - | - |
| | 1 | - | 1 | 1 |
| | 1 | - | - | 1+1+1 |

**Option 3:**

| Semester | Open elective Courses | No. of online Courses | | |
|---|---|---|---|---|
| | | 3 credit courses | 2 credit courses | 1 credit course |
| I - IV | 2 | - | - | - |

## COURSE OUTCOME AND PROGRAMME OUTCOME MAPPING

### PROGRAMME CORE (PC)

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

| Course Code | Course Title | CO | Course outcomes<br>At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| MA624 | Applied Mathematics for Structural Engineering | CO1 | To solve boundary value problems using Laplace and Fourier transform techniques. | 2 | 1 | 2 |
| | | CO2 | To solve fluid flow and heat flow problems using conformal mapping. | 3 | 2 | 1 |
| | | CO3 | To develop the mathematical methods of applied mathematics and mathematical physics with an emphasis on calculus of variation and integral transforms. | 3 | 2 | 1 |
| | | CO4 | To apply vector calculus in linear approximations, optimization, physics and engineering. | 1 | 1 | 2 |
| | | CO5 | To solve physical problems such as elasticity, fluid mechanics and general relativity. | 3 | 2 | 1 |
| CE651 | Theory of Elasticity and Plasticity | CO1 | To apply elastic analysis to study the fracture mechanics. | 3 | 2 | 3 |
| | | CO2 | To apply linear elasticity in the design and analysis of structures such as beams, plates, shells and sandwich composites. | 3 | 2 | 3 |
| | | CO3 | To apply hyper-elasticity to determine the response of elastomer-based objects. | 3 | 2 | 3 |
| | | CO4 | To analyse the structural sections subjected to torsion. | 3 | 2 | 3 |
| | | CO5 | To understand various theories of failure and concept of plasticity. | 3 | 2 | 3 |
| CE652 | Structural Dynamics | CO1 | To analyse structures subjected to blast loading and apply finite element method. | 2 | 1 | 1 |

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|---|---|---|---|---|---|---|
| | | CO2 | To analyse structures using various methods of vibration analysis. | 2 | 2 | 2 |
| | | CO3 | To use structural property matrices to study structural behaviour. | 3 | 2 | 2 |
| | | CO4 | To arrive at solution to Eigen value problem and idealize multi storied frames. | 2 | 2 | 1 |
| | | CO5 | To perform deterministic analysis for earthquake response. | 3 | 1 | 1 |
| CE653 | Advanced Reinforced Concrete Design | CO1 | To understand structural behaviour of flexural members and cracks | 3 | 2 | 3 |
| | | CO2 | To compute deflection of flexural members. | 3 | 1 | 3 |
| | | CO3 | To understand redistribution of moments. | 3 | 2 | 3 |
| | | CO4 | To design compression members and make interaction charts | 3 | 2 | 3 |
| | | CO5 | To understand the concept of shear and torsion. | 3 | 2 | 3 |
| CE654 | Finite Element Analysis of Structural Members | CO1 | To use displacement models to solve practical problems in structural engineering. | 3 | 2 | 2 |
| | | CO2 | To apply numerical techniques of finite element analysis to solve real time problems. | 3 | 1 | 2 |
| | | CO3 | To make use of shape function and interpolation function to study structural behaviour. | 3 | 1 | 1 |
| | | CO4 | To apply linear and quadratic elements in the finite element analysis of various types of structures. | 2 | 1 | 1 |
| | | CO5 | To predict structural behaviour using strain displacement matrix and element stiffness matrix. | 3 | 2 | 2 |
| CE656 | Advanced Design of | CO1 | To compute wind load on structures and determine deflection of beams. | 2 | 3 | 3 |

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|---|---|---|---|---|---|---|
| | Metal Structures | CO2 | To understand design of stacks. | 2 | 3 | 2 |
| | | CO3 | To get familiarized with cold formed steel sections and different types of connections. | 2 | 3 | 1 |
| | | CO4 | To get exposed to design of compression, tension members and base plates. | 2 | 2 | 1 |
| | | CO5 | To design members subjected to torsion and understand plastic analysis of structures. | 2 | 2 | 2 |

**LABORATORY**

| Course Code | Course Title | CO | Course Outcomes At the end of the course student will be able | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| CE655 | Structural Engineering Laboratory | CO1 | To arrive at concrete mix design for various types of concrete as per codal provisions. | 2 | 3 | 3 |
| | | CO2 | To be familiar with the properties of concrete and perform non-destruction testing on concrete. | 2 | 3 | 3 |
| | | CO3 | To cast and test structural RC elements for strength and deformation behaviour. | 2 | 3 | 3 |
| | | CO4 | To carry out dynamic testing on structural components. | 2 | 3 | 3 |
| | | CO5 | To assess the behaviour of structures subjected to cyclic load testing. | 2 | 3 | 3 |
| CE657 | Computational Laboratory for Structural Engineers | CO1 | To work on spreadsheets and worksheets. | 2 | 3 | 3 |
| | | CO2 | To understand regression and matrix inversion concepts. | 2 | 3 | 3 |
| | | CO3 | To arrive at programs to solve problems using numerical techniques. | 2 | 3 | 3 |
| | | CO4 | To use computer methods of structural analysis to solve structural problems. | 2 | 3 | 3 |
| | | CO5 | To work on finite element programming to solve real time problems. | 2 | 3 | 2 |

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|---|---|---|---|---|---|---|
| CE658 | Structural Design Studio | CO1 | Analyse, design and create structural drawings of RCC buildings | 2 | 3 | 3 |
| | | CO2 | Analyse, design and create structural drawings of steel industrial buildings | 2 | 3 | 3 |
| | | CO3 | Create conceptual designs and design basis reports | 2 | 3 | 3 |
| | | CO4 | Analyse and design of bridges and special structures | 2 | 3 | 3 |
| | | CO5 | Use ETABS and SAP2000 for specialised structural designs | 2 | 3 | 3 |

**PROGRAMME ELECTIVES**

| Course Code | Course Title | CO | Course outcomes | PO1 | PO2 | PO3 |
|---|---|---|---|---|---|---|
| CE661 | Matrix Methods of Structural Analysis | CO1 | To understand energy concepts in structures, characteristics of structures, transformation of information in structures. | 2 | 2 | 1 |
| | | CO2 | To perform analysis by iteration method and determine deflection of structures using Maxwell-Betti Law of Reciprocal Deflections. | 2 | 1 | 1 |
| | | CO3 | To understand generalized and constrained measurements. | 2 | 2 | 1 |
| | | CO4 | To apply principle of superposition in practical problems. | 3 | 2 | 2 |
| | | CO5 | To understand fundamental relationships for structural analysis and develop analytical models. | 3 | 2 | 2 |
| CE662 | Non-Linear Analysis | CO1 | Analyse the Frames including the Material nonlinearity. | 3 | 2 | 3 |
| | | CO2 | Analyse the Frames including the Geometry nonlinearity. | 3 | 2 | 3 |
| | | CO3 | Analyse frames using the elastic-plastic approach. | 3 | 2 | 3 |
| | | CO4 | Analyse frames using numerical solution techniques. | 3 | 2 | 3 |
| | | CO5 | Apply the Finite element method to solve nonlinear problems. | 3 | 2 | 3 |
| CE663 | Reliability analysis of structures | CO1 | Demonstrate the ability to apply basic statistical methods and probability theory to analyze structural safety and performance. | 2 | 1 | 2 |

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|---|---|---|---|---|---|---|
| | | CO2 | Analyze and interpret resistance distributions and statistical parameters for materials like concrete and steel. | 2 | 1 | 2 |
| | | CO3 | Compute the reliability of structural components using various methods | 3 | 2 | 3 |
| | | CO4 | Evaluate reliability indices for simple structural problems viz., beams, trusses. | 2 | 2 | 3 |
| | | CO5 | Apply reliability methods to solve practical civil engineering problems, ensuring the safety and performance of structures. | 2 | 2 | 2 |
| CE664 | Stochastic Processes in Structural Mechanics | CO1 | To understand basic theory of stochastic processes and its relevance in the realistic modeling of natural phenomena. | 2 | 2 | 2 |
| | | CO2 | To understand the basic theory of random variables, multiple random variables and random processes. | 2 | 2 | 2 |
| | | CO3 | To be familiar with probability distribution of a random variable | 2 | 2 | 2 |
| | | CO4 | To be familiar with covariance, conditional mean and variance. | 2 | 1 | 2 |
| | | CO5 | To understand the concept of Fourier analysis and data processing. | 1 | 1 | 2 |
| CE665 | Structural Optimization | CO1 | To use the optimization tools for the design of structures effectively. | 2 | 2 | 1 |
| | | CO2 | To understand the concept of optimality criteria and reanalysis techniques. | 1 | 1 | 1 |
| | | CO3 | To use approximation concepts and stochastic optimization methods. | 2 | 1 | 1 |
| | | CO4 | To be familiar with genetic algorithm and simulated annealing. | 2 | 2 | 1 |
| | | CO5 | To be able to work in artificial intelligence and artificial neural networks. | 2 | 2 | 1 |
| CE666 | Failure Analysis of Structures | CO1 | To identify the objective of study of fracture mechanics. | 3 | 2 | 2 |
| | | CO2 | To model linear elastic fracture mechanics. | 3 | 1 | 3 |
| | | CO3 | To simulate actual failure analysis problems in site. | 3 | 2 | 3 |

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|---|---|---|---|---|---|---|
| | | CO4 | To understand repair and maintenance of structures and product liability issues. | 2 | 3 | 2 |
| | | CO5 | To analyse and design structures for failure prevention. | 3 | 2 | 3 |
| CE667 | Forensic Engineering and Rehabilitation of Structures | CO1 | To understand the causes of failure of structures. | 2 | 1 | 2 |
| | | CO2 | To diagnose distress of structures. | 2 | 1 | 2 |
| | | CO3 | To understand various environmental problems and natural hazards. | 2 | 1 | 2 |
| | | CO4 | To be exposed to modern techniques of retrofitting. | 3 | 2 | 2 |
| | | CO5 | To be familiar with case studies. | 2 | 2 | 2 |
| CE668 | Fracture Mechanics | CO1 | To understand fracture toughness and fracture energy. | 3 | 2 | 3 |
| | | CO2 | To be familiar with energy release rate. | 3 | 1 | 2 |
| | | CO3 | To get exposed to the concept of crack mouth opening displacement. | 3 | 2 | 2 |
| | | CO4 | To understand fracture mechanics of concrete. | 3 | 2 | 3 |
| | | CO5 | To be familiar with linear and nonlinear fracture mechanics. | 3 | 1 | 3 |
| CE669 | Advanced Steel and Concrete Composite Structures | CO1 | To understand steel-concrete composite structures and types of shear connectors. | 2 | 2 | 3 |
| | | CO2 | To understand analysis and design of composite beams and deflection of composite beams using IS:11384 and EC4. | 3 | 3 | 2 |
| | | CO3 | To be familiar with composite slabs, analysis and design of composite floor systems. | 2 | 3 | 3 |
| | | CO4 | To get exposed to types of composite columns. | 2 | 3 | 3 |
| | | CO5 | To learn vibration of composite beams and cyclic behaviour of composite sections. | 2 | 3 | 3 |
| CE670 | Design of Metal Structures II | CO1 | To recollect the mechanical and material properties of stainless steel and aluminium | 2 | 1 | 3 |
| | | CO2 | To use the Indian Standard for permissible stress design and Eurocode EC9 for limit state design of aluminium structures | 3 | 2 | 3 |

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|---|---|---|---|---|---|---|
| | | CO3 | To propose the usage of stainless steel for extreme exposure structures | 3 | 2 | 3 |
| | | CO4 | To use the Eurocode for limit state design of stainless steel structures | 3 | 2 | 3 |
| | | CO5 | To design structures using fabric materials | 3 | 2 | 3 |
| CE671 | Design of thin-walled steel structures | CO1 | Basics design principle of thin walled structures | 1 | 2 | 1 |
| | | CO2 | Design of cold-formed steel members using working stress method | 2 | 2 | 3 |
| | | CO3 | Design of cold-formed steel members using Limit state method | 3 | 2 | 3 |
| | | CO4 | Design of connections and storage Racks. | 1 | 2 | 2 |
| | | CO5 | Design of steel storage Racks systems. | 1 | 3 | 2 |
| CE672 | Stability of Structures | CO1 | To understand stability of static and dynamic equilibrium. | 3 | 3 | 3 |
| | | CO2 | To evaluate static stability criteria using stability equations. | 3 | 2 | 2 |
| | | CO3 | To solve stability problems by energy method and finite difference method. | 3 | 2 | 2 |
| | | CO4 | To predict critical loads on structures. | 2 | 2 | 1 |
| | | CO5 | To create discrete and continuous models to solve stability problems. | 2 | 2 | 1 |
| CE673 | Theory of Plates and Shells | CO1 | To assess the strength of thin plates under different types of loads. | 3 | 2 | 3 |
| | | CO2 | To analyze thin plates using Navier’s method and Levy’s method. | 3 | 2 | 3 |
| | | CO3 | Analyse circular plates under axi-symmetric deflection. | 3 | 2 | 3 |
| | | CO4 | To classify different types of shells and study their behavior. | 3 | 2 | 3 |
| | | CO5 | To analyze shells using membrane theory. | 3 | 2 | 3 |
| CE674 | Analysis and Design of Tall Buildings | CO1 | To understand the design philosophy, loading, different types of frames, types of shear | 3 | 3 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | walls. | | | |
| | | CO2 | To be exposed to different lateral load resisting systems. | 2 | 2 | 1 |
| | | CO3 | To understand approximate analysis, accurate analysis and reduction techniques. | 3 | 2 | 2 |
| | | CO4 | To be familiar with design of structural elements, buckling analysis, p-delta analysis. | 3 | 3 | 3 |
| | | CO5 | To understand translational – torsional instability | 2 | 1 | 1 |
| CE675 | Design of Offshore Structures | CO1 | To understand different types of ocean structures, different structural systems of ocean structures and types of environmental loads. | 3 | 3 | 2 |
| | | CO2 | To be familiar with structural action of ocean structures, planning guidelines and design principles and regulations and codes of practice. | 2 | 2 | 1 |
| | | CO3 | To understand the concepts of foundation of ocean structures, sea bed anchors, dredging methods and equipment. | 3 | 2 | 2 |
| | | CO4 | To get exposed to materials for marine applications, deterioration of materials, inspection and testing of marine structures. | 3 | 3 | 3 |
| | | CO5 | To be familiar with non-destructive techniques, repair and rehabilitation of marine structures and structural health monitoring of marine structures. | 2 | 1 | 1 |
| CE676 | Seismic Design of Structures | CO1 | To understand the basics of earthquake engineering and how they influence the structural design. | 2 | 1 | 2 |
| | | CO2 | To understand engineering | 2 | 1 | 1 |

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|---|---|---|---|---|---|---|
| | | | seismology and building characteristics. | | | |
| | | CO3 | To learn structural irregularities, do's and don'ts in earthquake engineering design, code provision on different types of structures. | 2 | 1 | 1 |
| | | CO4 | To be familiar with structural modelling and lateral load resisting design. | 3 | 2 | 2 |
| | | CO5 | To get exposed to strength, stiffness and ductility requirements and energy dissipation devices. | 3 | 2 | 2 |
| CE677 | Wind Effects on Structures | CO1 | To understand the basics of wind engineering and how they influence the structural design. | 2 | 1 | 1 |
| | | CO2 | Analyze wind load effects on various types of structures. | 3 | 2 | 1 |
| | | CO3 | To learn bluff-body aerodynamics and various aeroelastic phenomenon | 3 | 2 | 2 |
| | | CO4 | Design structures to withstand wind loads. | 2 | 2 | 3 |
| | | CO5 | Use relevant codes and apply them for wind design of structures | 2 | 2 | 3 |
| CE678 | Advanced Concrete Technology | CO1 | To understand concrete technology, admixtures, non-destructive testing, semi destructive testing, special concrete. | 3 | 2 | 3 |
| | | CO2 | To be familiar with structure of hydrated cement paste, types of cement, cement production quality control. | 3 | 1 | 3 |
| | | CO3 | To learn transition zone in concrete, measurement of workability, properties of concrete, rheological behaviour of concrete, economic concrete mix design. | 3 | 2 | 3 |
| | | CO4 | To be exposed to strength- | 2 | 2 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | porosity relationship, failure modes in concrete, elastic behaviour in concrete, ageing properties and long term behaviour. | | | |
| | | CO5 | To better understand the causes of concrete deterioration, permeability of concrete, durability of concrete, alkali aggregation reaction. | 3 | 2 | 3 |
| CE679 | Prefabricated Structures | CO1 | To get introduced to prefabrication and its types. | 2 | 2 | 3 |
| | | CO2 | To know the different types of prefabrication systems. | 2 | 2 | 3 |
| | | CO3 | To learn different structural connections. | 3 | 2 | 3 |
| | | CO4 | To be exposed to erection of RC structures. | 3 | 1 | 2 |
| | | CO5 | To be familiar with designing and detailing of prefabricated units. | 3 | 2 | 3 |
| CE680 | Prestressed Concrete Structures | CO1 | Ensure the design philosophy of prestressing | 2 | 2 | 3 |
| | | CO2 | Design the flexural members due to shear, torsion, bond by incorporating the prestress losses. | 3 | 1 | 3 |
| | | CO3 | Design the connections for compression and tension prestressing elements and floor systems. | 3 | 2 | 3 |
| | | CO4 | Design the prestressed concrete girder bridges by incorporating the long-term effects | 3 | 1 | 3 |
| | | CO5 | Design the prestressed concrete pipes and tanks | 3 | 2 | 3 |
| CE681 | Smart Structures and Applications | CO1 | To understand the concept of passive and active systems. | 3 | 2 | 2 |
| | | CO2 | To be familiar with components of smart systems. | 2 | 1 | 1 |

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|---|---|---|---|---|---|---|
| | | CO3 | To be exposed to different types of smart materials. | 2 | 1 | 1 |
| | | CO4 | To better understand control systems. | 2 | 2 | 1 |
| | | CO5 | To be familiar with the methods and techniques for developing and designing multifunctional structures. | 2 | 1 | 1 |
| CE682 | Special Concrete | CO1 | To select an apt concrete for specialized construction viz. in high-rise buildings, arches, shells, long-span bridges, containment structures etc. | 3 | 2 | 3 |
| | | CO2 | To get a thorough knowledge in the sequence of concreting techniques under different conditions. | 3 | 2 | 3 |
| | | CO3 | To understand High Performance Concrete (HPC), fresh and hardened properties of HPC, mix design of HPC, properties of Ultra HPC, Special HPC. | 3 | 2 | 3 |
| | | CO4 | To be familiar in reactive powder concrete, bio-concrete and geo-polymer concrete. | 2 | 1 | 3 |
| | | CO5 | 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. | 3 | 2 | 3 |
| CE683 | Structures in Disaster Prone Areas | CO1 | To understand earthquake resistant design, cyclone resistant design, flood resistant design, by laws. | 3 | 2 | 1 |
| | | CO2 | To be familiar with traditional and modern structures, response of different structures to multi hazard, different types of foundation, ground improvement | 3 | 2 | 2 |

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|---|---|---|---|---|---|---|
| | | | techniques. | | | |
| | | CO3 | To understand various methods of strengthening, strengthening of different structures exposed to multi hazard. | 2 | 2 | 2 |
| | | CO4 | To be exposed to testing and evaluation of structures, classification of structures, qualification test, modern materials for disaster reduction. | 1 | 1 | 1 |
| | | CO5 | To get to learn modern analysis, design and construction techniques, optimization for performance, damage survey, improve hazard resistance. | 2 | 1 | 1 |
| CE684 | Design of Boiler Structures | CO1 | To understand boiler structures, types of boilers. | 2 | 1 | 3 |
| | | CO2 | To learn structural components of boilers, design and construction of boilers. | 3 | 2 | 3 |
| | | CO3 | To understand safety monitoring and operation, drum lifting structure. | 3 | 1 | 2 |
| | | CO4 | To be familiar with design loads, foundation analysis. | 3 | 2 | 3 |
| | | CO5 | To be exposed to platform structure. | 2 | 1 | 2 |
| CE685 | Design of Bridges | CO1 | To be familiar with the components of bridges, classification of bridges, importance of bridges. | 2 | 2 | 3 |
| | | CO2 | To understand the investigation for bridges, subsoil exploration, choice of bridge type. | 3 | 1 | 3 |
| | | CO3 | To understand the specification of road bridges, loads to be considered. | 3 | 2 | 3 |
| | | CO4 | To be familiar with various types of bridges such as slab-bridge, T-beam bridge, pre- stressed | 2 | 2 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | concrete bridge, continuous bridge, arch bridge, box girder bridge decks. | | | |
| | | CO5 | To get exposed to evaluation of sub structures, type of foundations, importance of bearings, lessons from bridge failures. | 3 | 1 | 3 |
| CE686 | Façade Design and Engineering | CO1 | Understanding about the Façade engineering in context of energy and sustainability | 1 | 2 | 3 |
| | | CO2 | Glazing system and supports of façade system | 1 | 2 | 2 |
| | | CO3 | Basic component Design of glass and aluminium members | 1 | 2 | 1 |
| | | CO4 | Recognize structural demands on façades and tolerances, | 3 | 2 | 1 |
| | | CO5 | To learn from façade failures of existing buildings | 1 | 2 | 1 |
| CE687 | Design of structures for Accidental Loads | CO1 | To predict the behaviour of different materials and fire | 3 | 1 | 3 |
| | | CO2 | To design structural elements resistant to fire using codebook provisions | 3 | 2 | 3 |
| | | CO3 | To suggest appropriate methods of strengthening and protecting against fire | 3 | 2 | 3 |
| | | CO4 | To predict the response of structures subjected to blast or impact loads | 3 | 2 | 3 |
| | | CO5 | To analyse structures subjected to impulse loads as a dynamic system | 3 | 2 | 3 |
| CE688 | Green Building Design | CO1 | To determine embodied energy and operational energy in buildings | 2 | 2 | 1 |
| | | CO2 | To understand the role of building materials in sustainable design | 3 | 2 | 3 |
| | | CO3 | To design building envelopes to preserve natural resources | 3 | 2 | 3 |
| | | CO4 | To learn recycle-reuse methods in building design | 3 | 3 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | CO5 | To know the building rating systems | 2 | 2 | 2 |
| CE689 | Hydraulic Structures | CO1 | To carry out investigation and planning of hydraulic structures. | 3 | 2 | 3 |
| | | CO2 | To analyse and design different types of dams. | 3 | 2 | 3 |
| | | CO3 | To understand construction of different types of dams. | 3 | 2 | 3 |
| | | CO4 | To be familiar with foundation treatment for dams. | 2 | 1 | 2 |
| | | CO5 | To design weirs on permeable foundation. | 3 | 1 | 2 |
| CE690 | Structures for Power Plants | CO1 | To understand power plant structure, different types of power plants. | 2 | 1 | 3 |
| | | CO2 | To understand planning, analysis and design of power plants and sag tension and load calculations as per IS:802 codebooks | 3 | 2 | 3 |
| | | CO3 | To be familiar with the analysis and design of chimneys, cooling towers. | 3 | 2 | 3 |
| | | CO4 | To be exposed to analysis and design of turbo generator foundation. | 3 | 2 | 3 |
| | | CO5 | To understand the components of intake towers, storage structures. | 2 | 1 | 3 |
| CE691 | Soil Structure Interaction | CO1 | To understand soil foundation interaction and its importance. | 3 | 2 | 3 |
| | | CO2 | To be familiar with model analysis, Winkler model for soil structure interaction analysis. | 3 | 2 | 2 |
| | | CO3 | To be exposed to beams and plates on elastic foundation. | 2 | 1 | 2 |
| | | CO4 | To carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction. | 3 | 2 | 3 |
| | | CO5 | To better understand the concepts of laterally loaded pile. | 2 | 1 | 2 |
| CE692 | Seismic Design of Steel Structures | CO1 | Evaluate steel structures for seismic loading | 3 | 1 | 3 |
| | | CO2 | Analyse steel structures for | 3 | 2 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | seismic loading by linear and nonlinear methods | | | |
| | | CO3 | Use Eurocode 8 for seismic design of steel structures | 3 | 2 | 3 |
| | | CO4 | Differentiate force and ductility based seismic design of steel structures | 3 | 2 | 3 |
| | | CO5 | Design various braced steel frames for earthquake loads | 3 | 2 | 3 |
| CE693 | Introduction to 3D printing technology | CO1 | Analyze the fundamentals and historical development of 3D printing, including advantages and key terms. | 3 | 2 | 3 |
| | | CO2 | Demonstrate proficiency in 3D modeling, data conversion, and preparation for 3D printing, and understand various RP data formats. | 3 | 3 | 3 |
| | | CO3 | Compare and contrast different 3D printing technologies (SLA, SGC, LOM, FDM) in terms of models, specifications, processes, and applications. | 2 | 2 | 3 |
| | | CO4 | Execute practical demonstrations of 3D printing techniques and perform post-processing tasks effectively. | 2 | 3 | 2 |
| | | CO5 | Evaluate case studies to understand the real-world applications, advantages, and disadvantages of various 3D printing technologies. | 1 | 2 | 2 |
| CE694 | Modelling, Simulation and Computer Applications | CO1 | Implement the numerical methods for solving nonlinear equations | 3 | 2 | 2 |
| | | CO2 | Perform matrix operations to solve linear systems and perform matrix inversion | 3 | 3 | 3 |
| | | CO3 | Develop and simulate stochastic models using Monte Carlo techniques, | 2 | 2 | 2 |
| | | CO4 | Implement supervised machine learning algorithms | 2 | 1 | 1 |
| | | CO5 | Integrate numerical methods, matrix algebra, stochastic | 2 | 2 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | modeling, and machine learning techniques to develop and simulate comprehensive models in engineering and scientific applications | | | |
| CE695 | Random Vibrations | CO1 | Demonstrate a thorough understanding of the fundamental concepts of stochastic processes | 2 | 1 | 1 |
| | | CO2 | Evaluate the deterministic and stochastic dynamics of linear SDOF systems | 2 | 2 | 2 |
| | | CO3 | Conduct time domain and frequency analysis of the stochastic response of linear MDOF and continuous systems | 2 | 1 | 1 |
| | | CO4 | Assess the response of non-linear systems to random excitations | 2 | 2 | 2 |
| | | CO5 | Assess the fatigue damage of structures subjected to random loads using appropriate stochastic methods | 3 | 1 | 2 |
| CE696 | Uncertainty Modeling, Analysis and Quantification | CO1 | Represent mathematically the uncertainty in the parameters of physical models. | 2 | 2 | 1 |
| | | CO2 | Propagate parametric uncertainty through physical models to quantify the induced uncertainty on quantities of interest. | 2 | 1 | 2 |
| | | CO3 | Develop and implement models for representing random fields and their uncertainties. | 2 | 1 | 1 |
| | | CO4 | Combine multiple sources of information to enhance the predictive capabilities of models | 3 | 1 | 1 |
| | | CO5 | Apply methods to quantify the uncertainties in a system | 3 | 2 | 2 |

## CORE AND LABORATORY COURSES

| | | |
|---|---|---|
| **Course Code** | : | MA624 |
| **Course Title** | : | Applied Mathematics for Structural Engineering |
| **Type of Course** | : | Core |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 48 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

### Course Learning Objectives (CLO)

| | |
|---|---|
| **CLO1** | To develop students with knowledge in Laplace and Fourier transform |
| **CLO2** | To familiarize the students in the field of differential equations to solve boundary value problems associated with engineering applications |
| **CLO3** | To expose the students to calculus of variation, conformal mappings and tensor analysis |
| **CLO4** | To familiarize students in the field of bilinear transformations |
| **CLO5** | 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.

### References


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|---|---|
| 1. | Sankara Rao K., Introduction to Partial Differential Equations, Prentice Hall of India Pvt. Ltd., New Delhi, 1997 |

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|---|---|
| 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 (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To solve boundary value problems using Laplace and Fourier transform techniques |
| **CO2** | To solve fluid flow and heat flow problems using conformal mapping |
| **CO3** | To develop the mathematical methods of applied mathematics and mathematical physics with an emphasis on calculus of variation and integral transforms |
| **CO4** | To apply vector calculus in linear approximations, optimization, physics and engineering |
| **CO5** | To solve physical problems such as elasticity, fluid mechanics and general relativity |

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| | | |
|---|---|---|
| **Course Code** | : | CE651 |
| **Course Title** | : | Theory of Elasticity and Plasticity |
| **Type of Course** | : | Core |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 48 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To make students understand the principles of elasticity and plasticity |
| **CLO2** | To familiarize students with basic equations of elasticity |
| **CLO3** | To expose students to two dimensional problems in Cartesian and polar coordinates |
| **CLO4** | To make students understand the principle of torsion of prismatic bars |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To apply elastic analysis to study the fracture mechanics |
| **CO2** | To apply linear elasticity in the design and analysis of structures such as beams, plates, shells and sandwich composites |
| **CO3** | To apply hyper-elasticity to determine the response of elastomer-based objects |
| **CO4** | To analyse the structural sections subjected to torsion |
| **CO5** | To understand various theories of failure and concept of plasticity |

| | | |
|---|---|---|
| **Course Code** | : | CE653 |
| **Course Title** | : | Advanced Reinforced Concrete Design |
| **Type of Course** | : | Core |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 48 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To provide better understanding on theoretical background of RC structural elements under axial, bending and combined forces. |

| | |
|---|---|
| **CLO2** | To understand 1D and 2D structural sections. |
| **CLO3** | To familiarize with analytical tools such as yield line theory. |
| **CLO4** | To get exposed to behaviour of concrete and steel. |
| **CLO5** | 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.

Note: i. *Design of slabs, deep beams, corbels, water tanks, walls etc shall be covered along with detailing according to SP:34 and ductile detailing by IS:13920*

ii. *Site visits shall be encouraged during the course for experiential learning*

**References**


| | |
|---|---|
| 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. |
| 7. | SP 34: Handbook on Concrete Reinforcement and Detailing, Bureau of Indian Standards, 1987 |
| 8. | IS 13920: Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces - Code of Practice, Bureau of Indian Standards, 2016 |


**Course outcomes**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To understand structural behaviour of flexural members and cracks |
| **CO2** | To compute deflection of flexural members. |

| | |
|---|---|
| **CO3** | To understand redistribution of moments. |
| **CO4** | To design compression members and make interaction charts |
| **CO5** | To understand the concept of shear and torsion. |

| | | |
|---|---|---|
| **Course Code** | : | CE655 |
| **Course Title** | : | Structural Engineering Laboratory |
| **Type of Course** | : | Laboratory |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 20 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To study the properties of concrete. |
| **CLO2** | To learn the method of concrete mix design as per ACI and IS code and to get exposure to special concrete. |
| **CLO3** | To carry out strength tests and non-destructive tests on concrete. |
| **CLO4** | To investigate the structural behaviour of RC beams and measure strain. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To arrive at concrete mix design for various types of concrete as per codal provisions |
| **CO2** | To be familiar with the properties of concrete and perform non-destruction testing on concrete |
| **CO3** | To cast and test structural RC elements for strength and deformation behaviour |
| **CO4** | To carry out dynamic testing on structural components |
| **CO5** | To assess the behaviour of structures subjected to cyclic load testing |

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| | | |
|---|---|---|
| **Course Code** | : | CE657 |
| **Course Title** | : | Computational Laboratory for Structural Engineers |
| **Type of Course** | : | Laboratory |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 20 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To gain knowledge on using various computational tools |
| **CLO2** | To familiarize the data analysis using MS Excel |
| **CLO3** | To learn regression and macros using MS Excel |
| **CLO4** | To introduce programming skills for structural engineering |
| **CLO5** | To get exposed to the various statistical techniques in SPSS |

**Course Content**

MS Excel: Using functions, Entering functions, Conditions, Multiple Conditions, Pivot Tables, Creating a Pivot Table for analysing, Goal-Seek, Regression using Excel, Charts and Data Representation, Introduction to Macros and Command buttons.

Programming for structural engineering: 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.

Statistical Analysis using SPSS: Regression analysis, Clustering and classification, Multivariate analysis, Basic descriptive statistics, Measures of central tendency and variability, Interaction test

**References**


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|---|---|
| 1. | N Brown, B Lave, J Romey, Beginning Excel 2019, Open Oregon Educational Resources, 2019 |
| 2. | P McFedries, Microsoft Excel Formulas and Functions (Office 2021 and Microsoft 365), Pearson Education, 2023 |

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|---|---|
| 3. | R Pratap, Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers, Oxford, 2010 |
| 4. | R K Bansal, A K Goel, M K Sharma, MATLAB and its Applications in Engineering, Pearson, 2016 |
| 5. | L Prasad, P Mishra, Data Analysis using SPSS: Text and Cases For Researchers Teachers and Students, Nirali Prakashan, 2022 |



**Course outcomes**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To work on spreadsheets and worksheets. |
| **CO2** | To understand regression and matrix inversion concepts. |
| **CO3** | To arrive at programs to solve problems using numerical techniques. |
| **CO4** | To use computer methods of structural analysis to solve structural problems. |
| **CO5** | To work on finite element programming to solve real time problems. |

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| | | |
|---|---|---|
| **Course Code** | : | CE652 |
| **Course Title** | : | Structural Dynamics |
| **Type of Course** | : | Core |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 48 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | 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. |
| **CLO2** | To learn free and forced vibration response of structural systems. |
| **CLO3** | To familiarize students with mathematical models representing real time problems of discrete and continuous vibratory systems. |
| **CLO4** | To make students understand the principle of virtual displacements |
| **CLO5** | 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. – Numerical Evaluation of Dynamic Response

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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To analyse structures subjected to blast loading and apply finite element method. |
| **CO2** | To analyse structures using various methods of vibration analysis. |
| **CO3** | To use structural property matrices to study structural behaviour. |
| **CO4** | To arrive at solution to Eigen value problem and idealize multi storied frames. |
| **CO5** | To perform deterministic analysis for earthquake response. |

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|---|---|---|
| **Course Code** | **:** | CE654 |
| **Course Title** | **:** | Finite Element Analysis of Structural Members |
| **Type of Course** | **:** | Core |
| **Prerequisites** | **:** | - |
| **Contact Hours** | **:** | 48 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To study the energy principles, finite element concept, stress analysis, meshing, nonlinear problems and applications. |
| **CLO2** | To arrive at approximate solutions to finite element problems. |
| **CLO3** | To perform finite element analysis on one dimensional and two dimensional problems. |
| **CLO4** | To familiarize students with isoparametric element components. |
| **CLO5** | 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 finite element 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

Note: *Assignments shall include modelling, analysis and visualization in general purpose finite element software such as ABAQUS*

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To use displacement models to solve practical problems in structural engineering. |
| **CO2** | To apply numerical techniques of finite element analysis to solve real time problems. |
| **CO3** | To make use of shape function and interpolation function to study structural behaviour. |
| **CO4** | To apply linear and quadratic elements in the finite element analysis of various types of structures. |
| **CO5** | To predict structural behaviour using strain displacement matrix and element stiffness matrix. |

| | | |
|---|---|---|
| **Course Code** | **:** | CE656 |
| **Course Title** | **:** | Advanced Design of Metal Structures |
| **Type of Course** | **:** | Core |
| **Prerequisites** | **:** | - |
| **Contact Hours** | **:** | 48 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To compute wind load on structures and deflection of beams. |
| **CLO2** | To understand design of stacks. |
| **CLO3** | To get familiarized with cold formed steel sections and different types of connections. |
| **CLO4** | To get exposed to design of compression and tension members. |
| **CLO5** | 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 – base plate 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

Note: *Site visits shall be encouraged during the course for experiential learning*

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To compute wind load on structures and determine deflection of beams. |
| **CO2** | To understand design of stacks. |
| **CO3** | To get familiarized with cold formed steel sections and different types of connections. |
| **CO4** | To get exposed to design of compression, tension members and base plates. |
| **CO5** | To design members subjected to torsion and understand plastic analysis of structures. |

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| | | |
|---|---|---|
| **Course Code** | : | CE658 |
| **Course Title** | : | Structural Design Studio |
| **Type of Course** | : | Laboratory |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 20 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | Learn design and detailing of RCC buildings |
| **CLO2** | Understand design of steel industrial pre-engineered buildings |
| **CLO3** | To familiarize with conceptual design and design basis report |
| **CLO4** | Learn design of bridges and special structures |
| **CLO5** | To get exposure to usage of popular software such as ETABS and SAP2000 |

**Course Content**

Reinforced concrete buildings, Structural steel industrial sheds, Bridges for each of the structures, the following are covered in the form of a mini-project: conceptual design, design basis report, numerical model and analysis, structural design, structural drawings, bill of quantities, Special structures: tall structures, industrial structures, large span roof structures. The conceptual design and methods of construction are covered, Special topics: Thumb rule design, integrated approach for design, process and stages of design, building information modelling.

**References**


| | |
|---|---|
| 1. | K Raju, Structural Design & Drawing, Universities Press, 2009 |
| 2. | D J Victor, Essentials Of Bridge Engineering, Oxford, 2019 |
| 3. | N Subramanian, Design Of Steel Structures: Limit State, Oxford University Press, 2017 |
| 4. | SP:34, Handbook on Concrete Reinforcement and Detailing, Bureau of Indian Standards, 1987 |
| 5. | IRC 6, Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Load Combinations, Indian Roads Congress, 2017 |

| | |
|---|---|
| 6. | IS 800, General construction in steel - Code of practice, Bureau of Indian Standards, 2007 |
| 7. | About STAAD.Pro Documentation, Bentley. |
| 8. | SAP2000 Documentation. https://wiki.csiamerica.com/display/doc/SAP2000 |
| 9. | ETABS Documentation. https://wiki.csiamerica.com/display/doc/ETABS |

**Course outcomes**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Analyse, design and create structural drawings of RCC buildings |
| **CO2** | Analyse, design and create structural drawings of steel industrial buildings |
| **CO3** | Create conceptual designs and design basis reports |
| **CO4** | Analyse and design of bridges and special structures |
| **CO5** | Use ETABS and SAP2000 for specialised structural designs |

## ELECTIVE COURSES

| | | |
|---|---|---|
| | : | CE661 |
| **Course Title** | : | Matrix Methods of Structural Analysis |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce the classical, matrix and finite element methods of structural analysis. |
| **CLO2** | To make students understand structural behaviour. |
| **CLO3** | To enable students to analyse determinate and indeterminate structures. |
| **CLO4** | To familiarize students with displacement method. |
| **CLO5** | 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.

**References**



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|---|---|
| 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. |



**Course outcomes**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To understand energy concepts in structures, characteristics of structures, transformation of information in structures. |
| **CO2** | To perform analysis by iteration method and determine deflection of structures using Maxwell-Betti Law of Reciprocal Deflections. |
| **CO3** | To understand generalized and constrained measurements. |
| **CO4** | To apply principle of superposition in practical problems. |
| **CO5** | To understand fundamental relationships for structural analysis and develop analytical models. |

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| | | |
|---|---|---|
| **Course Code** | : | CE662 |
| **Course Title** | : | Non-Linear Analysis |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To provide an understanding of the nonlinear behaviour of structures |
| **CLO2** | To study the methods for analysing nonlinear response of framed structures |
| **CLO3** | To study the Basic equations for continuum; Beams, plates and shells |
| **CLO4** | To study the Analytical and discrete numerical solution techniques |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | Analyse the Frames including the Material nonlinearity |
| **CO2** | Analyse the Frames including the Geometry nonlinearity |
| **CO3** | Analyse frames using the elastic-plastic approach |
| **CO4** | Analyse frames using numerical solution techniques |
| **CO5** | Apply the Finite element method to solve nonlinear problems |

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| | | |
|---|---|---|
| **Course Code** | : | CE663 |
| **Course Title** | : | Reliability analysis of structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | Grasp the fundamentals of basic statistics and probability theory relevant to civil engineering. |
| **CLO2** | Perform probabilistic analysis of various loads, including gravity and wind loads |
| **CLO3** | Develop skills in modeling structural systems for reliability analysis |
| **CLO4** | Gain proficiency in applying FOSM and Monte Carlo methods |
| **CLO5** | Analyze and solve real-world reliability issues in civil engineering, demonstrating the application of statistical and probabilistic methods to ensure structural safety and performance |

**Course Content**

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

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

Basic structural reliability:- Introduction, computation of structural reliability. Level 2 Reliability methods: Introduction, basic variables and failure surface, first order second moment methods (FOSM).

Reliability based design: Introduction, determination of partial safety factors, development of reliability based design criteria, optimal safety factors

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

**References**


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


**Course outcomes**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Demonstrate the ability to apply basic statistical methods and probability theory to analyze structural safety and performance. |
| **CO2** | Analyze and interpret resistance distributions and statistical parameters for materials like concrete and steel. |
| **CO3** | Compute the reliability of structural components using various methods |
| **CO4** | Evaluate reliability indices for simple structural problems viz., beams, trusses. |
| **CO5** | Apply reliability methods to solve practical civil engineering problems, ensuring the safety and performance of structures. |

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|---|---|---|
| **Course Code** | **:** | CE664 |
| **Course Title** | **:** | Stochastic Processes in Structural Mechanics |
| **Type of Course** | **:** | Programme Elective |
| **Prerequisites** | **:** | - |
| **Contact Hours** | **:** | 36 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand the basic concept of random variables and its extension to stochastic processes. |
| **CLO2** | To know the modelling of natural phenomena through random processes. |
| **CLO3** | To learn probability distribution of a random variable. |
| **CLO4** | To understand the concept of multiple random variables. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand basic theory of stochastic processes and its relevance in the realistic modeling of natural phenomena. |
| **CO2** | To understand the basic theory of random variables, multiple random variables and random processes. |
| **CO3** | To be familiar with probability distribution of a random variable. |
| **CO4** | To be familiar with covariance, conditional mean and variance. |
| **CO5** | To understand the concept of Fourier analysis and data processing. |

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| | | |
|---|---|---|
| **Course Code** | : | CE665 |
| **Course Title** | : | Structural Optimization |
| **Type of Course** | : | Programme Elective / Open Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | 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. |
| **CLO2** | To understand the formulation of structural optimization problems. |
| **CLO3** | To get familiarized with the application of linear and non-linear programming to structural optimization. |
| **CLO4** | To get exposed to unconstrained and constrained optimization. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To use the optimization tools for the design of structures effectively. |
| **CO2** | To understand the concept of optimality criteria and reanalysis techniques. |
| **CO3** | To use approximation concepts and stochastic optimization methods. |
| **CO4** | To be familiar with genetic algorithm and simulated annealing. |
| **CO5** | To be able to work in artificial intelligence and artificial neural networks. |

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| | | |
|---|---|---|
| **Course Code** | : | Programme Elective |
| **Course Title** | : | Failure Analysis of Structures |
| **Type of Course** | : | Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand the causes of failure, failure modes and mechanism. |
| **CLO2** | To know how engineering materials and components fail. |
| **CLO3** | To understand the concept of design and manufacturing integrity. |
| **CLO4** | To understand material selection procedure based on requirement. |
| **CLO5** | 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.

**References**


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|---|---|
| 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

| | |
|---|---|
| **CO1** | To identify the objective of study of fracture mechanics. |
| **CO2** | To model linear elastic fracture mechanics. |
| **CO3** | To simulate actual failure analysis problems in site. |
| **CO4** | To understand repair and maintenance of structures and product liability issues. |
| **CO5** | To analyse and design structures for failure prevention. |

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| | | |
|---|---|---|
| **Course Code** | : | CE667 |
| **Course Title** | : | Forensic Engineering and Rehabilitation of Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand the causes of failure of structures. |
| **CLO2** | To enable students to diagnose distress of structures. |
| **CLO3** | To make students understand various environmental problems and natural hazards. |
| **CLO4** | To expose students to modern techniques of retrofitting. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand the causes of failure of structures. |
| **CO2** | To diagnose distress of structures. |
| **CO3** | To understand various environmental problems and natural hazards. |
| **CO4** | To be exposed to modern techniques of retrofitting. |
| **CO5** | To be familiar with case studies. |

| | | |
|---|---|---|
| **Course Code** | : | CE668 |

| | | |
|---|---|---|
| **Course Title** | : | Fracture Mechanics |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand the concept of fracture mechanics. |
| **CLO2** | To get exposed to method of stress analysis. |
| **CLO3** | To understand failure mechanisms. |
| **CLO4** | To understand design methods. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand fracture toughness and fracture energy. |
| **CO2** | To be familiar with energy release rate. |
| **CO3** | To get exposed to the concept of crack mouth opening displacement. |
| **CO4** | To understand fracture mechanics of concrete. |
| **CO5** | To be familiar with linear and nonlinear fracture mechanics. |

| | | |
|---|---|---|
| **Course Code** | : | CE669 |
| **Course Title** | : | Advanced Steel And Concrete Composite Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce students to steel-concrete composite structures and types of shear connectors. |
| **CLO2** | To make students understand analysis and design of composite beams and deflection of composite beams. |
| **CLO3** | To make students be familiar with composite slabs, analysis and design of composite floor systems. |
| **CLO4** | To get students exposed to types of composite columns. |
| **CLO5** | 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.

Type 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand steel-concrete composite structures and types of shear connectors. |
| **CO2** | To understand analysis and design of composite beams and deflection of composite beams using IS:11384 and EC4. |
| **CO3** | To be familiar with composite slabs, analysis and design of composite floor systems. |
| **CO4** | To get exposed to types of composite columns. |
| **CO5** | To learn vibration of composite beams and cyclic behaviour of composite sections. |

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| | | |
|---|---|---|
| **Course Code** | : | CE670 |
| **Course Title** | : | Design of Metal Structures II |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To learn the applications of aluminium in structural engineering |
| **CLO2** | To understand permissible stress and limit design of aluminium structural members |
| **CLO3** | To learn the applications of stainless steel in structural engineering |
| **CLO4** | To understand limit state design of stainless steel structural members |
| **CLO5** | To learn the design of fabric material construction |

**Course Content**

Applications of aluminium in structural engineering, alloy grades and material composition, manufacturing, properties

Design by permissible stresses for aluminium (IS:8147-1976): axial compression and bending, tension members, lateral buckling of beams, combined stresses, laced and battened struts

Limit State design for aluminium (EN:1999-1-1): Section classification, resistance of cross-sections in tension, compression, bending and shear, design of joints

Applications of stainless steel in structural engineering, grades and properties

Ultimate limit states (EN:1993-1-4): classification of cross-sections, resistance of cross-sections, buckling resistances, design of connections.

Fabric material characteristics - form determination - Loadings based on forms - Supports and end conditions - Fabrication & construction.

**References**

| | |
|---|---|
| 1. | SCI P413, DESIGN MANUAL FOR STRUCTURAL STAINLESS STEEL, 4th EDITION, The Steel Construction Institute, 2017 |
| 2. | N R BADDOO, B A BURGAN, SCI P291 Structural Design of Stainless Steel, The Steel Construction Institute, 2001 |
| 3. | ASCE/SEI 8-02, Specification for the Design of Cold-Formed Stainless Steel Structural Members, American Society of Civil Engineers, 2002 |
| 4. | F M Mazzolani, Aluminium Structural Design, Springer-Verlag, Wien, 2014 |
| 5. | BEAULIEU DENIS, Design of Aluminium Structures, PRAL, 2006 |
| 6. | EN 1999-1-1, Eurocode 9: Design of aluminium structures, European Committee for Standardization, 1998 |
| 7. | EN 1993-1-4, Eurocode 3 - Design of steel structures - Part 1-4: General rules - Supplementary rules for stainless steels, European Committee for Standardization, 2006 |
| 8. | IS 8147, Code of Practice for Use of Aluminium Alloys in Structures, Bureau of Indian Standards, 1976 |
| 9. | Craig Huntington, Tensile Fabric structures - Design, Analysis & Construction, American Society of Civil Engineers, 2014 |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To recollect the mechanical and material properties of stainless steel and aluminium |
| **CO2** | To use the Indian Standard for permissible stress design and Eurocode EC9 for limit state design of aluminium structures |
| **CO3** | To propose the usage of stainless steel for extreme exposure structures |
| **CO4** | To use the Eurocode for limit state design of stainless steel structures |
| **CO5** | To design structures using fabric materials |

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| | | |
|---|---|---|
| **Course Code** | : | CE671 |
| **Course Title** | : | Design of thin-walled steel structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand the significance of Thin-walled structures |
| **CLO2** | To design the member components using Permissible stress method |
| **CLO3** | To understand the limit state design of cold-formed steel members. |
| **CLO4** | To design a storage Rack structures and understand the effect of lateral loads |
| **CLO5** | To design connections for storage Rack structures |

**Course Content**

Applications of Thin-walled steel structures in structural engineering, Introduction to Cold-formed steel and Light gauge framing system, low cost and modular housing.

Basics to buckling and section classifications. Design of cold-formed steel members using permissible stresses method (IS:801-1974): axial compression and bending, tension members, lateral buckling of beams, combined stresses, laced and battened struts.

Limit State design for steel (AISI-S100-2021): Section classification, resistance of cross-sections in tension, compression, bending and shear, Design using Effective width method and Direct strength method.

Design of connections, self-drilling screws, Moment capacity, Roofing design, Standing seam clip connections. Beam-column design

Design of Storage Racks, Behaviour of member under lateral and earthquake loads. Application of Finite element analysis on cold-formed steel design.

**References**


| | |
|---|---|
| 1. | W W Yu, R A LaBoube, H Chen, Cold-Formed Steel Design, Wiley, 2019 |
| 2. | M L Gambhir, Stability Analysis and Design of Structures, Springer, 2013 |
| 3. | S Timoshenko, Theory of Plates and Shells, McGraw Hill Education, 2017 |
| 4. | W F Chen, Theory of Beam-Columns, Volume 1: In-Plane Behavior and Design, J Ross Publishing, 2007 |
| 5. | D Dubina, V Ungureanu, R Landolfo, Design of Cold-formed Steel Structures: Eurocode 3: Design of Steel Structures. Part 1-3 Design of cold-formed Steel Structures (Eurocode Design Manuals), Ernst & Sohn, 2012 |
| 6. | AISI S100, North American Specification for the Design of Cold-Formed Steel Structural Members, American Iron and Steel Institute, 2016 |
| 7. | AS/NZS 4600, Cold-formed steel structures, Standards Australia, 2018 |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Basics design principle of thin walled structures |
| **CO2** | Design of cold-formed steel members using working stress method |
| **CO3** | Design of cold-formed steel members using Limit state method |
| **CO4** | Design of connections and storage Racks. |
| **CO5** | Design of steel storage Racks systems. |

| | | |
|---|---|---|
| **Course Code** | : | CE672 |
| **Course Title** | : | Stability of Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | This course deals with stability problems in structural forms and systems. |
| **CLO2** | It also takes care of special consideration for stability during design of structural elements. |
| **CLO3** | It also aims for studying the buckling and analysis of structural elements. |
| **CLO4** | To study the stability analysis problems in column, beam and beam-column. |
| **CLO5** | 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

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand stability of static and dynamic equilibrium. |
| **CO2** | To evaluate static stability criteria using stability equations. |
| **CO3** | To solve stability problems by energy method and finite difference method. |
| **CO4** | To predict critical loads on structures. |
| **CO5** | To create discrete and continuous models to solve stability problems. |

| | | |
|---|---|---|
| **Course Code** | : | CE673 |
| **Course Title** | : | Theory of Plates and Shells |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce the concept of plate theory. |
| **CLO2** | To study the behaviour and analysis of thin plates. |
| **CLO3** | To study the procedure for rectangular plates and circular plates subjected to lateral loads. |
| **CLO4** | To study the classification and behaviour of shells. |
| **CLO5** | 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

**References**

| | |
|---|---|
| 1. | Timoshenko, S. and Krieger S.W. "Theory of Plates and Shells", McGraw Hill Book |
| 2. | Company, New York, 2003 |
| 3. | Chandrashekahara, K. Theory of Plates, University Press (India) Ltd., Hyderabad, 2001. |
| 4. | Szilard, R., "Theory and Analysis of Plates - Classical and Numerical Methods", |


**Course outcomes**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To assess the strength of thin plates under different types of loads. |
| **CO2** | To analyze thin plates using Navier's method and Levy's method. |
| **CO3** | Analyse circular plates under axi-symmetric deflection. |
| **CO4** | To classify different types of shells and study their behavior. |
| **CO5** | To analyze shells using membrane theory. |

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|---|---|---|
| **Course Code** | : | CE674 |
| **Course Title** | : | Analysis and Design of Tall Buildings |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce design philosophy, loading, different types of frames, types of shear walls. |
| **CLO2** | To expose students to different lateral load resisting systems. |
| **CLO3** | To make students understand approximate analysis, accurate analysis and reduction techniques. |
| **CLO4** | To familiarize students with design of structural elements, buckling analysis, pdelta analysis. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand the design philosophy, loading, different types of frames, types of shear walls. |
| **CO2** | To be exposed to different lateral load resisting systems. |
| **CO3** | To understand approximate analysis, accurate analysis and reduction techniques. |
| **CO4** | To be familiar with design of structural elements, buckling analysis, p-delta analysis. |
| **CO5** | To understand translational – torsional instability. |

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| | | |
|---|---|---|
| **Course Code** | : | CE675 |
| **Course Title** | : | Design of Offshore Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand the demand for coastal and offshore structures, overview of different types of ocean structures. |
| **CLO2** | 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. |
| **CLO3** | To learn various types of structural systems/forms, brief overview of various environmental loads. |
| **CLO4** | To be familiar with the problems associated with the material behavior in marine environment and various protection methods. |

| | |
|---|---|
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand different types of ocean structures, different structural systems of ocean structures and types of environmental loads. |
| **CO2** | To be familiar with structural action of ocean structures, planning guidelines and design principles and regulations and codes of practice. |
| **CO3** | To understand the concepts of foundation of ocean structures, sea bed anchors, dredging methods and equipment. |
| **CO4** | To get exposed to materials for marine applications, deterioration of materials, inspection and testing of marine structures. |
| **CO5** | To be familiar with non-destructive techniques, repair and rehabilitation of marine structures and structural health monitoring of marine structures. |

| | | |
|---|---|---|
| **Course Code** | : | CE676 |
| **Course Title** | : | Seismic Design of Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce the basics of earthquake engineering and how they influence the structural design. |
| **CLO2** | To aim at introducing engineering seismology and building characteristics. |
| **CLO3** | To make students understand structural irregularities, do's and don'ts in earthquake engineering design, code provision on different types of structures. |
| **CLO4** | To make students be familiar with structural modelling and lateral load resisting design. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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, |
| 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

| | |
|---|---|
| **CO1** | To understand the basics of earthquake engineering and how they influence the structural design. |
| **CO2** | To understand engineering seismology and building characteristics. |
| **CO3** | To learn structural irregularities, do's and don'ts in earthquake engineering design, code provision on different types of structures. |
| **CO4** | To be familiar with structural modelling and lateral load resisting design. |
| **CO5** | To get exposed to strength, stiffness and ductility requirements and energy dissipation devices. |

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| | | |
|---|---|---|
| **Course Code** | : | CE677 |
| **Course Title** | : | Wind Effects on Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | Understand the fundamental principles of wind engineering. |
| **CLO2** | Analyze wind load effects on various types of structures. |
| **CLO3** | Basic concept of bluff-body aerodynamics and various aeroelastic phenomenon |
| **CLO4** | Design structures to withstand wind loads. |
| **CLO5** | Understanding the principle behind the provision in relevant codes and their application |

**Course Content**

Introduction to wind engineering; Importance of studying wind effects on structures; Structure and characteristics of the atmospheric boundary layer; Wind profiles and turbulence; Wind speed, direction, and frequency

Basic fluid dynamics principles related to wind flow; Bluff body aerodynamics; Pressure distribution around structures; Overview of relevant codes and standards

Basic concepts of structural dynamics; Dynamic response of structures to wind loads; Aeroelasticity; Vortex shedding and galloping; Flutter analysis; Suspended-span bridges

Wind-resistant design of building; Equivalent static wind loads; Along and across wind response; Wind-induced discomfort in and around duildings; Mitigation of building motions

**References**


| | |
|---|---|
| 1 | E Simiu, R H Scanlan, Wind Effects on Structures: Fundamentals and Applications to Design, Wiley-Interscience, 1996 |
| 2 | J D Holmes, Wind Loading of Structures, CRC Press, 2017 |

| | |
|---|---|
| 3 | C Dyrbye, M L Hansen, Wind Loads on Structures, Wiley 1997 |
| 4 | Y Tamura, A Kareem, Advanced Structural Wind Engineering, Springer Tokyo, 2015 |

**Course outcomes**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To understand the basics of wind engineering and how they influence the structural design. |
| **CO2** | Analyze wind load effects on various types of structures. |
| **CO3** | To learn bluff-body aerodynamics and various aeroelastic phenomenon |
| **CO4** | Design structures to withstand wind loads. |
| **CO5** | Use relevant codes and apply them for wind design of structures |

| | | |
|---|---|---|
| **Course Code** | : | CE678 |
| **Course Title** | : | Advanced Concrete Technology |
| **Type of Course** | : | Programme Elective / Open Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To make students understand concrete admixtures, non-destructive testing, semi-destructive testing, special concrete. |
| **CLO2** | To familiarize students with structure of hydrated cement paste, types of cement, cement production quality control. |
| **CLO3** | To make students learn transition zone in concrete, measurement of workability, properties of concrete, concrete mix design. |
| **CLO4** | To expose students to strength porosity relationship, failure modes in concrete, elastic behaviour in concrete. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand concrete technology, admixtures, non-destructive testing, semi destructive testing, special concrete. |
| **CO2** | To be familiar with structure of hydrated cement paste, types of cement, cement production quality control. |
| **CO3** | To learn transition zone in concrete, measurement of workability, properties of concrete, rheological behaviour of concrete, economic concrete mix design. |
| **CO4** | To be exposed to strength-porosity relationship, failure modes in concrete, elastic behaviour in concrete, ageing properties and long term behaviour. |
| **CO5** | To better understand the causes of concrete deterioration, permeability of concrete, durability of concrete, alkali aggregation reaction. |

| | | |
|---|---|---|
| **Course Code** | : | CE679 |
| **Course Title** | : | Prefabricated Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce prefabrication and its types. |
| **CLO2** | To make students know the different types of prefabrication systems. |

| | |
|---|---|
| **CLO3** | To make students learn different structural connections. |
| **CLO4** | To make students exposed to erection of RC structures. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To get introduced to prefabrication and its types. |
| **CO2** | To know the different types of prefabrication systems. |
| **CO3** | To learn different structural connections. |
| **CO4** | To be exposed to erection of RC structures. |
| **CO5** | To be familiar with designing and detailing of prefabricated units. |

| | | |
|---|---|---|
| **Course Code** | : | CE680 |
| **Course Title** | : | Prestressed Concrete Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To develop an understanding of the philosophy of pre-stressing design. |
| **CLO2** | To study the design of indeterminate pre-stressed concrete structures. |
| **CLO3** | To have a better understanding about the connections for pre-stressed concrete elements. |
| **CLO4** | To design pre-stressed concrete bridges. |
| **CLO5** | To study the design of pre-stressed concrete pipes and tanks. |

**Course Content**

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

**References**


| | |
|---|---|
| 1. | Antonnie. E. Naaman, Prestressed Concrete Analysis and Design, Technopress, 3rd |
| 2. | Edition, 2012. |
| 3. | Edward. G .Nawy, Prestressed Concrete, Prentice Hall, 5th Edition, 2010. |
| 4. | Arthur. H. Nilson, Design of Prestressed Concrete, John Wiley and sons, 2nd Edition, 1987. |
| 5. | Raja Gopalan N. Prestressed Concrete, Alpha Science International, 2nd Edition, 2005. |


**Course outcomes**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Ensure the design philosophy of prestressing |
| **CO2** | Design the flexural members due to shear, torsion, bond by incorporating the prestress losses. |
| **CO3** | Design the connections for compression and tension prestressing elements and floor systems. |
| **CO4** | Design the prestressed concrete girder bridges by incorporating the long-term effects |

| | |
|---|---|
| **CO5** | Design the prestressed concrete pipes and tanks |

| | | |
|---|---|---|
| **Course Code** | **:** | CE681 |
| **Course Title** | **:** | Smart Structures and Applications |
| **Type of Course** | **:** | Programme Elective |
| **Prerequisites** | **:** | - |
| **Contact Hours** | **:** | 36 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce passive and active systems. |
| **CLO2** | To familiarize students with components of smart systems. |
| **CLO3** | To make students exposed to different types of smart materials. |
| **CLO4** | To make students understand control systems. |
| **CLO5** | 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.

**References**


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|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand the concept of passive and active systems. |
| **CO2** | To be familiar with components of smart systems. |
| **CO3** | To be exposed to different types of smart materials. |
| **CO4** | To better understand control systems. |
| **CO5** | To be familiar with the methods and techniques for developing and designing multifunctional structures. |

| | | |
|---|---|---|
| **Course Code** | : | CE682 |
| **Course Title** | : | Special Concrete |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand High Performance Concrete (HPC), fresh and hardened properties of HPC, mix design of HPC. |
| **CLO2** | To understand the properties of Ultra HPC, Special HPC. |
| **CLO3** | To familiarize students in reactive powder concrete, bio-concrete and geopolymer concrete. |
| **CLO4** | To understand the concept of Self Compacting Concrete (SCC), mix design of SCC and properties of SCC. |
| **CLO5** | 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.

**References**

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|---|---|
| 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

| | |
|---|---|
| **CO1** | To select an apt concrete for specialized construction viz. in high-rise buildings, arches, shells, long-span bridges, containment structures etc. |
| **CO2** | To get a thorough knowledge in the sequence of concreting techniques under different conditions. |
| **CO3** | To understand High Performance Concrete (HPC), fresh and hardened properties of HPC, mix design of HPC, properties of Ultra HPC, Special HPC. |
| **CO4** | To be familiar in reactive powder concrete, bio-concrete and geo-polymer concrete. |
| **CO5** | 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** | : | CE683 |
| **Course Title** | : | Structures in Disaster Prone Areas |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce earthquake resistant design, cyclone resistant design, flood resistant design, by laws. |
| **CLO2** | To make students be familiar with traditional and modern structures, response of different structures to multi hazard, different types of foundation, ground improvement techniques. |
| **CLO3** | To make students understand various methods of strengthening, strengthening of different structures exposed to multi hazard. |
| **CLO4** | To make students get exposed to testing and evaluation of structures, classification of structures, qualification test, modern materials – disaster reduction. |
| **CLO5** | 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.

**References**


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|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand earthquake resistant design, cyclone resistant design, flood resistant design, by laws. |
| **CO2** | To be familiar with traditional and modern structures, response of different structures to multi hazard, different types of foundation, ground improvement techniques. |
| **CO3** | To understand various methods of strengthening, strengthening of different structures exposed to multi hazard. |
| **CO4** | To be exposed to testing and evaluation of structures, classification of structures, qualification test, modern materials for disaster reduction. |
| **CO5** | To get to learn modern analysis, design and construction techniques, optimization for performance, damage survey, improve hazard resistance. |

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|---|---|---|
| **Course Code** | **:** | CE684 |

| | | |
|---|---|---|
| **Course Title** | : | Design of Boiler Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce boiler structures, types of boilers. |
| **CLO2** | To make students learn structural components of boilers, design and construction of boilers. |
| **CLO3** | To make students understand safety monitoring and operation, drum lifting structure. |
| **CLO4** | To familiarize students with design loads, foundation analysis. |
| **CLO5** | 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.

**References**


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|---|---|
| 1. | Subramanian N, Design of Steel Structures, Oxford University Press, New Delhi, 2008. |

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|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand boiler structures, types of boilers. |
| **CO2** | To learn structural components of boilers, design and construction of boilers. |
| **CO3** | To understand safety monitoring and operation, drum lifting structure. |
| **CO4** | To be familiar with design loads, foundation analysis. |
| **CO5** | To be exposed to platform structure. |

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| | | |
|---|---|---|
| **Course Code** | : | CE685 |
| **Course Title** | : | Design of Bridges |
| **Type of Course** | : | Programme Elective / Open Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To learn the components of bridges, classification of bridges, importance of bridges. |
| **CLO2** | To understand the investigation for bridges, subsoil exploration, choice of bridge type. |
| **CLO3** | To study the specification of road bridges, loads to be considered. |
| **CLO4** | 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. |
| **CLO5** | 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.

**References**


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|---|---|
| 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

| | |
|---|---|
| **CO1** | To be familiar with the components of bridges, classification of bridges, importance of bridges. |
| **CO2** | To understand the investigation for bridges, subsoil exploration, choice of bridge type. |
| **CO3** | To understand the specification of road bridges, loads to be considered. |
| **CO4** | 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. |
| **CO5** | To get exposed to evaluation of sub structures, type of foundations, importance of bearings, lessons from bridge failures. |

| | | |
|---|---|---|
| **Course Code** | : | CE686 |
| **Course Title** | : | Façade Design and Engineering |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | CE656 |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To Explore the main principles involved in façade design in the context of sustainability |

| | |
|---|---|
| **CLO2** | Categorize different façade technologies and materials, their potential and shortcomings |
| **CLO3** | To familiarize adoption of glass and aluminium members for facades |
| **CLO4** | Incorporate façades' lines of defense (air, wind, water) systematically into individual designs. |
| **CLO5** | Recognize structural demands on façades and tolerances, and integrate them into façade development. |

**Course Content**

Building envelope, basic principles behind its different functions, construction elements, design strategies, relation between façades and energy, sustainability and circularity.

Façade systems, monolithic walls, curtain-walls (stick and unitized systems), and double-skins, construction principles and components, suitability in different contexts, advantages and disadvantages.

Materials in façade construction, Glass on Facades, Types of glass, production processes, application as façade components, potential impact and general performance of the envelope.

Glazing system, Mullion and Transform system, Façade detailing, main structural requirements, movement and tolerances in façade systems, structural testing of components and systems.

Iconic buildings, Glass bridges, design motivations, arguments and reasons for different engineering strategies and systems during design and construction stages.

**References**


| | |
|---|---|
| 1. | M Patterson, Structural Glass Facades and Enclosures, John Wiley and Sons, 2011 |
| 2. | S L Chan, Basic structural design considerations and properties of glass and aluminum structures, Hong Kong institute of Steel Construction, 2016 |
| 3. | IS 16231 Part 1, Use of Glass in Buildings — General Methodology for Selection, Bureau of Indian Standards, 2019 |
| 4. | IS 16231 Part 3, Use of Glass in Buildings — Fire and Loading, Bureau of Indian Standards, 2019 |
| 5. | IS 8147, Code of Practice for Use of Aluminium Alloys in Structures, Bureau of Indian Standards, 1976 |
| 6. | W W Yu, R A LaBoube, H Chen, Cold-Formed Steel Design, Wiley, 2019 |
| 7. | U Knaack, T Klein, M Bilow, T Auer, Façades Principles of Construction, Delft University TU Delft, |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Understanding about the Façade engineering in context of energy and sustainability |
| **CO2** | Glazing system and supports of façade system |
| **CO3** | Basic component Design of glass and aluminium members |
| **CO4** | Recognize structural demands on façades and tolerances |
| **CO5** | To learn from façade failures of existing buildings |

| | | |
|---|---|---|
| **Course Code** | : | CE687 |
| **Course Title** | : | Design of Structures for Accidental Loads |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce fire characteristics and fire curves and behaviour of steel and concrete at elevated temperatures |
| **CLO2** | To learn the different code provisions for fire resistant design |
| **CLO3** | To familiarize various strengthening and fire protection methods |
| **CLO4** | To learn about the effects of blasts and impacts on structures and interaction |
| **CLO5** | To introduce dynamic modelling of structures subjected to impulse loads |

**Course Content**

Fire characteristics, standard fire curves, properties and load estimate, Material properties at elevated temperature: concrete, steel, composites and FGM, Code provisions for fire-resistant design with Design examples - Fire protection system: Design, working mechanisms and usability

Modeling and design of structural members in fire conditions, Steel-concrete composite systems (CFT) for extreme loading conditions, Composite materials for strengthening and fire protection applications

Introduction to explosion effects, TNT-equivalence, Blast load structure interaction Contact / Near contact, close-in and far-field loading, Front face loading, blast clearing, stagnation pressure, Side wall and roof loading, Back face loading, Net loading on structure, Ground Shock Material Response to High strain Rate loading

forced vibration to generalized loading, Duhamel integral, response to triangular loading (blast load). Equivalent SDOF analysis of structural elements and nonlinear systems, pressure-impulse diagrams for elastic system and elastoplastic systems

**References**


| | |
|---|---|
| 1. | S Chandrasekaran, G Srivastava, Fire-Resistant Design of Structures, CRC Press, 2022 |
| 2. | Andrew Buchanan, Structural Design for Fire Safety, Wiley,2nd Edition, 2017 |
| 3. | Bangash, Al-Obaid and Bangash, Fire Engineering of Structures: Analysis and Design, Springer, 1st Edition, 2013 |
| 4. | D. Drysdale, An Introduction to Fire Dynamics, Wiley, 2nd Edition, 2011 |
| 5. | ISO 834-11:2014, Fire resistance tests — Elements of building constructionPart 11: Specific requirements for the assessment of fire protection to structural steel elements, International Standards Organisation, 2014 |

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|---|---|
| 6. | IS 4991: Criteria for blast resistant design of structures for explosions above ground, Bureau of Indian Standards, 1968 |
| 7. | P.D.Smith, J.G.Hetherington, Blast and Ballistic Loading of Structures, Butterwoth & Heinemann, Elsevier,2003 |
| 8. | Design of Blast Resistant Buildings in Petrochemical Facilities, 2nd Ed., ASCE Publication |

**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To predict the behaviour of different materials and fire |
| **CO2** | To design structural elements resistant to fire using codebook provisions |
| **CO3** | To suggest appropriate methods of strengthening and protecting against fire |
| **CO4** | To predict the response of structures subjected to blast or impact loads |
| **CO5** | To analyse structures subjected to impulse loads as a dynamic system |

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|---|---|---|
| **Course Code** | **:** | CE688 |
| **Course Title** | **:** | Green Building Design |
| **Type of Course** | **:** | Programme Elective / Open Elective |
| **Prerequisites** | **:** | - |
| **Contact Hours** | **:** | 36 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To teach the fundamentals of sustainable and energy-efficient building design |
| **CLO2** | To make students understand the role of materials in sustainable design |
| **CLO3** | To familiarize students with building envelopes, operational energy reduction and net zero building concepts |
| **CLO4** | To teach recycle-reuse methods in building design and round economy |
| **CLO5** | To expose the students to passive house standards building rating systems |

**Course Content**

Introduction - Embodied energy, Operational energy in Building and Life cycle energy. Ecological footprint, Bio-capacity and calculation of planet equivalent

Role of Material: Carbon from Cement, alternative cements and cementitious material - Sustainability issues for concrete – Green steel

Operational energy in building - role of materials and thermal conductivity - Building envelopes - Building systems and operations (HVAC, lighting, water supply, sewage, garbage disposal, recycling and composting) Clean & renewable energy in buildings - Rainwater harvesting - Effects of trees and microclimatic modification through greening

Recycle and reuse methods of building design – recycling of industrial and other waste for concrete production – reuse of steel members for new buildings – case studies

Smart buildings (Sensing and control systems) Net Zero buildings, Passive house standards Building Rating systems (LEED, BREEAM, IGBC etc)

**References**



| | |
|---|---|
| 1. | J Newman, B S Choo, Advanced Concrete Technology-Processes, 1 st Edition, Elsevier, 2003 |
| 2. | S Kubba, LEED Practices, Certification, and Accreditation Hand book, 1st ed. Elsevier, 2010 |
| 3. | Energy Conservation Building Code, Revised Version, Ministry of Power, Bureau of Energy Efficiency, 2018 |
| 4. | Building Envelope Stringency Analysis, Architectural Energy Corporation, International Institute for Energy Conservation, 2004 |
| 5. | Practical Handbook on Energy Conservation in Buildings, Indian Building Congress, 1st ed, Nabhi Publication, 2008 |
| 6. | F C McQuiston, J D Parker, Heating, Ventilating, and Air Conditioning, Analysis and Design, Fourth Ed. John Wiley & Sons, 1994 |
| 7. | TERI-Griha's Green Design practices (www.teriin.org/bcsd/griha/griha.htm) |
| 8. | A H Buchanan, G Brian, Energy and carbon dioxide implications of building construction, Energy and Buildings, 1994 |
| 9. | Green Building Basics, California Integrated Waste Management Board (www.ciwmb.ca.gov/GREENBUILDING/Basics.htm#What) |
| 10. | C J Kibert, Sustainable Construction: Green Building Design and Delivery, 3rd edition, Wiley, 2022 |



**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To determine embodied energy and operational energy in buildings |
| **CO2** | To understand the role of building materials in sustainable design |
| **CO3** | To design building envelopes to preserve natural resources |
| **CO4** | To learn recycle-reuse methods in building design |
| **CO5** | To know the building rating systems |

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| | | |
|---|---|---|
| **Course Code** | : | CE689 |
| **Course Title** | : | Hydraulic Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |

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|---|---|---|
| **Contact Hours** | **:** | 36 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand preliminary investigations for hydraulic structures. |
| **CLO2** | To understand geological and hydrological investigations for hydraulic structures. |
| **CLO3** | To get exposed to analysis and design of dams. |
| **CLO4** | To familiarize students with construction of dams and foundation for dams. |
| **CLO5** | 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.

**References**


| | |
|---|---|
| 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

| | |
|---|---|
| **CO1** | To carry out investigation and planning of hydraulic structures. |
| **CO2** | To analyse and design different types of dams. |
| **CO3** | To understand construction of different types of dams. |
| **CO4** | To be familiar with foundation treatment for dams. |
| **CO5** | To design weirs on permeable foundation. |

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| | | |
|---|---|---|
| **Course Code** | **:** | CE690 |

| | | |
|---|---|---|
| **Course Title** | : | Structures for Power Plants |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To introduce power plant structure, different types of power plants. |
| **CLO2** | To make students understand planning, analysis and design of power plants, and do sag tension calculations of Overhead high voltage transmission lines |
| **CLO3** | To make students be familiar with analysis and design of chimneys, cooling towers. |
| **CLO4** | To make students exposed to analysis and design of turbo generator foundation. |
| **CLO5** | 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. Planning analysis and design of transmission line & substation structures involved in evacuation of generated electricity in power plants - sag tension calculations of Overhead high voltage transmission lines, proportioning OHTL support dimension based on the requisite electrical clearances, loadings for OHTL supports as IS 802- 3D indeterminate truss model, design members using IS:802

**References**


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|---|---|
| 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. |
| 6. | SS Murthy and A.R. Santhakumar., Transmission Line structures, McGraw Hill, 1990 |
| 7. | Leon Kempner., Substation Structure Design guide - ASCE Manuals and Reports on Engineering Practice No. 113, 2008 |


**Course outcomes**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | To understand power plant structure, different types of power plants. |
| **CO2** | To understand planning, analysis and design of power plants and sag tension and load calculations as per IS:802 codebooks |
| **CO3** | To be familiar with the analysis and design of chimneys, cooling towers. |

| | |
|---|---|
| **CO4** | To be exposed to analysis and design of turbo generator foundation. |
| **CO5** | To understand the components of intake towers, storage structures. |

| | | |
|---|---|---|
| **Course Code** | **:** | CE691 |
| **Course Title** | **:** | Soil Structure Interaction |
| **Type of Course** | **:** | Programme Elective / Open Elective |
| **Prerequisites** | **:** | - |
| **Contact Hours** | **:** | 36 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To make students understand soil foundation interaction and its importance. |
| **CLO2** | To familiarize students with model analysis, Winkler model for soil structure interaction analysis. |
| **CLO3** | To expose students to beams and plates on elastic foundation. |
| **CLO4** | To enable students to carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction. |
| **CLO5** | 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.

**References**


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|---|---|
| 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. |

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|---|---|
| 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

| | |
|---|---|
| **CO1** | To understand soil foundation interaction and its importance. |
| **CO2** | To be familiar with model analysis, Winkler model for soil structure interaction analysis. |
| **CO3** | To be exposed to beams and plates on elastic foundation. |
| **CO4** | To carry out elastic analysis of pile, soil-pile interaction analysis, dynamic soil-pile interaction. |
| **CO5** | To better understand the concepts of laterally loaded pile. |

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|---|---|---|
| **Course Code** | : | CE692 |
| **Course Title** | : | Seismic Design of Steel Structures |
| **Type of Course** | : | Programme Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To understand fundamentals of seismic design of steel structures |
| **CLO2** | To learn the methods of linear and nonlinear seismic analysis |
| **CLO3** | To introduce force and ductility based design concepts |
| **CLO4** | To familiarize the seismic design of various steel structural framing members |
| **CLO5** | To learn the seismic design of braced steel frames |

**Course Content**

Fundamentals of Seismic Structural Design - inelastic deformation, energy of dissipation, ductility, damage, behavior factor and overstrength, capacity design rules, performance-based design (deterministic and probabilistic)

Seismic Structural Analysis, Linear elastic global analysis, Material and geometric nonlinear global analysis

Force-based design, Design Response Spectra (EN1998-1:2004), Behaviour factors, Characterisation of structures, Ductility classes, Plastic redistribution, Ductility-Based Plastic Design, global collapse mechanisms

Seismic Design of Moment Resisting Frames, Redistribution of bending moments in beams, Plastic hinges and connections, design for beam to column connections, Connection of columns to foundations

Frames with Concentric Bracing, X bracings, V or Δ bracings, dissipative connections in frames with concentric bracing, frames with eccentric bracing, type of eccentric bracing

**References**


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|---|---|
| 1. | Earthquake Resistant Steel Structures, ArcelorMittal Technical Brochure, |
| 2. | G. A. Papagiannopoulos, G. D. Hatzigeorgiou, D. E. Beskos, Seismic Design Methods for Steel Building Structures, Springer Cham, 2022 |
| 3. | C-M Uang, M Bruneau, A. S. Whittaker, K Chyuan, Seismic Design of Steel Structures, Chapter in The Seismic Design Handbook, Springer New York, 2012 |
| 4. | Earthquake Resistant Design of Steel Structures, Chapter 45, INSDAG Learning Material |
| 5. | EN:1998, Eurocode 8: Design of structures for earthquake resistance, European Commission |


**Course outcomes**

At the end of the course student will be able

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|---|---|
| **CO1** | Evaluate steel structures for seismic loading |
| **CO2** | Analyse steel structures for seismic loading by linear and nonlinear methods |
| **CO3** | Use Eurocode 8 for seismic design of steel structures |
| **CO4** | Differentiate force and ductility based seismic design of steel structures |
| **CO5** | Design various braced steel frames for earthquake loads |

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|---|---|---|
| **Course Code** | : | CE693 |
| **Course Title** | : | Introduction to 3D printing technology |
| **Type of Course** | : | Programme Elective / Open Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | To learn the fundamentals of prototyping in 3D printing |
| **CLO2** | To understand the various data formats and processes |
| **CLO3** | To introduce the different apparatus and technologies |
| **CLO4** | To familiarize with SGC, LOM and FDM |
| **CLO5** | To demonstrate the process and techniques of 3D printing |

**Course Content**

Introduction to Design, Prototyping fundamentals. Introduction to 3D printing, its historical development, advantages. Commonly used terms, process chain, 3D modelling, Data Conversion, and transmission, Checking and preparing, Building, Post processing, RP data formats, Classification of 3D printing process, Applications to various fields

Stereo lithography apparatus (SLA): Models and specifications, process, working principle, photopolymers, photo polymerization, layering technology, laser and laser scanning, applications, advantages and disadvantages, case studies. Solid ground curing (SGC): Models and specifications, process, working ,principle, applications, advantages and disadvantages, case studies

Laminated object manufacturing(LOM): Models and specifications, Process, Working principle, Applications, Advantages and disadvantages, Case studies. Fused Deposition Modeling (FDM): Models and specifications, Process, Working principle, Applications, Advantages and disadvantages, Case studies, practical demonstration

**References**


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|---|---|
| 1. | R Horne, K K Hausman, 3D Printing for Dummies, 2nd edition, Wiley, 2017 |
| 2. | G K Awari, C S Thorat, V Ambade, D P Kothari, Additive Manufacturing and 3D Printing Technology, CRC Press; 1st edition, 2021 |
| 3. | R Noorani, 3D Printing: Technology, Applications, and Selection, CRC Press, Taylor & Francis Group, 2018 |
| 4. | H K Dave, J P Davim, Fused Deposition Modeling Based 3D Printing, Springer Cham, 2021 |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Analyze the fundamentals and historical development of 3D printing, including advantages and key terms. |
| **CO2** | Demonstrate proficiency in 3D modeling, data conversion, and preparation for 3D printing, and understand various RP data formats. |
| **CO3** | Compare and contrast different 3D printing technologies (SLA, SGC, LOM, FDM) in terms of models, specifications, processes, and applications. |
| **CO4** | Execute practical demonstrations of 3D printing techniques and perform post-processing tasks effectively. |
| **CO5** | Evaluate case studies to understand the real-world applications, advantages, and disadvantages of various 3D printing technologies. |

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|---|---|---|
| **Course Code** | : | CE694 |
| **Course Title** | : | Modelling, Simulation and Computer Applications |
| **Type of Course** | : | Programme Elective / Open Elective |
| **Prerequisites** | : | - |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | Develop an understanding of various numerical methods to solve algebraic and differential equations |
| **CLO2** | Gain proficiency in matrix operations to compute eigenvalues and eigenvectors for solving linear systems in engineering and scientific applications |

| | |
|---|---|
| **CLO3** | Learn the fundamentals of stochastic modeling and simulation |
| **CLO4** | Explore and implement supervised machine learning algorithms |
| **CLO5** | To create, simulate, and optimize complex models for solving practical problems in engineering and scientific domains |

**Course Content**

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

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

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

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

**References**


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


**Course Outcomes (CO)**

At the end of the course student will be able to

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|---|---|
| **CO1** | Implement the numerical methods for solving nonlinear equations |
| **CO2** | Perform matrix operations to solve linear systems and perform matrix inversion |
| **CO3** | Develop and simulate stochastic models using Monte Carlo techniques, |
| **CO4** | Implement supervised machine learning algorithms |
| **CO5** | Integrate numerical methods, matrix algebra, stochastic modeling, and machine learning techniques to develop and simulate comprehensive models in engineering and scientific applications |

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|---|---|---|
| **Course Code** | **:** | CE695 |

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|---|---|---|
| **Course Title** | **:** | Random Vibrations |
| **Type of Course** | **:** | Programme Elective |
| **Prerequisites** | **:** | |
| **Contact Hours** | **:** | 36 |
| **Course Assessment Methods** | **:** | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | Grasp fundamental concepts of stochastic processes with an emphasis on their application to random vibrations |
| **CLO2** | Learn to analyze and evaluate the stochastic response of linear single-degree-of-freedom (SDOF) systems |
| **CLO3** | Acquire the skills to model and analyze linear multi-degree-of-freedom (MDOF) systems under stochastic excitation |
| **CLO4** | Gain the ability to approach and solve problems involving the response of non-linear systems to random excitations |
| **CLO5** | Develop the capability to evaluate fatigue damage in structures subjected to random loads |

**Course Content**

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

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

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

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

**References**


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|---|---|
| 1. | Nigam N. C., Introduction to Random Vibrations, MIT Press, Cambridge, USA, 1983. |
| 2. | Loren D Lutes & Shahram Sarkani., Stochastic Analysis of Structural and Mechanical Vibrations, Prentice Hall, NJ, 1997. |
| 3. | J Solnes, Stochastic Processes & Random Vibration, Theory and Practice, John Wiley,1997 |
| 4. | Lin, Y. K., Probabilistic Theory in Structural Dynamics, McGraw Hill, 1967. |
| 5. | Bendat & Piesol., Random Data Analysis and Measurement Procedure, John Wiley, 1991. |

**Course Outcomes (CO)**

At the end of the course student will be able to

| | |
|---|---|
| **CO1** | Demonstrate a thorough understanding of the fundamental concepts of stochastic processes |
| **CO2** | Evaluate the deterministic and stochastic dynamics of linear SDOF systems |
| **CO3** | Conduct time domain and frequency analysis of the stochastic response of linear MDOF and continuous systems |
| **CO4** | Assess the response of non-linear systems to random excitations |
| **CO5** | Assess the fatigue damage of structures subjected to random loads using appropriate stochastic methods |

| | | |
|---|---|---|
| **Course Code** | : | CE696 |
| **Course Title** | : | Uncertainty Modeling, Analysis and Quantification |
| **Type of Course** | : | Programme Elective / Open Elective |
| **Prerequisites** | : | |
| **Contact Hours** | : | 36 |
| **Course Assessment Methods** | : | Continuous Assessment, End Assessment |

**Course Learning Objectives (CLO)**

| | |
|---|---|
| **CLO1** | Understanding the basics and sources of uncertainty, and differentiate between deterministic and nondeterministic perspectives |
| **CLO2** | Utilize fundamental concepts of probability and statistics |
| **CLO3** | Employ various uncertainty modeling methods and sampling techniques |
| **CLO4** | Develop and apply computational tools for uncertainty propagation |
| **CLO5** | Develop and apply methods for uncertainty quantification |

**Course Content**

Introduction – Basics of Uncertainty, Classification of Uncertainty, Sources of Uncertainty, Propagation of uncertainty. Deterministic vs nondeterministic perspectives. Sources of uncertainty. Epistemic vs. aleatoric uncertainty. Data driven vs. physics driven uncertainty modelling. Different approaches such as probabilistic, interval, fuzzy.

Introductory probability and statistics, Uncertain Variable – Variables, Distribution, Operational Laws, Expected value, Variance, Moment, Entropy, Distance, Conditional Uncertainty Distribution, Uncertain Sequence, Uncertain Vector, Point estimation, hypothesis testing, time series.

Uncertainty Modeling methods and Sampling Techniques - High dimensional model representation, Response Surface methods, Kriging model, Model reduction, Various Sampling and optimization techniques and solutions.

Modelling: connecting data to the probabilistic models. Discretization of random fields. Tools for uncertainty propagation. Computational aspects of uncertainty propagation. Uncertainty quantification – sensitivity analysis

**References**


| | |
|---|---|
| 1. | Probability models in engineering and science, Haym Benaroya and Seon Mi Han, Taylor and Francis 2005 |
| 2. | Roger Ghanem, David Higdon and Houman Owhadi (Eds.). Handbook of Uncertainty Quantification. Springer |
| 3. | Eduardo Souza de Cursi and Rubens Sampaio. Uncertainty Quantification and Stochastic Modeling with Matlab . Springer |
| 4. | Ralph C. Smith. (2013) Uncertainty Quantification: Theory, Implementation, and Applications.SIAM. |
| 5. | T.J. Sullivan. Introduction to Uncertainty Quantification. Springer. |


**Course Outcomes (CO)**

At the end of the course student will be able

| | |
|---|---|
| **CO1** | Represent mathematically the uncertainty in the parameters of physical models. |
| **CO2** | Propagate parametric uncertainty through physical models to quantify the induced uncertainty on quantities of interest. |
| **CO3** | Develop and implement models for representing random fields and their uncertainties. |
| **CO4** | Combine multiple sources of information to enhance the predictive capabilities of models |
| **CO5** | Apply methods to quantify the uncertainties in a system |