M.I.E.T. ENGINEERING COLLEGE
(Autonomous)

Curriculum & Syllabus

(Regulations 2024)

M.E. Structural Engineering

M.I.E.T. ENGINEERING COLLEGE

(AUTONOMOUS)

(Approved by AICTE, New Delhi and Affiliated to Anna University, Chennai)
Accredited by NBA (CIVIL, CSE, ECE, EEE & MECH)
Accredited with 'A+' grade by NAAC
(An ISO 9001:2015 Certified Institution)
(Recognized by UGC under section 2(f) & 12(B) of UGC Act, 1956)
TRICHY - PUDUKKOTTAI MAIN ROAD, TRICHY - 620 007

DEPARTMENT OF CIVIL ENGINEERING

CURRICULUM AND SYLLABUS

M.E. STRUCTURAL ENGINEERING
(Regulations 2024)

Vision

A knowledge hub in Civil Engineering sciences, contributing to the progress of humanity through innovative thinking, domain expertise and high ethical values.

Mission

- To provide quality education through industry based value-added trainings and develop skilled Civil Engineers.
- To nurture competent professionals trained in designing and implementing Civil Engineering systems and to perform professionally and ethically.
- To provide a conducive environment that fosters aptitude for research, higher education, entrepreneurship skills, leadership quality, and lifelong learning.

Programme Outcomes (POs)

1. An ability to independently carry out research/investigation and development work to solve practical problems.
2. An ability to write and present a substantial technical report/document.
3. Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor's program.
4. Acquire in-depth knowledge of the Structural Engineering discipline, with an ability to evaluate, analyze and synthesize existing and new knowledge in structural design.
5. Critically analyze complex Structural Engineering problems, apply independent judgment for synthesizing information and make innovative advances in a theoretical, practical and policy context.
6. Conceptualize and solve Structural Engineering problems, evaluate potential solutions and arrive at technically feasible, economically viable and environmentally sound solutions with due consideration of health, safety, and socio-cultural factors.

Program Educational Objectives (PEOs)

1. Gain knowledge and skills in structural engineering which will enable them to have a career and professional accomplishment in the public or private sector organizations.
2. Become consultants in Structural Engineering and solve complex real-life issues related to the analysis, design and maintenance of structures under various environmental conditions.
3. Contribute to the enhancement of knowledge in Structural Engineering by performing quality research in institutions of international repute or Research organizations or Academia.

PO-PEO Mapping

Program Educational Objectives	Program Outcomes					
	PO1	PO2	PO3	PO4	PO5	PO6
PEO1	2	2	3	3	3	3
PEO2	3	2	3	3	3	3
PEO3	3	2	3	3	3	3

1-Low, 2 -Medium, 3- High

CHOICE BASED CREDIT SYSTEM

I TO IV SEMESTERS (REGULAR) CURRICULUM AND SYLLABUS

SEMESTER I

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
THEORY								
1.	24MP1101	Advanced Mathematical Methods	FC	3	0	0	3	3
2.	24ST1101	Theory of Elasticity and Plasticity	PCC	3	1	0	4	4
3.	24ST1102	Structural Dynamics	PCC	3	1	0	4	4
4.	24RE1101	Research Methodology and IPR	RMC	2	0	0	2	2
5.	-	Professional Elective I	PEC	3	0	0	3	3
6.	-	Professional Elective II	PEC	3	0	0	3	3
PRACTICAL								
7.	24ST1201	Advanced Structural Laboratory	PCC	0	0	4	4	2
8.	24ST1701	Technical Seminar	EEC	0	0	2	2	1
							TOTAL	**22**

SEMESTER II

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
THEORY								
1.	24ST2101	Finite Element Analysis in Structural Engineering	PCC	3	1	0	4	4
2.	24ST2102	Advanced Steel Structures	PCC	3	1	0	4	4
3.	24ST2103	Advanced Design of Concrete Structures	PCC	3	1	0	4	4
4.	-	Professional Elective III	PEC	3	0	0	3	3
5.	-	Professional Elective IV	PEC	3	0	0	3	3
PRACTICAL								
6.	24ST2201	Structural Design Studio	PCC	0	0	4	4	2
7.	24ST2202	Computational Laboratory	PCC	0	0	4	4	2
							TOTAL	**22**

SEMESTER III

S. NO.	COURSE CODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
THEORY								
1.	24ST3101	Stability of Structures	PCC	3	1	0	4	4
2.	24RE3102	Research article review and Scientific Report Writing	RMC	2	0	0	2	2
3.	-	Professional Elective V	PEC	3	0	0	3	3
4.	-	Open Elective – I	OEC	3	0	0	3	3
PRACTICAL								
4.	24ST3601	Practical Training	EEC	0	0	2	2	1
5.	24ST3501	Project Work Phase- I	EEC	0	0	12	12	6
							TOTAL	**19**

SEMESTER IV

S. NO.	COURSEC ODE	COURSE TITLE	CATE GORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
PRACTICAL								
1.	24ST4501	Project Work Phase- II	EEC	0	0	24	24	12
							TOTAL	**12**

TOTAL CREDITS TO BE EARNED FOR THE AWARD OF THE DEGREE=75

FOUNDATION COURSE (FC)

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24MP1101	Advanced Mathematical Methods	FC	3	0	0	3	3
							TOTAL	**3**

PROFESSIONAL CORE COURSES (PCC)

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24ST1101	Theory of Elasticity and Plasticity	PCC	3	1	0	4	4
2.	24ST1102	Structural Dynamics	PCC	3	1	0	4	4
3.	24ST1201	Advanced Structural Laboratory	PCC	0	0	4	4	2
4.	24ST2101	Finite Element Analysis in Structural Engineering	PCC	3	1	0	4	4
5.	24ST2102	Advanced Steel Structures	PCC	3	1	0	4	4
6.	24ST2103	Advanced Design of Concrete Structures	PCC	3	1	0	4	4
7.	24ST2201	Structural Design Studio	PCC	0	0	4	4	2
8.	24ST2202	Computational Laboratory	PCC	0	0	4	4	2
9.	24ST3101	Stability of Structures	PCC	3	1	0	4	4
							TOTAL	**30**

RESEARCH METHODOLOGY COURSES (RMC)

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24RE1101	Research Methodology and IPR	RMC	2	0	0	2	2
2.	24RE3102	Research article review and Scientific Report Writing	RMC	2	0	0	2	2
							TOTAL	**4**

EMPLOYABILITY ENHANCEMENT COURSES (EEC)

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24ST1701	Technical Seminar	EEC	0	0	2	2	1
2.	24ST3601	Practical Training	EEC	0	0	2	2	1
3.	24ST3501	Project Work Phase- I	EEC	0	0	12	12	6
4.	24ST4501	Project Work Phase- II	EEC	0	0	24	24	12
							TOTAL	**20**

PROFESSIONAL ELECTIVES COURSES (PEC)

SEMESTER I, PROFESSIONAL ELECTIVE- I

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24ST1301	Advanced Concrete Technology	PEC	3	0	0	3	3
2.	24ST1302	Experimental Techniques in Structural Engineering	PEC	3	0	0	3	3
3.	24ST1303	Disaster management	PEC	3	0	0	3	3
4.	24ST1304	Mechanics of fiber reinforced polymer concrete	PEC	3	0	0	3	3

SEMESTER I, PROFESSIONAL ELECTIVE- II

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24ST1305	Prefabricated Structures	PEC	3	0	0	3	3
2.	24ST1306	Advanced Prestressed Concrete	PEC	3	0	0	3	3
3.	24ST1307	Masonry Structures Design	PEC	3	0	0	3	3
4.	24ST1308	Composite Structures	PEC	3	0	0	3	3

SEMESTER II, PROFESSIONAL ELECTIVE- III

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24ST2301	Maintenance, Repair and Rehabilitation of Structures	PEC	3	0	0	3	3
2.	24ST2302	Structural Safety and Reliability	PEC	3	0	0	3	3
3.	24ST2303	Corrosion Prevention and Control in RC structures	PEC	3	0	0	3	3
4.	24ST2304	Structural Health Monitoring	PEC	3	0	0	3	3

SEMESTER II, PROFESSIONAL ELECTIVE- IV

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24ST2305	Design of Bridge	PEC	3	0	0	3	3
2.	24ST2306	Advanced Industrial Structures	PEC	3	0	0	3	3
3.	24ST2307	Tall Structures	PEC	3	0	0	3	3
4.	24ST2308	Design of Steel-Concrete Composite Structures	PEC	3	0	0	3	3

SEMESTER III, PROFESSIONAL ELECTIVE- V

S. NO.	COURSE CODE	COURSE TITLE	CATEGORY	PERIODS PER WEEK			TOTAL CONTACT PERIODS PER WEEK	CREDITS
				L	T	P		
1.	24ST3301	Advanced Foundation Design	PEC	3	0	0	3	3
2.	24ST3302	Earth retaining Structures	PEC	3	0	0	3	3
3.	24ST3303	Design of offshore Structures	PEC	3	0	0	3	3
4.	24ST3304	Soil Structure Interaction	PEC	3	0	0	3	3

24MP1101 ADVANCED MATHEMATICAL METHODS L T P C
3 0 0 3

COURSE OBJECTIVES

- To develop the ability to apply the principles of matrix theory in solving linear algebraic equations and optimization problems.
- To enhance skills in utilizing Laplace and Fourier transform techniques for analyzing and solving partial differential equations.
- To cultivate the ability to employ calculus of variations in addressing complex functional optimization problems in engineering and physics.

UNIT I MATRIX THEORY 9

The Cholesky decomposition - Generalized Eigenvectors - Canonical basis - QR factorization- Singular value decomposition - Pseudo inverses - Least square approximation.

UNIT II LAPLACE TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS 9

Laplace transform - Definitions – Properties – Transform 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.

UNIT III FOURIER TRANSFORM TECHNIQUES FOR PARTIAL DIFFERENTIAL EQUATIONS 9

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.

UNIT 1V CALCULUS OF VARIATIONS 9

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 – Isoperimetric problems – Direct methods – Ritz and Kantorovich methods.

UNIT V TENSOR ANALYSIS 9

Summation convention – Contravariant and covariant vectors – Contraction of tensors –Inner product – Quotient law – Metric tensor – Christoffel symbols – Covariant differentiation – Gradient - Divergence and curl.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Apply the principles of elasticity to analyze and solve problems involving stress and strain in various materials, using fundamental equations and theories.

CO2: Develop the ability to determine the relationships between applied forces and resulting deformations in elastic bodies, incorporating boundary conditions and material properties into calculations.

CO3: Utilize advanced techniques, such as the finite element method, to model complex structures and predict their behavior under various loading conditions.

CO4: Evaluate the impact of different loading scenarios on elastic materials, including tensile, compressive, and shear forces, and analyze their effects on structural integrity.

CO5: Integrate the principles of elasticity with practical applications in engineering, enabling the design and assessment of materials and structures for safety and performance.

TEXT BOOKS

1. Andrews L.C. and Shivamoggi, B., "Integral Transforms for Engineers", Prentice Hall of India Pvt. Ltd., New Delhi, 2003.
2. Elsgolc, L.D., "Calculus of Variations", Dover Publications Inc., New York, 2007.
3. Mathews, J. H., and Howell, R.W., "Complex Analysis for Mathematics and Engineering", 6th Edition, Jones and Bartlett Publishers, 2011.

REFERENCE BOOKS

1. Richard Bronson, matrix operation, Schaum's outline series, Second Edition, McGrawHill, New Delhi , 2011.
2. Sankara Rao, K., "Introduction to Partial Differential Equations", 3rd Edition, Prentice Hall of India Pvt. Ltd., New Delhi, 2010.
3. Spiegel, M.R., "Theory and Problems of Complex Variables and its Applications", Schaum's Outline Series, McGraw Hill Book Co., 1981.
4. Ramaniah. G. "Tensor Analysis", S. Viswanathan Pvt. Ltd., 1990.
5. Naveen Kumar, "An Elementary Course on Variational Problems in Calculus ", Narosa Publishing House, 2005.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	-	3	2	2	2
CO2	-	-	3	2	2	2
CO3	-	-	3	2	2	2
CO4	-	-	3	2	2	2
CO5	-	-	3	2	2	2
AVG	-	-	3	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1101 THEORY OF ELASTICITY AND PLASTICITY L T P C
3 1 0 4

COURSE OBJECTIVES

- To develop the ability to use the principles of theory of elasticity
- To enable students to solve problems on semi-infinite and finite beams
- To introduce theoretical fundamentals of the theory of plasticity

UNIT I ANALYSIS OF STRESS AND STRAIN 9+3

Basic concepts of deformation of deformable bodies, notations for stress and strain in two and three dimensions. Stress transformation laws - differential equations of equilibrium in two and three dimensions in Cartesian coordinates, generalized Hooke's law - lame's constants.

UNIT II TWO DIMENSIONAL PROBLEMS 9+3

Plane stress and plane strain problems – examples- Two dimensional problems in rectangular coordinates - bending of a cantilever loaded at free end - Two dimensional problems in polar coordinates for curved beam, thick cylinders and plate with holes.

UNIT III STRAIN ENERGY METHODS 9+3

Total strain energy- complementary energy - Principle of virtual work and total potential energy- Theorem of minimum complementary energy- Griffith's theory of rupture - Castigliano's theorem - Principle of least work.

UNIT IV BEAMS ON ELASTIC FOUNDATIONS 9+3

Beams on Elastic foundation – Methods of analysis – Elastic line method – Idealization of soil medium – Winkler model – Infinite beams – Semi-infinite and finite beams – Rigid and flexible –Uniform Cross Section – Point load and UDL – Solution by Finite Differences.

UNIT V PLASTICITY **9+3**

Introduction - physical assumptions, yield criteria of metals, graphical representation of yield criteria, Flow rule (plastic stress - strain relation)- Application to simple problems in tension – compression - Solution of elasto-plastic problems.

TOTAL:60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Derive and write the fundamental equations of elasticity describing the linear behavior of elements and develop constitutive models based on material behavior

CO2:Demonstrate the application of plane stress and plane strain in a given situation in both cartesian and polar coordinate systems

CO3:Solve torsion problems in circular and non-circular cross-sections

CO4:Analyze beams resting on elastic foundations

CO5:Solve analytically the simple boundary value problems with elasto-plastic and strain hardening properties

TEXT BOOKS

1. Arthur P Boresi, Ken P.Chong, “Elasticity in Engineering Mechanics”, John Wiley & Sons, 2000.
2. Kachanov L M, “Fundamentals of the Theory of Plasticity”, Dover Publications, 2013.
3. Timoshenko and Goodier, “Theory of Elasticity”, 3rd Edition, McGraw Hill, 2010.

REFERENCE BOOKS

1. Stuart Antman, “Nonlinear Problems of Elasticity”, Springer Publication, 2nd Edition, 2005.
2. Sadhusingh, “Theory of Elasticity”, Khanna Publishers, New Delhi 2012.
3. Ansel.C.Ugural and Saul.K.Fenster, “Advanced Strength and Applied Elasticity,” Fourth Edition, Prentice Hall Professional Technical Reference, New Jersey, 2003.
4. Chakrabarty. J, “Theory of Plasticity”, Third Edition, Elsevier Butterworth – Heinmann UK, 2007.
5. Jane Helena H, "Theory of Elasticity and Plasticity", PHI, New Delhi 2017.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	2	3	2
CO2	3	-	3	2	3	2
CO3	3	-	3	2	3	2
CO4	3	-	3	2	3	2
CO5	3	-	3	2	3	2
AVG	3	-	3	2	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1102 STRUCTURAL DYNAMICS L T P C
3 1 0 4

COURSE OBJECTIVES

- To help students understand the fundamentals of dynamic analysis in structural systems.
- To enable students to apply vibration analysis techniques for assessing structural responses to dynamic loads.
- To equip students with the skills to evaluate structural property matrices and natural vibrations in multi-storeyed frames.

UNIT I INTRODUCTION TO DYNAMIC ANALYSIS 9+3

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.

UNIT II VIBRATION ANALYSIS 9+3

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.

UNIT III STRUCTURAL PROPERTY MATRICES 9+3

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

UNIT IV MULTI STOREYED FRAMES 9+3

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

UNIT V VIBRATION ANALYSIS USING FINITE ELEMENT **9+3**

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

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Analysis of system/structures with a single degree of freedom

CO2:Dynamic analysis of system/structures with Multi degrees of freedom under free and forced vibration

CO3:Derive a mathematical model of a continuous system and do a dynamic analysis under free and forced vibration

CO4:Analysis of earthquake response

CO5:Evaluate the vibration analysis using finite element method

TEXT BOOKS

1. Mario Paz, Structural Dynamics -Theory and Computation, Kluwer Academic Publishers, Fifth Edition, 2006.
2. Roy R.Craig, Jr, Andrew J. Kurdila, Fundamentals of Structural Dynamics, John Wiley& Sons, 2011.
3. A. K. Chopra "Dynamics of Structures Theory and Application to Earthquake Engineering" Pearson Education, 2001.

REFERENCE BOOKS

1. Madhujit Mukhopadhyay," Structural Dynamics: Vibrations and Systems", Ane's Student Edition,2017
2. Srinivasan Chandrasekaran, Dynamic Analysis and Design of Ocean Structures,Springer, 2015.
3. Anil K.Chopra, Dynamics of Structures, Fifth edition, Pearson Education, 2020
4. Pankaj Agarwal and Manish Shrikhande, "Earthquake Resistant Design of Structures",Prentice Hall of India, 2014.
5. Mohiuddin Ali Khan "Earthquake-Resistant Structures: Design, Build and Retrofit", Elsevier Science& Technology, 2013

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	2	3	2
CO2	3	-	2	2	3	2
CO3	3	-	2	2	3	2
CO4	3	-	2	2	3	2
CO5	3	-	2	2	3	2
AVG	3	-	2	2	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24RE1101 RESEARCH METHODOLOGY AND IPR L T P C
2 0 0 2

COURSE OBJECTIVES

- To give an overview of the research methodology and explain the technique of defining a research problem
- To explain the functions of the literature review in research.
- To explain the art of interpretation and the art of writing research reports

UNIT I RESEARCH DESIGN **6**

Overview of the research process and design, Use of Secondary and exploratory data to answer the research question, Qualitative research, Observation studies, Experiments and Surveys, Research problem formulation, Research gap identification, Formulation of materials and methods.

UNIT II DATA COLLECTION AND SOURCES **6**

Measurements, Measurement Scales, Questionnaires and Instruments, Sampling and methods. Data - Preparing, Exploring, examining and displaying, Advanced tools and techniques

UNIT III DATA ANALYSIS AND REPORTING **6**

Overview of Multivariate analysis, Hypotheses testing and Measures of Association. Presenting Insights and findings using written reports and oral presentations, Computer aided Research – Simulation – Case study

UNIT IV INTELLECTUAL PROPERTY RIGHTS **6**

Intellectual Property – Concept of IPR, Evolution and development of the concept of IPR, IPR development process, Trade secrets, utility Models, IPR & Bio diversity, Role of WIPO and WTO in IPR establishments, Right of Property, Common rules of IPR practices, Types and Features of IPR Agreement, Trademark, Functions of UNESCO in IPR maintenance.

UNIT V PATENTS **6**

Patents – Objectives and benefits of patent, Concept, features of patent, Inventive step, Specification, Types of patent application, process E-filling, Examination of patent, Grant of patent, Revocation, Equitable Assignments, Licenses, Licensing of related patents, patent agents, Registration of patent agents.

TOTAL: 30 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the research problem formulation

CO2:Design experiments for different statistical concepts

CO3:Demonstrate research ethics

CO4:Formulate research proposals and reports

CO5:Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D

TEXT BOOKS

1. Cooper Donald R, Schindler Pamela S and Sharma JK, "Business Research Methods", Tata McGraw Hill Education, 12e (2018).
2. Catherine J. Holland, "Intellectual property: Patents, Trademarks, Copyrights, Trade Secrets", Entrepreneur Press, 2007.
3. David Hunt, Long Nguyen, Matthew Rodgers, "Patent searching: tools & techniques", Wiley, 2012.

REFERENCE BOOKS

1. Ellapu Venkatesh Palagati Anusha, Savuturu Sujith Kumar, Syed Mastan Basha fundamentals of Research Methodology and Intellectual Property Rights, Fedshine Publication, 2023.
2. The Institute of Company Secretaries of India, Statutory body under an Act of parliament, "Professional Programme Intellectual Property Rights, Law and practice", September 2013.
3. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
4. Kothari, C. R. Research Methodology - Methods and Techniques, New Age International publishers, New Delhi, 2004.
5. Robert P. Merges, Peter S. Menell and Mark A. Lemley, "Intellectual Property in New Technological Age", Aspen Publishers, 2016.

Mapping of COs and POs

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	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	2	2
CO2	3	2	2	2	2	2
CO3	3	2	2	2	2	2
CO4	3	2	2	2	2	2
CO5	3	2	2	2	2	2
AVG	3	2	2	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1201 ADVANCED STRUCTURAL LABORATORY L T P C
0 0 4 2

COURSE OBJECTIVES

- To provide hands-on experience in testing reinforced concrete beams and columns for strength and deflection behavior.
- To equip students to perform dynamic and static tests on steel beams and frames, evaluating damping coefficients, drift, stiffness, and energy dissipation.
- To enhance skills in assessing in-situ concrete strength and quality using rebound hammers and ultrasonic pulse velocity testers.

LIST OF EXPERIMENTS

1. Fabrication, casting and testing of simply supported reinforced concrete beam for strength and deflection behavior.
2. Testing of simply supported steel beam for strength and deflection behavior.
3. Fabrication, casting and testing of reinforced concrete column subjected to concentric and eccentric loading.
4. Dynamic testing of cantilever steel beam
   a. To determine the damping coefficients from free vibrations.
   b. To evaluate the mode shapes.
5. Static cyclic testing of single bay two storied steel frames and evaluate
   a. Drift of the frame.
   b. Stiffness of the frame.
   c. Energy dissipation capacity of the frame.
6. Determination of in-situ strength and quality of concrete using
   a. Rebound hammer
   b. Ultrasonic Pulse Velocity Tester.

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Fabricate, cast, and test reinforced concrete beams and columns, analyzing their strength and deflection behavior under different loading conditions.

CO2: Conduct dynamic and static tests on steel beams and frames, interpreting results related to damping coefficients, mode shapes, drift, and stiffness.

CO3: Evaluate the energy dissipation capacity of steel frames through static cyclic testing and assess the implications for structural design.

CO4: Determine the in-situ strength and quality of concrete using non-destructive testing methods, including rebound hammers and ultrasonic pulse velocity testers.

CO5: Effectively communicate testing procedures, results, and analyses in written reports and oral presentations.

REFERENCE BOOK

1. Dally J W, and Riley W F, "Experimental Stress Analysis", McGraw-Hill Inc. New York, 1991

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	3	2
CO2	3	3	2	2	3	2
CO3	3	3	2	2	3	2
CO4	3	3	2	2	3	2
CO5	3	3	2	2	3	2
AVG	3	3	2	2	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1701 TECHNICAL SEMINAR L T P C
0 0 2 1

COURSE OBJECTIVES

- To work on a specific technical topic in Structural Engineering
- To acquire the skills of oral presentation
- To acquire technical writing abilities for seminars and conferences.

SYLLABUS

A group of 2 students have to choose a problem and carry out scientific systematic investigation experimentally/ theoretically in suggesting a viable solution. At the end of the semester, each group of students have to submit a report for evaluation. Depth of

understanding, coverage, quality of presentation material (PPT/OHP) and communication skill of the student will be taken as measures for evaluation.

TOTAL:30 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Identify the latest developments in the field of Structural Engineering

CO2:Acquire technical writing abilities for seminars, conferences and journal publications

CO3:Use modern tools to present the technical details

CO4:Conduct brainstorming sessions on technical concepts

CO5:Gain insight on upcoming trends in Structural Engineering

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2	2	3	2
CO2	3	3	2	2	3	2
CO3	3	3	2	2	3	2
CO4	3	3	2	2	3	2
CO5	3	3	2	2	3	2
AVG	3	3	2	2	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST2101 FINITE ELEMENT ANALYSIS IN STRUCTUTRAL ENGINEERING **L T P C 3 1 0 4**

COURSE OBJECTIVES

- To make the students understand the basics of the Finite Element Technique
- To cover the analysis methodologies for 1-D, 2-D and 3-D Structural Engineering problems
- To understand the assembly process and imposition of boundary conditions in FEM analysis.

UNIT I CONCEPTS OF FINITE ELEMENT METHOD **9+3**

General description of the finite element method – Overview of matrix techniques- basic equations from solid mechanics - Variation formulation – approximate methods – Rayleigh Ritz, Weighted residual (Galerkin) and finite difference methods.

UNIT II PLANE STRESS AND PLANE STRAIN **9+3**

The concept of an element - derivation of Elemental Equations – assembly -Imposition of boundary Conditions - solution of the equations – Basic functions and shape functions – one dimensional element - Two dimensional problems in plane stress and plain strain.

UNIT III AXISYMMETRIC STRESS ANALYSIS AND 3D-STRESS ANALYSIS **9+3**

Ax symmetric problems - Triangular and quadrilateral Elements – natural coordinates - Isoperimetric formulation - numerical Integration - Plate bending and shell elements - brick elements - Higher Order Elements.

UNIT IV MESHING AND SOLUTION PROBLEMS **9+3**

Pre and post processor interpretations –'p' and 'h' methods of refinement – ill conditioned elements - Discretization errors – patch test - auto and adaptive mesh generation techniques - error evaluation - Finite element programming and FEA Software – ANSYS.

UNIT V NONLINEAR AND VIBRATION PROBLEMS **9+3**

Material and geometric non-linearity - Consistent system matrices – dynamic condensation - Eigen value extraction - modal methods – Integration methods - application to thermal analysis.

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Formulate a finite element problem using basic mathematical principles

CO2:Understand the fundamental concepts of plane stress and plane strain

CO3:Analyze a frame using truss element

CO4:Formulate and analyze the two- dimensional and three-dimensional solid finite element problems

CO5:Analyze shells, thick and thin plates and explain the dynamic analysis using FEM

TEXT BOOKS

1. Seshu, P., TEXT BOOKS of Finite Element Analysis, Prentice-Hall of India Pvt.Ltd., New Delhi, 2007.
2. Reddy, J.N., An Introduction to the Finite Element Method, McGraw-Hill International Editions (Engineering Mechanics Series), 1993.
3. Chandrupatla, R.T. and Belegundu, A.D., "Introduction to Finite Elements in Engineering", Fourth Edition, Prentice Hall of India, 2015.

REFERENCE BOOKS

1. Logan D. L,A First Course in the Finite Element Method, Thomson- Engineering, 3rd edition, 2010.
2. David V. Hutton Fundamentals of Finite Element Analysis, Tata McGrawHill Edition, 2005.
3. Cook Robert. D., Plesha, Michael. E & Witt, Robert.J. Concepts and Applications of Finite Element Analysis, Wiley Students Edition, 2004.

4. Moaveni, S., “Finite Element Analysis Theory and Application with ANSYS”, Prentice Hall Inc., 2020.
5. Zienkiewicz, O.C. and Taylor, R.L., “The Finite Element Method”, Seventh Edition, McGraw – Hill, 2013.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	3	2	2
CO2	3	-	2	3	2	2
CO3	3	-	2	3	2	2
CO4	3	-	2	3	2	2
CO5	3	-	2	3	2	2
AVG	3	-	2	3	2	2

1-Low, 2-Medium, 3-High, “-” – no correlation

24ST2102 ADVANCED STEEL STRUCTURES L T P C
3 1 0 4

COURSE OBJECTIVES

- To familiarize students with design philosophies, codes, and stability criteria for steel structures
- To enable students to design various types of connections, including welded and bolted connections
- To equip students with the knowledge to analyze and design industrial buildings

UNIT I GENERAL **9+3**

Design Philosophies and Design Codes (IS, EC, AISC) – Stability Criteria –Beam- Columns and Frames (Sway and Non-Sway) – Design of members subjected to combined forces – Design of Purlins, Louver rails, Gable column and Gable wind girder.

UNIT II DESIGN OF CONNECTIONS **9+3**

Types of connections – Welded and Bolted – Design of simple base, Gusseted base and Moment Resisting Base – Flexible Connections - Seated Connections – Unstiffened and Stiffened Seated Connections – Moment Resistant Connections– Clip angle Connections – Split beam Connections.

UNIT III ANALYSIS AND DESIGN OF INDUSTRIAL BUILDINGS **9+3**

Structural Configurations - Functional and Serviceability Requirements- Analysis and design of different types of trusses – Analysis and design of industrial buildings – Sway and non-sway frames –Gantry Girders –Earthquake resistant design of steel buildings.

UNIT IV PLASTIC ANALYSIS OF STRUCTURES **9+3**

Introduction, Shape factor - Moment redistribution - Beam, Sway, Joint and Gable mechanisms -Combined mechanisms– Analysis of portal frames, Effect of axial force and shear force on plastic moment capacity, Connection Requirements– Moment resisting connections - Design of Straight Corner Connections –Design of continuous beams

UNIT V DESIGN OF LIGHT GAUGE STEEL STRUCTURES **9+3**

Introduction to Direct Strength Method - Behavior of Compression Elements - Effective width for load and deflection determination – Behavior of Unstiffened and Stiffened Elements – Design of webs of beams – Flexural members – Lateral buckling of beams – Shear Lag – Flange Curling –Design of Compression Members – Wall Studs

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Design steel members such as purlins, gable wind girders subjected to combined forces

CO2:Design different types of steel connections such as welded and bolted flexible and moment resisting connections

CO3:Analyze and design industrial structures such as trusses and portal frames subjected to wind and seismic forces

CO4:Understand the effect of axial force and shear force on steel structures and analyze continuous beams and frames using plastic theory

CO5:Evaluate the behavior and design of compression and flexural Cold-formed Steel members

TEXT BOOKS

1. Lynn S. Beedle, Plastic Design of Steel Frames, John Wiley and Sons, 1997.
2. Narayanan.R.et.al., Teaching Resource on Structural steel Design, INSDAG, Ministry of Steel Publishing, 2000.
3. Subramanian. N, Design of Steel Structures, Oxford University Press, 2016.

REFERENCE BOOKS

1. Teaching Resources for “Structural Steel Design”. Vol. 2 of 3, Institute of Steel Development and Growth (INSDAG), 2000.
2. Wie Wen Yu, Design of Cold-Formed Steel Structures, McGraw Hill Book Company,2019
3. S.K. Duggal, Limit State Design of Steel Structures, McGraw Hill Book Company, 2017.

4. Bhavikatti, S.S., Design of Steel Structures, I.K. International Publishing House Pvt.Ltd., New Delhi, 2010.
5. Punmia B.C., Comprehensive Design of Steel Structures, Lakshmi Publications, New Delhi, 2000.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST2103 ADVANCED DESIGN OF CONCRETE STRUCTURES L T P C
3 1 0 4

COURSE OBJECTIVES

- To make the students familiar with the behavior of RCC beams
- To gain knowledge on design principle of columns
- To design special structural members with detailing

UNIT I DESIGN OF BEAMS 9+3

Overall review on behavior of RC beams in flexure and shear - behavior and design of RCC beams under combined Shear, Torsion and Bending -Serviceability limit states - computation of deflections and crack width as per codal provisions.

UNIT II DESIGN OF SLENDER COLUMNS 9+3

Behavior of slender RCC Columns - Failure modes - Calculation of design moments for braced and unbraced columns - Design of slender columns.

UNIT III DESIGN OF SPECIAL RC ELEMENTS 9+3

Design of RC walls – ordinary and Shear walls - Strut and tie method of analysis for Corbels and Deep beams

UNIT IV DESIGN OF FLAT SLABS AND PLATES 9+3

Yield line theory and Hiller berg method of design of slabs - Design of flat slabs and flat plates according to BIS method - Shear in flat slabs and flat plates -Design of Grid floors

UNIT V INELASTIC BEHAVIOUR OF CONCRETE STRUCTURES **9+3**

Inelastic behavior of concrete beams - Moment-rotation curves – Moment redistribution concept of Ductility – Detailing for ductility – design of beams, Columns for ductility - design of cast-in-situ joints in frames.

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the structural behavior of flexural members and columns

CO2:Design the compression members and construct interaction diagrams

CO3:Design the special elements like corbels, deep beams and grid floors

CO4:Design flat slab and spandrel beam

CO5:Predict the moment curvature behavior and design and detail concrete elements based on ductility

TEXT BOOKS

1. Varghese, P.C. Advanced Reinforced Concrete Design, Prentice Hall of India, 2005.
2. Gambhir.M.L, Design of Reinforced Concrete Structures, Prentice Hall of India, 2012.
3. Subramanian. N, Design of Reinforced Concrete Structures, Oxford University Press, 2013.

REFERENCE BOOKS

1. Sinha.S.N., Reinforced Concrete Design, Tata-McGraw-Hill,1996.
2. Purushothaman, P, Reinforced Concrete Structural Elements: Behaviour Analysis and Design, Tata McGraw-Hill, 1986.
3. Park. R., &Paulay .T, Reinforced Concrete Structures, John Wiley & Sons,2009.
4. Arthur H.Nilson, Design of Concrete Structures, Tata McGraw-Hill, 2003.
5. IS 456-2000, Plain and Reinforced Concrete - Code of Practice.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST2201 STRUCTURAL DESIGN STUDIO L T P C
0 0 4 2

COURSE OBJECTIVES

- To enable students to design structures using modern software tools such as ETABS, STAAD, and STRAP, ensuring compliance with relevant standards and codes.
- To equip students with skills in analyzing and detailing structural components, culminating in the creation of comprehensive drawings and reports that reflect their design process.
- To foster independent learning and problem-solving abilities by requiring students to complete a detailed project that includes both a written report and a presentation of their design work.

EXPERIMENTS/ EXERCISES

To design a structure using modern software tools available like ETABS, STAAD, STRAP, etc. and present it in the form of a complete detailed drawing. Students have to work individually with standard codes, computational tools and software packages for analyzing, designing and detailing a structure. A detailed report on the work done shall be submitted by individual students in the form of a report and presentation.

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the requirements of a structure and model it accordingly using computer software

CO2:Analyze the structure for various loads and load combinations according to the relevant IS codes

CO3:Design and detail structures using computer software/tools and check the correctness using manual approximate methods

CO4:Prepare the complete structural drawings using computer software

CO5:Prepare a detailed report on the work done

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2
CO5	3	3	3	3	3	2
AVG	3	3	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST2202 COMPUTATIONAL LABORATORY L T P C
0 0 4 2

COURSE OBJECTIVES

- To enable students to solve mathematical equations and conduct finite element analysis using computational methods and software tools.
- To equip students with practical skills in applying finite element software like ABAQUS and ANSYS to model, analyze, and interpret Engineering problems.
- To foster a deep understanding of numerical methods and their application in solving complex Engineering problems through hands-on experience with advanced computational tools.

EXPERIMENTS/ EXERCISES

1. Dynamic analysis of frame using mathematical computational software
2. Finite Element Analysis of 2D truss
3. Finite Element Analysis of 3D space trusses
4. Modeling and Finite Element Analysis of RC beams
5. Modeling and Finite Element Analysis of slabs
6. Finite Element Analysis of thin plates
7. Finite Element Analysis of thick plates
8. Stability analysis using FEM

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Acquire knowledge to handle Finite Element software
CO2:Do Dynamic analysis of frames
CO3:Analyze thin and thick plates
CO4:Carryout Stability Analysis
CO5:Use finite element softwares such as ABAQUS / ANSYS for FE modeling

Mapping of COs and POs

COs	**POs**					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2
CO5	3	3	3	3	3	2
AVG	3	3	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST3101	STABILITY OF STRUCTURES	L T P C 3 1 0 4

COURSE OBJECTIVES

- To introduce students to the fundamental concepts of stability analysis, including energy methods
- To enable students to analyze the buckling behavior of beam, columns and frames
- To equip students with the knowledge of torsional and lateral buckling

UNIT I BUCKLING OF COLUMNS **9+3**

States of equilibrium - concept of equilibrium, energy, imperfection and vibration approaches to stability analysis. Governing equation for column buckling - critical load using Equilibrium, Energy methods - Approximate methods - Rayleigh Ritz, Galerkins approach - Numerical Techniques - Finite difference method.

UNIT II BUCKLING OF BEAM-COLUMNS AND FRAMES **9+3**

Theory of beam column - Stability analysis of beam column with single and several concentrated loads, distributed load and end couples - Analysis of rigid jointed frames with and without sway – Use of stability function to determine the critical load.

UNIT III TORSIONAL AND LATERAL BUCKLING **9+3**

Torsional buckling – Combined Torsional and flexural buckling - Local buckling - Buckling of Open Sections - Lateral buckling of beams - simply supported and cantilever beams.

UNIT IV BUCKLING OF PLATES **9+3**

Governing differential equation - Buckling of thin plates with various edge conditions - Analysis by equilibrium and energy approach – Finite difference method.

UNIT V INELASTIC BUCKLING **9+3**

Double modulus theory - Tangent modulus theory - Shanley's model - Eccentrically loaded inelastic column. Inelastic buckling of plates - Post buckling behavior of plates.

TOTAL: 60 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1: Understand the phenomenon of buckling of columns and calculate the buckling load on column by various approaches

CO2: Estimate the buckling load of beams, columns and frames

CO3: Explore the concepts of torsional and lateral buckling of thin-walled members

CO4: Explain the phenomenon of buckling of plates

CO5: Analyze the inelastic buckling of columns and plates

TEXT BOOKS

1. Ashwini Kumar, "Stability Theory of Structures", Allied publishers Ltd. New Delhi,003.
2. Chajes, A. "Principles of Structures Stability Theory", Prentice Hall, 1974.
3. Gambhir.M.L, "Stability Analysis and Design of Structures", springer, New York, 2013.

REFERENCE BOOKS

1. Simitser.G.J and Hodges D.H, "Fundamentals of Structural Stability", Elsevier Ltd.,2006.
2. Timoshenko.S.P, and Gere.J.M, "Theory of Elastic Stability", Dover Publication, 2012.
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. Alexandar Chajes, Principles of Structural Stability Theory, Prentice Hall, New Jersey, 1980.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	3	3	2
CO2	2	-	3	3	3	2
CO3	2	-	3	3	3	2
CO4	2	-	3	3	3	2
CO5	2	-	3	3	3	2
AVG	2	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24RE3102 RESEARCH ARTICLE REVIEW AND SCIENTIFIC REPORT WRITING **L T P C 2 0 0 2**

COURSE OBJECTIVES

- To improve writing skills and level of readability.
- To learn the structure of scientific report.
- To understand the comprehensive research process, including hypotheses, methodologies, and findings.

UNIT I RESEARCH ARTICLE REVIEW **6**

Writing Skills – Essential Grammar and Vocabulary – Collection of latest Research articles- Summary of literature review – Classification and arrangement of the literatures with template – Preparation of review article.

UNIT II SCIENTIFIC REPORT WRITING **6**

Scientific report writing – Definition, Structure, Types of Reports, Purpose – Intended Audience – Plagiarism – Report Writing in STEM fields – Experiment – Statistical Analysis.

UNIT III STRUCTURE OF PROJECT REPORT **6**

Structure of the Project Report: Framing a Title – Content – Acknowledgement – Funding Details -Abstract – Introduction – Aim of the Study – Background - Writing the research question -Need of the Study/Project Significance, Relevance – Determining the feasibility – Theoretical Framework.

UNIT IV DATA ANALYSIS **6**

Extract data from Literature Review, Research Design, Methods of Data Collection - Tools and Procedures - Data Analysis - Interpretation - Findings –Limitations -Recommendations – Conclusion – Bibliography.

UNIT V PROOF READNG **6**

Proof reading a report – Avoiding Typographical Errors – Bibliography in required Format – Font –Spacing – Checking Tables and Illustrations – Presenting a Report Orally – Techniques.

TOTAL:30 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Critically review and summarize research literature, organize findings systematically, and prepare a well-structured review article following academic conventions.

CO2:Effectively structure and write scientific reports tailored to their intended audience, adhering to ethical standards and conventions specific to STEM fields.

CO3:Understand and implement the essential components of a project report, including the title, abstract, introduction, methodology, and theoretical framework, to effectively communicate their research findings.

CO4:Analyze and interpret data through appropriate research designs and statistical methods, leading to well-supported conclusions and recommendations.

CO5:Acquire skills in proofreading and formatting reports to ensure clarity, correctness, and professionalism in presentation, including attention to detail in bibliographies and oral presentation techniques.

TEXT BOOKS

1. Gerson and Gerson - Technical Communication: Process and Product, 7th Edition, Prentice Hall (2012)
2. Virendra K. Pamecha - Guide to Project Reports, Project Appraisals and Project Finance (2012)
3. .Daniel Riordan - Technical Report Writing Today (1998) Darla-Jean Weatherford Technical Writing for Engineering Professionals (2016) Penwell Publishers.

REFERENCE BOOKS

1. Adrian Wall work, English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011
2. Day R How to Write and Publish a Scientific Paper, Cambridge University Press 2006
3. Goldbort R Writing for Science, Yale University Press (available on Google Books) 2006
4. Highman N, Handbook of Writing for the Mathematical Sciences, SIAM. Highman's book 1998.
5. C.R.Kothari, Research Methodology, Wishva Prakashan, New Delhi, 2001.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	2	2
CO2	3	2	2	2	2	2
CO3	3	2	2	2	2	2
CO4	3	2	2	2	2	2
CO5	3	2	2	2	2	2
AVG	3	2	2	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST3601 PRACTICAL TRAINING L T P C
0 0 2 1

COURSE OBJECTIVES

- To provide practical exposure to structural engineering principles through hands-on training in reputable companies.
- To enhance technical reporting skills by guiding students in the preparation of comprehensive training reports.
- To develop effective communication skills through viva-voce examinations, enabling students to articulate their experiences clearly.

SYLLABUS

The students individually undertake training in reputed engineering companies doing Structural Engineering during the summer vacation for a specified duration of four weeks. At the end of the training, a detailed report on the work done should be submitted within ten days from the commencement of the semester. The students will be evaluated through a viva-voce examination by a team of internal staff.

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Describe the Structural Engineering organization
CO2:Realize the various functions of construction activities
CO3:Gain an understanding of groups and group dynamics
CO4:Participate in real-life construction projects
CO5:Put to use the theoretical knowledge gained so far

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	2	2
CO2	3	2	2	2	2	2
CO3	3	2	2	2	2	2
CO4	3	2	2	2	2	2
CO5	3	2	2	2	2	2
AVG	3	2	2	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST3501 **PROJECT WORK PHASE I** **L T P C**
0 0 12 6

COURSE OBJECTIVES

- To identify a specific problem for the current need of the society and collect information related to the same through a detailed review of literature.
- To develop the methodology to solve the identified problem.
- To train the students in preparing project reports and to face reviews and viva-voce examinations.

SYLLABUS

The student individually works on a specific topic approved by the faculty member who is familiar with this area of interest. The student can select any topic which is relevant to his/her specialization of the programme. The topic may be experimental or analytical or case studies. At the end of the semester, a detailed report on the work done should be submitted which contains a clear definition of the identified problem, detailed literature review related to the area of work and a methodology for carrying out the work. The students will be evaluated through a viva-voce examination by a panel of examiners including one external examiner.

TOTAL:180 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Apply the knowledge gained from theoretical and practical courses in solving problems

CO2:Recognize the importance of literature review

CO3:Develop a clear outline and methodology for the project

CO4:Identify the potential research gap and list parameters to work with

CO5:Report and present the findings of the work conducted.

Mapping of COs and POs

COs	POs					
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3
AVG	3	3	3	3	3	3

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST4501 **PROJECT WORK PHASE II** **L T P C**
0 0 24 12

COURSE OBJECTIVES

- To solve the identified problem based on the formulated methodology.
- To develop skills to analyze and discuss the test results, and make conclusions.
- To prepare a project report in the specific format mentioned

SYLLABUS

The student should continue the phase I work on the selected topic as per the formulated methodology / Undergo internship. At the end of the semester, after completing the work to the satisfaction of the supervisor and review committee, a detailed report should be prepared and submitted to the head of the department. The students will be evaluated based on the report and the viva-voce examination by a panel of examiners including one external examiner.

TOTAL:360 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Discover potential research areas in the field of Structural Engineering
CO2:Apply the knowledge gained from theoretical and practical courses to be creative, well-planned, organized and coordinated
CO3:Represent data acquired in graphical and reader-friendly formats
CO4:Derive detailed conclusions from work carried out
CO5:Report and present the findings of the work conducted

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	3
CO2	3	3	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3
AVG	3	3	3	3	3	3

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1301 ADVANCED CONCRETE TECHNOLOGY L T P C
3 0 0 3

COURSE OBJECTIVES

- To provide students with a comprehensive understanding of concrete-making materials
- To equip students with the principles and methods of concrete mix design, including IS Method, ACI Method, and DOE Methods
- To familiarize students with various concreting methods and techniques, including manufacturing, transportation, curing, and special concrete types

UNIT I CONCRETE MAKING MATERIALS 9

Aggregates classification IS Specifications, Properties, Grading, Methods of combining aggregates, specified grading, Testing of aggregates - Cement, Grade of cement, Chemical composition, Testing of concrete, Hydration of cement, Structure of hydrated cement, special cements - Water - Chemical admixtures, Mineral admixture.

UNIT II MIX DESIGN 9

Principles of concrete mix design, Methods of concrete mix design, IS Method, ACI Method, DOE Method – Mix design for special concretes- changes in Mix design for special materials.

UNIT III CONCRETING METHODS 9

Process of manufacturing of concrete, methods of transportation, placing and curing, cracking, plastic shrinkage, Extreme weather concreting, special concreting methods, Vacuum dewatering – Underwater Concrete

UNIT IV SPECIAL CONCRETES 9

Light weight concrete Fly ash concrete, Fiber reinforced concrete, Sulphur impregnated concrete, Polymer Concrete – High performance concrete. High performance fiber reinforced concrete, Self-Compacting Concrete, Geo Polymer Concrete, Waste material-based concrete – Ready mixed concrete.

UNIT V TESTS ON CONCRETE 9

Properties of fresh concrete, Hardened concrete, Strength, Elastic properties, Creep and shrinkage – Durability of concrete, Non-destructive Testing Techniques - microstructure of concrete.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Develop knowledge on various materials needed for concrete manufacturing

CO2:Carryout Mix Designs for concrete by various methods

CO3:Understand the methods of concreting

CO4:Understand special concretes

CO5:Understand various tests on fresh and hardened concrete

TEXT BOOKS

1. Gupta.B.L., Amit Gupta, "Concrete Technology, Jain Book Agency, 2017.
2. Shetty M.S., Concrete Technology, S.Chand and Company Ltd. Delhi, 2019.
3. P. Kumar Metha and Paulo J. M. Monteiro., Concrete: Microstructure, Properties and Materials, Mc Graw Hill, Fourth Edition, 2014.

REFERENCE BOOKS

1. Gambhir.M.L., Concrete Technology, McGraw Hill Education, 2006.
2. Neville, A.M., Properties of Concrete, Prentice Hall, 1995, London.
3. Job Thomas., Concrete Technology, Cencage learning India Private Ltd, New Delhi, 2015.
4. A. R. Santhakumar, Concrete Technology" Oxford University Press, 2006.
5. P. C. Aitcin, High Performance Concrete, E & FN SPON, 1998.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	2	2	2
CO2	2	-	3	2	2	2
CO3	2	-	3	2	2	2
CO4	2	-	3	2	2	2
CO5	2	-	3	2	2	2
AVG	2	-	3	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1302	EXPERIMENTAL TECHNIQUES IN STRUCTURAL ENGINEERING	L T P C 3 0 0 3

COURSE OBJECTIVES

- To introduce students to various experimental stress analysis methods
- To equip students with the knowledge and skills to measure structural vibrations and wind flow
- To familiarize students with non-destructive testing methods for assessing structural integrity

UNIT I FORCES AND STRAIN MEASUREMENT **9**

Choice of Experimental stress analysis methods, Errors in measurements - Strain gauge, principle, types, performance and uses, Photo elasticity - principle and applications - Hydraulic jacks and pressure gauges – Electronic load cells – Proving Rings – Calibration of Testing Machines – Long-term monitoring – vibrating wire sensors– Fibre optic sensors.

UNIT II MEASUREMENT OF VIBRATION AND WIND FLOW **9**

Characteristics of Structural Vibrations – Linear Variable Differential Transformer (LVDT) – Transducers for velocity and acceleration measurements, Vibration meter – Seismographs – Vibration Analyzer – Display and recording of signals – Cathode Ray Oscilloscope – XY Plotter – wind tunnels – Flow meters – Venturimeter – Digital data Acquisition systems.

UNIT III DISTRESS MEASUREMENTS AND CONTROL **9**

Diagnosis of distress in structures – Crack observation and measurements – corrosion of reinforcement in concrete – Half cell, construction and use – damage assessment – controlled blasting for demolition – Techniques for residual stress measurements – Structural Health Monitoring.

UNIT IV NON-DESTRUCTIVE TESTING METHODS **9**

Load testing on structures, buildings, bridges and towers – Rebound Hammer – acoustic emission – ultrasonic testing principles and application – Holography – use of laser for structural testing – Brittle coating, Advanced NDT methods – Ultrasonic pulse echo, Impact echo, impulse radar techniques, GECOR , Ground penetrating radar (GPR).

UNIT V MODEL ANALYSIS **9**

Model Laws – Laws of similitude – Model materials – Necessity for Model analysis – Advantages – Applications – Types of similitude – Scale effect in models – Indirect model study – Direct model study - Limitations of models – investigations – structural problems – Usage of influence lines in model studies.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Gain knowledge on measurement of strain

CO2:Understand the measurement of vibrations and wind blow.

CO3:Diagnose distress in structures.

CO4:Analyze the structure by non-destructive testing methods

CO5:Understand various laws used in model analysis

TEXT BOOKS

1. Dalley .J. W and Riley. W. F, "Experimental Stress Analysis", McGraw Hill Book Company, N.Y. 1991.
2. Ganesan.T.P, "Model Analysis of Structures", University Press, India, 2000.
3. Ravisankar.K. and Chellappan.A., "Advanced course on Non-Destructive Testing and Evaluation of Concrete Structures", SERC, Chennai, 2007.

REFERENCE BOOKS

1. Sadhu Singh, "Experimental Stress Analysis", Khanna Publishers, New Delhi, 2006.
2. Srinivasan, A. V. and Michael McFarland, D., Smart Structures: Analysis and Design, Cambridge University Press, 2000.
3. Yoseph Bar Cohen, Smart Structures and Materials, The International Society for Optical Engineering, 2003.
4. Brian Culshaw, Smart Structures and Materials , Artech House, Boston, 1996.
5. M. V. Gandhi and B. S. Thompson, Smart Materials and Structures, Chapman and Hall, 1992.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	3	2
CO2	3	3	3	3	3	2
CO3	3	3	3	3	3	2
CO4	3	3	3	3	3	2
CO5	3	3	3	3	3	2
AVG	3	3	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1303	DISASTER MANAGEMENT	L T P C 3 0 0 3

COURSE OBJECTIVES

- To understand the key concepts in disaster risk reduction and humanitarian response.
- To illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives.
- To describe an understanding of standards of humanitarian response and practical relevance in specific types of disasters and conflict situations.

UNIT I INTRODUCTION **9**

Disaster: Definition, Factors and Significance; Difference between Hazard and Disaster; Natural and Manmade Disasters: Difference, Nature, Types and Magnitude.

UNIT II REPERCUSSIONS OF DISASTERS AND HAZARDS **9**

Economic Damage, Loss of Human and Animal Life, Destruction of Ecosystem, Natural Disasters: Earthquakes, Volcanisms, Cyclones, Tsunamis, Floods, Droughts and Famines, Landslides and Avalanches, Man-made disaster: Nuclear Reactor Meltdown, Industrial Accidents, Oil Slicks and Spills, Outbreaks of Disease and Epidemics, War And Conflicts.

UNIT III DISASTER PRONE AREAS IN INDIA **9**

Study of Seismic Zones; Areas Prone to Floods and Droughts, Landslides and Avalanches; Areas Prone to Cyclonic and Coastal Hazards with Special Reference to Tsunami; Post-Disaster Diseases and Epidemics

UNIT IV DISASTER PREPAREDNESS AND MANAGEMENT **9**

Preparedness: Monitoring of Phenomena Triggering a Disaster or Hazard; Evaluation of Risk: Application of Remote Sensing, Data from Meteorological and other Agencies, Media Reports: Governmental and Community Preparedness.

UNIT V RISK ASSESSMENT **9**

Disaster Risk: Concept and Elements, Disaster Risk Reduction, Global and National Disaster Risk Situation, Techniques of Risk Assessment, Global Co-Operation in Risk Assessment and Warning, People's Participation in Risk Assessment. Strategies for Survival.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Summarize basics of disaster

CO2:Understand key concepts in disaster risk reduction and humanitarian response.

CO3:Illustrate disaster risk reduction and humanitarian response policy and practice from multiple perspectives

CO4:Understand standards of humanitarian response and practical relevance in specific types of disasters and conflict situations

CO5:Develop the strengths and weaknesses of disaster management approaches

TEXT BOOKS

1. Goel S. L., "Disaster Administration and Management text and Case Studies", Deep& Deep Publication Pvt. Ltd., New Delhi,2009.
2. Nishitha Rai, Singh AK, "Disaster Management in India: Perspectives, issues and strategies" New Royal book Company,2007.
3. Sahni, Pardeep Et Al., "Disaster Mitigation Experiences and Reflections", Prentice Hall of India, New Delhi,2001.

REFERENCE BOOKS

1. Natural Hazards and Disaster Management: Vulnerability and Mitigation" by R B Singh
2. "Disaster Mitigation: Experiences and Reflections" by Alka Dhameja and Pardeep Dhameja
3. Disaster Management and Mitigation" by Prof R B Singh
4. "Disaster Mitigation and Management: Post-Tsunami Perspectives" by Jegadish P Gandhi
5. "Disasters: Strengthening Community Mitigation and Preparedness" by Khanna B K

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	2	2	2
CO2	2	-	3	2	2	2
CO3	2	-	3	2	2	2
CO4	2	-	3	2	2	2
CO5	2	-	3	2	2	2
AVG	2	-	3	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1304	MECHANICS OF FIBER REINFORCED POLYMER CONCRETE	L T P C 3 0 0 3

COURSE OBJECTIVES

- To provide students with an understanding of composite materials
- To equip students with the knowledge of stress-strain relations specific to orthotropic and anisotropic materials
- To familiarize students with the analysis of laminated composites, including governing equations, static and dynamic analysis

UNIT I INTRODUCTION **9**

Introduction to Composites, Classifying composite materials, commonly used fiber and matrix constituents, Composite Construction, Properties of Unidirectional Long Fiber Composites and Short Fiber Composites.

UNIT II STRESS STRAIN RELATIONS **9**

Concepts in solid mechanics, Hooke's law for orthotropic and anisotropic materials, Linear Elasticity for Anisotropic Materials, Rotations of Stresses, Strains, Residual Stresses

UNIT III ANALYSIS OF LAMINATED COMPOSITES **9**

Governing equations for anisotropic and orthotropic plates, Angle-ply and cross ply laminates – Static, Dynamic and Stability analysis for Simpler cases of composite plates, Inter laminar stresses.

UNIT IV FAILURE AND FRACTURE OF COMPOSITES **9**

Netting Analysis, Failure Criterion, Maximum Stress, Maximum Strain, Fracture Mechanics of Composites, Sandwich Construction.

UNIT V APPLICATIONS AND DESIGN **9**

Meal and Ceramic Matrix Composites, Applications of Composites, Composite Joints, Design with Composites, Review, Environmental Issues

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the various types of composites and their constituents

CO2:Derive the constitutive relationship and determine the stresses and strains in a composite material

CO3:Analyze a laminated plate

CO4:Explain the various failure criteria and fracture mechanics of composites

CO5:Design simple composite elements

TEXT BOOKS

1. Agarwal. B.D. Broutman. L.J. and Chandrashekara. K. "Analysis and Performance of Fiber Composites", Fourth Edition, John-Wiley and Sons, 2017.
2. Daniel. I.M, and Ishai. O, "Engineering Mechanics of Composite Materials", Second Edition, Oxford University Press, 2005.
3. David Broek, Elementary Engineering Fracture Mechanics, Sijthoff and Noordhaff, Alphen Aan Den Rijn, The Netherlands, 2001.

REFERENCE BOOKS

1. Hyer M.W., and White S.R., "Stress Analysis of Fiber-Reinforced Composite Materials", Detach Publications Inc., 2009.
2. Jones R.M., "Mechanics of Composite Materials", Taylor and Francis Group 1999.
3. Analysis of Concrete Structure by Fracture Mechanics, Ed L. Elfgren and S.P. Shah, Proc of Rilem Workshop, Chapman and Hall, London, 2001.
4. Prashant Kumar, Elements of Fracture Mechanics, Tata McGraw Hill, New Delhi, India, 2009.
5. K. Ramesh, e-Book on Engineering Fracture Mechanics, IIT Madras, 2007

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	2	2	2
CO2	2	-	3	2	2	2
CO3	2	-	3	2	2	2
CO4	2	-	3	2	2	2
CO5	2	-	3	2	2	2
AVG	2	-	3	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1305 PREFABRICATED STRUCTURES L T P C
3 0 0 3

COURSE OBJECTIVES

- To introduce students to the design principles and requirements for prefabricated structures
- To equip students with the knowledge of reinforced concrete applications in prefabricated structures
- To familiarize students with the analysis and design of floors, stairs, roofs, and walls in prefabricated

UNIT I DESIGN PRINCIPLES **9**

General Civil Engineering requirements, specific requirements for planning and layout of prefabrication plant. IS Code specifications. Modular co-ordination, standardization, Disuniting of Prefabricates, production, transportation, erection, stages of loading and code provisions, safety factors, material properties, Deflection control, Lateral load resistance, Location and types of shear walls.

UNIT II REINFORCED CONCRETE **9**

Prefabricated structures - Long wall and cross-wall large panel buildings, one way and two way prefabricated slabs, Framed buildings with partial and curtain walls, -Connections – Beam to column and column to column.

UNIT III FLOORS, STAIRS AND ROOFS **9**

Types of floor slabs, analysis and design example of cored and panel types and two-way systems, staircase slab design, types of roof slabs and insulation requirements, Description of joints, their behavior and reinforcement requirements, Deflection control for short term and long term loads, Ultimate strength calculations in shear and flexure.

UNIT IV WALLS **9**

Types of wall panels, Blocks and large panels, Curtain, Partition and load bearing walls, load transfer from floor to wall panels, vertical loads, Eccentricity and stability of wall panels, Design Curves, types of wall joints, their behavior and design, Leak prevention, joint sealants, sandwich wall panels, approximate design of shear walls.

UNIT V INDUSTRIAL BUILDINGS AND SHELL ROOFS **9**

Components of single-storey industrial sheds with crane gantry systems, R.C. Roof Trusses, Roof Panels, corbels and columns, wind bracing design. Cylindrical, Folded plate and hyper prefabricated shells, Erection and jointing, joint design, hand book based design.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the design principles involved in prefabrication
CO2:Detail the different types of connection
CO3:Design for stripping forces during manufacture
CO4:Determine the forces in shear walls
CO5:Identify the different roof trusses used in industrial buildings

TEXT BOOKS

1. Koncz.T., "Manual of Precast Concrete Construction", Vol.I II and III & IV Bauverlag, GMBH, 1971.
2. Laszlo Mokk, "Prefabricated Concrete for Industrial and Public Structures", AkademiaiKiado, Budapest, 2007.

3. Hass, A. M. Precast Concrete Design and Applications, Applied Science Publishers,1983.

REFERENCE BOOKS

1. Lewicki.B, "Building with Large Prefabricates", Elsevier Publishing Company, Amsterdam/ London/New York, 1998.
2. "Structural Design Manual", Precast Concrete Connection Details, Society for the Studies in the use of Precase Concrete, Netherland Betor Verlag, 2009.
3. Hubert Bachmann and Alfred Steinle , Precast Concrete Structures, 2012.
4. Structural Design Manual - Precast concrete connection details", Society for studies in the use of Precast concrete, Netherland Betor Verlag, 2009.
5. "Construction and Design of Prestressed Concrete Structures" by H. J. B. P. N. Wang, 2008

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1306 ADVANCED PRESTRESSED CONCRETE L T P C
3 0 0 3

COURSE OBJECTIVES

- To develop an understanding of the philosophy of design of prestressed concrete
- To be able to design indeterminate prestressed concrete structure
- To design the prestressed concrete bridge and composite sections.

UNIT I INTRODUCTION 9

Concepts of Prestressing – Materials and methods of prestressing – Design philosophy-Analysis methods, Time-dependent deformation of concrete and losses of prestress.

UNIT II DESIGN FOR FLEXURE, SHEAR AND TORSION 9

Behavior of flexural members, determination of ultimate flexural strength using various Codal provisions - Design for Flexure, Shear, torsion and bond of pre-stressed concrete elements – Transfer of prestress – Box girders - Camber, deflection and crack control.

UNIT III DESIGN OF CONTINUOUS AND COMPOSITE BEAMS **9**

Statically indeterminate structures - Analysis and design of continuous beams and frames– Choice of cable profile - Methods of achieving continuity – concept of linear transformations, concordant cable profile and gap cables – Composite sections of prestressed concrete beam and cast in situ RC slab - Design of composite sections - Partial prestressing - Limit State design of partially prestressed concrete beams

UNIT IV DESIGN OF TENSION AND COMPRESSION MEMBERS **9**

Pre-stressed concrete compression and tension members – application in the design of prestressed pipes and prestressed concrete cylindrical water tanks – Design of compression members with and without flexure – its application in the design of piles, flag masts and similar structures – Two-way pre-stressed concrete floor systems – Connections for pre-stressed concrete elements

UNIT V DESIGN OF PRESTRESSED CONCRETE BRIDGES **9**

Review of IRC and IRS loadings. Effect of concentrated loads on deck slabs, load distribution methods for concrete bridges. Analysis and Design of superstructures - Design of pre-stressed concrete bridges incorporating long-term effects like creep, shrinkage, relaxation, and temperature effects, Dynamic response of bridge decks.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Identify the various methods of prestressing and estimate the loss
CO2:Design the beams for flexure, shear, bond and torsion
CO3:Design the continuous beams and composite beams
CO4:Design the water tank, piles and masts
CO5:Analyze and design the prestressed concrete bridge

TEXT BOOKS

1. Arthur H. Nilson, “Design of Prestressed Concrete”, John Wiley and Sons Inc, New York, 2004.
2. Krishna Raju, “Prestressed Concrete”, Tata McGraw Hill Publishing Co., New Delhi, 6th Edition, 2018.
3. Lin.T.Y.and Burns.H “Design of Prestressed Concrete Structures”, John Wiley and Sons Inc, 3rd Edition, 2010.

REFERENCE BOOKS

1. Rajagopalan.N, “Prestressed Concrete”, Narosa Publications, New Delhi, 2014.
2. Sinha.N.C. and. Roy.S.K, “Fundamentals of Prestressed Concrete”, S.Chand and Co.,1998.
3. Johnson Victor, D., Essentials of Bridge Engineering, Oxford and IBH Publishing Co New Delhi 2019.

4. Antonnie. E. Naaman, Prestressed Concrete Analysis and Design, Technopress, 3rd Edition, 2012
5. Edward. G .Nawy, Prestressed Concrete, Prentice Hall, 5th Edition, 2010.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1307 MASONRY STRUCTURES DESIGN L T P C
3 0 0 3

COURSE OBJECTIVES

- To design and detail masonry structures according to relevant codes and standards.
- To analyze the behavior of masonry under lateral loads and seismic conditions.
- To retrofit and strengthen existing masonry structures for improved performance.

UNIT I INTRODUCTION 9

Introduction – Masonry construction – National and International perspective – Historical development, Modern masonry, Material Properties – Masonry units: clay and concrete blocks, Mortar, grout and reinforcement, Bonding patterns, Shrinkage and differential movements.

UNIT II DESIGN OF COMPRESSION MEMBER 9

Principles of masonry design, Masonry standards: IS 1905 and others - Masonry in Compression – Prism strength, Eccentric loading -Kern distance. Structural Wall, Columns and Plasters, Retaining Wall, Pier and Foundation – Prestressed masonry

UNIT III DESIGN OF MASONRY UNDR LATERAL LOADS 9

Masonry under Lateral loads – In-plane and out-of-plane loads, Ductility of Reinforced Masonry Members Analysis of perforated shear walls, Lateral force distribution -flexible and rigid diaphragms. Behavior of Masonry – Shear and flexure – Combined bending and axial loads – Reinforced and unreinforced masonry – Infill masonry

UNIT IV EARTHQUAKE RESISTANT DESIGN OF MASONRY STRUCTURES 9

Structural design of Masonry – Consideration of seismic loads –concepts of confined masonry – Cyclic loading and ductility of shear walls for seismic design -Code provisions- Working and Ultimate strength design – In-plane and out-of-plane design criteria for load-bearing and infills, connecting elements and ties. Modeling Techniques, Static Push Over Analysis and use of Capacity Design Spectra – use of Software.

UNIT V RETROFITTING OF MASONRY 9

Seismic evaluation and Retrofit of Masonry – In-situ and non-destructive tests for masonry – properties – Repair and strengthening of techniques.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the properties of a masonry unit and the various components
CO2:Design a masonry structure for compression
CO3:Design a masonry structure for lateral loads
CO4:Design an earthquake-resistant masonry wall
CO5:Suggest retrofitting techniques for existing masonry walls

TEXT BOOKS

1. Drysdale, R. G. Hamid, A. H. and Baker, L. R, “Masonry Structures: Behaviour & Design”, Prentice Hall Hendry, 1994.
2. A.W. Hendry, B.P. Sinha and Davis, S. R, “Design of Masonry Structures”, E & FN Spon, UK, 2017.
3. Santha Kumar, A.R., “Concrete Technology”, Oxford University Press, New Delhi, 2007.

REFERENCE BOOKS

1. R.S. Schneider and W.L. Dickey, “Reinforced Masonry Design”, Prentice Hall, 3rd edition, 1994.
2. Paulay, T. and Priestley, M. J. N., “Seismic Design of Reinforced Concrete and Masonry Buildings”, John Wiley, 1992.
3. A.W. Hendry, “Structural Masonry”, 2nd Edition, Palgrave McMillan Press, 1998.
4. Yoshihiko Ohama, “Hand Book of Polymer Modified Concrete and Mortars”, Noyes Publications, U.K., 3rd Edition, 2013.
5. "Masonry Design and Construction" by A. P. M. H. S. N. MacGregor, 2009

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST1308 COMPOSITE STRUCTURES L T P C
3 0 0 3

COURSE OBJECTIVES

- To understand the principles and design codes governing steel-concrete composite construction.
- To design composite structural elements, including beams, slabs, columns, and trusses.
- To analyze and design connections in composite structures, focusing on shear connectors and their interactions.

UNIT I INTRODUCTION 9

Introduction to steel – concrete composite construction – Codes – Composite action – Serviceability and Construction issues in design.

UNIT II DESIGN OF COMPOSITE MEMBERS 9

Design of composite beams, slabs, columns, beam – columns – Design of composite trusses.

UNIT III DESIGN OF CONNECTIONS 9

Shear connectors – Types – Design of connections in composite structures – Design of shear connectors – Partial shear interaction.

UNIT IV COMPOSITE BOX GIRDER BRIDGES 9

Introduction –Design concepts of box girder bridges and corrugated web girder bridges

UNIT V CASE STUDIES 9

Case studies on steel – concrete composite construction in buildings – seismic behavior of composite structures.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand concrete composite construction and its codal provision

CO2:Design composite members

CO3:Design connections in composite connections

CO4:Understand the concept of design of composite box girder bridges

CO5:Study and evaluate case studies on concrete composite construction in buildings

TEXT BOOKS

1. Johnson R.P., "Composite Structures of Steel and Concrete Beams, Slabs, Columns and Frames for Buildings", Vol. I, Fourth Edition, Blackwell Scientific Publications, 2018
2. Oehlers D.J. and Bradford M.A., "Composite Steel and Concrete Structural Members, Fundamental behaviour", Revised Edition, Pergamon press, Oxford, 2013.
3. Owens. G.W and Knowles.P, "Steel Designers Manual", Seventh Edition, Steel Concrete Institute(UK), Oxford Blackwell Scientific Publications, 2011.

REFERENCE BOOKS

1. Narayanan R, "Composite steel structures – Advances, design and construction", Elsevier, Applied science, UK, 1987
2. Teaching resource for, "Structural Steel Design," Volume 2 of 3, Institute for Steel Development and Growth (INSDAG), 2002.
3. "Composite Structures: Design and Analysis" by S. P. Timoshenko, 2014
4. Principles of Composite Material Mechanics" by R. E. E. W. A. L. Jones, 2016
5. "Composite Materials Handbook" by A. C. W. H. T. K. C., 2014

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST2301	MAINTENANCE, REPAIR AND REHABILITATION OF STRUCTURES	L T P C 3 0 0 3

COURSE OBJECTIVES

- To understand the principles of maintenance, repair, and rehabilitation of structures, focusing on the causes and effects of deterioration.
- To evaluate the strength and durability of concrete, including quality assurance and the impact of environmental factors and corrosion.
- To explore various repair materials and techniques, along with protection methods and structural health monitoring for effective maintenance of structures.

UNIT I MAINTENANCE AND REPAIR STRATEGIES **9**

Maintenance, Repair and Rehabilitation, retrofit and strengthening, need for rehabilitation of structures- Service life behavior - importance of Maintenance, causes and effects of deterioration. Non-destructive Testing Techniques.

UNIT II STRENGTH AND DURABILITY OF CONCRETE **9**

Quality assurance for concrete based on Strength, Durability and Microstructure of concrete – NDT techniques- Cracks- different types, causes – Effects due to Environment, Fire, Earthquake, Corrosion of steel in concrete, Mechanism, quantification of corrosion damage

UNIT III REPAIR MATERIALS AND SPECIAL CONCRETES **9**

Repair materials-Various repair materials, Criteria for material selection, Methodology of selection, Special mortars and concretes- Polymer Concrete and Grouting materials- Bonding agents-Latex emulsions, Epoxy bonding agents, Protective coatings-Protective coatings for Concrete and Steel, FRP sheets

UNIT IV PROTECTION METHODS AND STRUCTURAL HEALTH MONITORING **9**

Concrete protection methods – reinforcement protection methods- cathodic protection – Sacrificial anode - Corrosion protection techniques – Corrosion inhibitors, concrete coatings- Corrosion resistant steels, Coatings to reinforcement, Structural health monitoring.

UNIT V REPAIR, RETROFITTING AND DEMOLITION OF STRUCTURES **9**

Various methods of crack repair, Grouting, Routing and sealing, Stitching, Dry packing, Autogenous healing, Repair to active cracks, Repair to dormant cracks. Repair of various corrosion damaged of structural elements (slab, beam and columns) Jacketing Techniques, Strengthening Methods for Structural Elements. Engineered Demolition -Case studies

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the importance of maintenance assessment and repair strategies

CO2:Acquire knowledge of strength and durability properties and their effects due to climate and temperature.

CO3:Gain knowledge of recent developments in repair

CO4:Understand the techniques for repair and protection methods

CO5:Understand the repair, rehabilitation and retrofitting of structures and demolition methods.

TEXT BOOKS

1. Dodge Woodson, Concrete Structures, Protection, Repair and Rehabilitation, Butter worth Heinemann, Elsevier, New Delhi 2012
2. Dov Kominetzky.M.S., - Design and Construction Failures, Galgotia Publications Pvt. Ltd., 2001
3. Ravishankar.K., Krishnamoorthy. T.S, Structural Health Monitoring, Repair and Rehabilitation of Concrete Structures, Allied Publishers, 2004.

REFERENCE BOOKS

1. Hand book on Seismic Retrofit of Buildings, CPWD and Indian Buildings Congress, Narosa Publishers, 2008.
2. Hand Book on "Repair and Rehabilitation of RCC Buildings" – Director General works CPWD, Govt of India, New Delhi – 2002
3. BS EN 1504 - Products and systems for the protection and repair of concrete structures -Definitions, requirements, quality control and evaluation of conformity.
4. "Structural Maintenance and Repair" by J. W. Bullock, 2006
5. "Durability of Concrete Structures" by T. W. M. J., 2016

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	2	2	2
CO2	2	-	3	2	2	2
CO3	2	-	3	2	2	2
CO4	2	-	3	2	2	2
CO5	2	-	3	2	2	2
AVG	2	-	3	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST2302 STRUCTURAL SAFETY AND RELIABILITY L T P C
3 0 0 3

COURSE OBJECTIVES

- To impart adequate knowledge on safety aspects involved in construction industry
- To impart knowledge on the quantitative estimates of the reliability of structures under different limit state conditions
- To implement reliability-based design methodologies

UNIT I INTRODUCTION TO STRUCTURAL SAFETY 9

Structural safety - role of safety officers, responsibilities of general employees, safety committee, safety monitoring. Concepts of Safety Factors, Safety, Reliability and Risk Analysis.

UNIT II PROBABILITY CONCEPTS 9

Fundamentals of Set Theory and Probability; Probability Distribution, Regression Analysis, Hypothesis Testing. Stochastic Process and Its Moments; Probability Distributions. Probability of failure. Fatal accident rate. Societal risk. Anatomy of failure. Management of safety.

UNIT III STRUCTURAL RELIABILITY THEORY AND METHODS 9

R-S problem in structural design and assessment - Probability of Failure and the Reliability Index. Convolution Integral, Standardized Method for Normal Variables, First Order Reliability Method, Monte Carlo Simulation. Second order Reliability Method.

UNIT IV RELIABILITY ANALYSIS 9

Measures of reliability-factor of safety, safety margin, reliability index, performance function and limiting state. Reliability Methods-First Order Second Moment Method (FOSM), Point Estimate Method (PEM), and Advanced First Order Second Moment Method (Hasofer-Lind's method)

UNIT V RELIABILITY BASED DESIGN 9

Specification of Characteristic Load/Resistance Values, Design Values, Partial Factors, Target Reliability, Methods of Code Calibration - Use of ISO 2394 method and its significance.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Describe the safety practices to be followed during various construction operations

CO2:Understand the quantifying uncertainties using theories of probability.

CO3:Illustrate the theory of methods of structural reliability based on the concept of reliability indices.

CO4:Perform the reliability-based limit state design for simple structural elements and recognize the sensitivity of the outcome to the uncertainty in different variables.

CO5:Understand the reasons leading to different values of partial safety factors for load and resistance variables in design and assessment standards.

TEXT BOOKS

1. Tim Howarth, Paul Watson, “Construction Safety Management” Wiley-Blackwell, 2008.
2. Choi S K, Grandhi R V and Canfield R A., “Reliability Based Structural Design”, Springer Verlag, London, UK, 2007.
3. "Structural Reliability Analysis and Prediction" by R. E. Melchers and R. D. Beck, 2018

REFERENCE BOOKS

1. Haldar, A., and Mahadevan, S., “Probability, Reliability and Statistical Methods in Engineering Design”, John Wiley and Sons, New York, 2000.
2. Ranganathan,R., “Structural Reliability Analysis and Design”, Jaico Publishing House, Mumbai, 2006.
3. "Fundamentals of Structural Reliability" by K. K. M. A. D. , 2006
4. "Reliability-Based Design in Civil Engineering" by J. R. W. L. M. K. S., 2017
5. Design for Structural Safety" by H. H. C. M. S., 2020

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	-	3	2	2	2
CO2	2	-	3	2	2	2
CO3	2	-	3	2	2	2
CO4	2	-	3	2	2	2
CO5	2	-	3	2	2	2
AVG	2	-	3	2	2	2

1-Low, 2-Medium, 3-High, “-” – no correlation

24ST2303 CORROSION PREVENTION AND CONTROL IN RC STRUCTURES **L T P C 3 0 0 3**

COURSE OBJECTIVES

- To impart knowledge on mechanism of corrosion of steel in concrete, major causes, influencing parameters and consequences in reinforced and pre-stressed concrete structures.
- To understand the techniques and methods for condition assessment, corrosion prevention, and corrosion control in reinforced concrete (RC) structures.
- To understand types of corrosion and its mechanism, non-destructive and destructive testing techniques for corrosion assessment in distressed concrete elements through hands on training.

UNIT I MECHANISM OF CORROSION OF STEEL IN RC STRUCTURES **9**

Corrosion mechanism – black rust - pits - stray current, causes of corrosion – carbonation - chloride attack – microbial induced corrosion in concrete – influencing parameters - corrosion damage in reinforced concrete and pre-stressed concrete - stress corrosion cracking - hydrogen embrittlement, cost of corrosion - worldwide scenario.

UNIT II CORROSION PREVENTION IN RC STRUCTURES **9**

Control of carbonation - control of chlorides - high performance concrete - corrosion inhibitors – anodic, cathodic and mixed inhibitors - protective coatings to steel rebars: fusion bonded epoxy coating, galvanization, cement polymer composite coating and anticorrosive polymer cementitious coatings - stainless steel reinforcement - sealers and membranes - cathodic protection.

UNIT III CONDITION EVALUATION **9**

Preliminary survey - visual inspection and detailed survey – delaminating survey - cover – half-cell potential measurements - carbonation depth measurement - chloride determination

UNIT IV CORROSION RATE MEASUREMENT **9**

Resistivity measurement, corrosion rate measurement – linear polarization resistance techniques - impedance studies - microcell techniques - potential-time behavior studies - accelerated corrosion studies.

UNIT V CORROSION CONTROL IN RC STRUCTURES **9**

Physical and chemical rehabilitation techniques – coatings - sealers and membranes - corrosion inhibitors - electrochemical repair techniques: basic principles, chloride removal and real kalization - cathodic protection.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand corrosion mechanism under different contexts, its causes and consequences.

CO2:Suggest techniques and methods for corrosion prevention in RC structures

CO3:Conduct corrosion audit in distressed RC elements by

CO4:Understand the scientific principles, and submit a professional report

CO5:Recommend techniques / methods for corrosion control in distressed RC structures

TEXT BOOKS

1. Baeckmann, W. von, W. Schwenk, and W. Prinz, Handbook of cathodic corrosion protection: Theory and practice of electrochemical protection processes, 3rd ed. Gulf Publishing Company, 1997.
2. John P. Broomfield, Corrosion of Steel in Concrete: Understanding, Investigation and Repair, second edition, CRC Press, 2006.

3. ACI (American Concrete Institute) 222R-01: Protection of metals in concrete against corrosion. American Concrete Institute, Farmington Hills, MI, USA, 2010.

REFERENCE BOOKS

1. ASTM G109-07: Standard test method for determining effects of chemical admixtures on corrosion of embedded steel reinforcement in concrete exposed to chlorides. ASTM International, West Conshohocken, PA, USA, 2013.
2. Chess, P. M. and J. P. Broomfield, Cathodic Protection of Steel in Concrete and Masonry, 2nd Edition. London: CRC Press, 2014.
3. ASTM A 775/A775 M-19, "Standard specification for epoxy-coated steel reinforcing bars", American Society for Testing and Materials, 2019.
4. ASTM C 876, Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete, American Society for Testing and Materials, 2015.
5. IS 13620, "Fusion bonded epoxy-coated reinforcing bars-Specification", Bureau of Indian Standards, New Delhi, 2020.

Mapping of COs and POs

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CO2	2	-	3	2	2	2
CO3	2	-	3	2	2	2
CO4	2	-	3	2	2	2
CO5	2	-	3	2	2	2
AVG	2	-	3	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST2304 STRUCTURAL HEALTH MONITORING L T P C
3 0 0 3

COURSE OBJECTIVES

- To understand the principles and methods of Structural Health Monitoring
- To explore various sensors and instrumentation used in SHM
- To apply advanced data processing techniques for damage detection and analysis

UNIT I INTRODUCTION TO STRUCTURAL HEALTH MONITORING 9

Need for SHM, Structural Health Monitoring versus Non-Destructive Evaluation, Methods of SHM Local & Global Techniques for SHM, Short & Long-Term Monitoring, Active & Passive Monitoring, Remote Structural Health Monitoring- Advantages of SHM - Challenges in SHM

UNIT II SENSORS AND INSTRUMENTATION FOR SHM **9**

Sensors for measurements: Electrical Resistance Strain Gages, Vibrating Wire Strain Gauges, Fiber Optic Sensors, Temperature Sensors, Accelerometers, Displacement Transducers, Load Cells, Humidity Sensors, Crack Propagation Measuring Sensors, Corrosion Monitoring Sensors, Pressure Sensors, Data Acquisition – Data Transmission - Data Processing – Storage of processed data -Knowledgeable information processing

UNIT III STATIC AND DYNAMIC MEASUREMENT TECHNIQUES FOR SHM **9**

Static measurement - Load test, Concrete core trepanning, Flat jack techniques, Static response measurement, Dynamic measurement -Vibration based testing- Ambient Excitation methods, Measured forced Vibration-Impact excitation, step relaxation test, shaker excitation method.

UNIT IV DAMAGE DETECTION **9**

Damage Diagnostic methods based on vibrational response- Method based on modal frequency/shape/damping, Curvature and flexibility method, Modal strain energy method, Sensitivity method, Baseline-free method, Cross-correlation method, Damage Diagnostic methods based on wave propagation Methods-Bulk waves/Lamb waves, Reflection and transmission, Wave tuning/mode selectivity, Migration imaging, Phased array imaging, Focusing array/SAFT imaging

UNIT V DATA PROCESSING AND CASE STUDIES **9**

Advanced signal processing methods -Wavelet, Hilbert-Huang transform, Neural networks, Support Vector Machine Principal component analysis, Outlier analysis. Applications of SHM on bridges and buildings, case studies of SHM in Civil/ Structural engineering.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the need, advantages and challenges of SHM
CO2:Understand the different types of sensors and instrumentation techniques
CO3:Gain knowledge of the static and dynamic measurement techniques
CO4:Compare the various damage detection techniques
CO5:Know the various data processing methods through case studies

TEXT BOOKS

1. Daniel Balageas, Peter Fritzen, Alfredo Guemes, Structural Health Monitoring, John Wiley &Sons,2006.
2. Douglas E Adams, Health Monitoring of Structural Materials and Components Methods with Applications, Wiley Publishers, 2007
3. Hua-Peng Chen, Structural Health Monitoring of Large Civil Engineering Structures, Wiley Publishers, 2018

REFERENCE BOOKS

1. Ansari, F Karbhari, Structural health monitoring of civil infrastructure systems, V.M, Woodhead Publishing, 2009
2. J. P. Ou, H. Li and Z. D, "Duan Structural Health Monitoring and Intelligent Infrastructure", Vol1, Taylor and Francis Group, London, UK, 2006.
3. Victor Giurglutiu, "Structural Health Monitoring with Wafer Active Sensors", Academic Press Inc, 2007.
4. Ravishankar K. and Krishnamoorthy T. S., "Structural Health Monitoring, Repair and Rehabilitation of Concrete Structures", Allied Publishers, 2004. 4.
5. "Hand book on Seismic Retrofit of Buildings", CPWD and Indian Buildings Congress, Narosa Publishers, 2008.

Mapping of COs and POs

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CO2	2	-	3	2	2	2
CO3	2	-	3	2	2	2
CO4	2	-	3	2	2	2
CO5	2	-	3	2	2	2
AVG	2	-	3	2	2	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST2305 **DESIGN OF BRIDGE** **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To understand the principles of bridge design, including site selection, classification, and standard loading as per various codes.
- To analyze and design different types of bridge superstructures and substructures.
- To apply design principles for prestressed concrete bridges and steel bridges

UNIT I INTRODUCTION **9**

Introduction-Selection of Site and Initial Decision Process - Classification of Bridges- General Features of Design- Standard Loading for Bridge Design as per different codes - Road Bridges –Railway Bridges - Design Codes - Working Stress Method- Limit State Method of Design.

UNIT II SUPERSTRUCTURES **9**

Selection of main bridge parameters, design methodologies -Choices of superstructure types orthotropic plate theory, load distribution techniques - Grillage analysis - Finite element

analysis Different types of superstructures (RCC and PSC); Longitudinal Analysis of Bridge – Transverse Analysis of Bridge

UNIT III BRIDGE DESIGN PRINCIPLES **9**

Analysis and Design of RCC solid slab culverts -Design of RCC Tee beam and slab bridges – Design principles of continuous girder bridges, box girder bridges, balanced cantilever bridges – Arch bridges – Box culverts – Segmental bridges–Design principles only.

UNIT IV SUBSTRUCTURE, BEARINGS AND DECK JOINTS **9**

Design of bridge bearings and substructure

UNIT V PRESTRESSED CONCRETE BRIDGES & STEEL BRIDGES **9**

Design principles of PSC bridges – PSC girders –Design principles of steel bridges - Plate girder bridges – Box girder bridges – Truss bridges – Vertical and Horizontal stiffeners.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the different types of bridges and design philosophies
CO2:Design a RC solid slab culvert bridge.
CO3:Design a RC Tee Beam and Slab bridge
CO4:Design the bridge bearings and substructure
CO5:Understand the design principles of PSC bridges, box girder bridges, truss bridges

TEXT BOOKS

1. Jagadeesh. T.R. and Jayaram. M.A., “Design of Bridge Structures”, Second Edition, Prentice Hall of India Pvt. Ltd. 2009.
2. Johnson Victor, D. “Essentials of Bridge Engineering”, Sixth Edition, Oxford and IBH Publishing Co. New Delhi, 2019.
3. Ponnuswamy, S., “Bridge Engineering”, Third Edition, Tata McGraw Hill, 2017.

REFERENCE BOOKS

1. Raina V.K.” Concrete Bridge Practice” Tata McGraw Hill Publishing Company, NewDelhi,2014.
2. Design of Highway Bridges, Richard M. Barker & Jay A. Puckett, John Wiley & Sons, Inc.,2021
3. "Bridge Engineering Handbook" by B. B. K. G., 2000
4. Richard M. Barker & Jay A. Puckett, “Design of Highway Bridges”, John Wiley & Sons Inc., 2021.
5. N. Krishna Raju, “Design of Bridges”, Fifth Edition, Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi, 2018.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST2306 ADVANCED INDUSTRIAL STRUCTURES L T P C
3 0 0 3

COURSE OBJECTIVES

- To understand the planning and functional requirements for industrial structures.
- To analyze and design various types of industrial buildings
- To design foundations for critical structures such as towers, chimneys, and cooling towers

UNIT I PLANNING AND FUNCTIONAL REQUIREMENTS 9

Classification of Industries and Industrial structures - planning for Layout Requirements regarding Lighting, Ventilation and Fire Safety - Protection against noise and vibration - Guidelines of Factories Act.

UNIT II INDUSTRIAL BUILDINGS 9

Steel and RCC -Sway and non-sway frames–Gantry Girder, Crane Girders - Design of Corbels and Nibs – Design of Staircase- Earthquake resistant design of steel buildings.

UNIT III POWER PLANT STRUCTURES 9

Types of power plants – Containment structures - Cooling Towers - Bunkers and Silos - Pipe supporting structures

UNIT IV TRANSMISSION LINE STRUCTURES AND CHIMNEYS 9

Analysis and design of transmission line towers - Saj and Tension calculations, Testing of towers – Design of self-supporting chimney, Design of Chimney bases.

UNIT V FOUNDATION 9

Design of foundation for Towers, Chimneys and Cooling Towers - Machine Foundation - Design of Turbo Generator Foundation.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Develop the concept of planning & functional requirements of industrial standards.

CO2:Analyze and design Steel Gantry girders & Crane girders and RCC design of corbels, nibs and staircase.

CO3:Analyze & design cooling towers, bunkers, silos and pipe supporting structures.

CO4:Analyze and design Steel transmission line towers and chimneys.

CO5:Design foundations for cooling tower, chimneys and turbo generator.

TEXT BOOKS

1. Jurgen Axel Adam, Katharria Hausmann, Frank Juttner, Klauss Daniel, "Industrial Buildings: A Design Manual", Birkhauser Publishers, 2004.
2. Manohar S.N, "Tall Chimneys - Design and Construction", Tata McGraw Hill, 1985
3. Santhakumar A.R. and Murthy S.S., "Transmission Line Structures", Tata McGraw Hill, 1992.

REFERENCE BOOKS

1. Srinivasulu P and Vaidyanathan.C, "Handbook of Machine Foundations", Tata McGraw Hill, 1976.
2. Jurgen Axel Adam, Katharria Hausmann, Frank Juttner, Klauss Daniel, “Industrial Buildings: Design Manual”, Birkhauser Publishers, 2004.
3. Swami Saran, “Analysis & Design of Substructures - Limit state Design”, Second Edition, 2018.
4. N. Subramaniyan, “Design of Steel Structures”, 2018.
5. N. Krishna Raju, “Advanced Reinforced Concrete Design”, 3rd Edition, 2016.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, “-” – no correlation

24ST2307 **TALL STRUCTURES** **L T P C**
3 0 0 3

COURSE OBJECTIVES

- To introduce design philosophy, loading, different types of frames, types of shear walls.
- To make students understand approximate analysis, accurate analysis and reduction techniques.
- To familiarize students with design of structural elements, buckling analysis, p delta analysis.

UNIT I LOADING AND DESIGN PRINCIPLES **9**

Loading- sequential loading, Gravity loading, Wind loading, Earthquake loading, - Equivalent lateral force, modal analysis - combination of loading, – Static and Dynamic approach - Analytical and wind tunnel experimental methods - Design philosophy - working stress method, limit state method and plastic design.

UNIT II BEHAVIOUR OF VARIOUS STRUCTURAL SYSTEMS **9**

Factors affecting growth, height and structural form. High rise behaviour, Rigid frames, braced frames, In-filled frames, shear walls, coupled shear walls, wall-frames, tubulars, cores, outrigger - braced and hybrid mega systems.

UNIT III ANALYSIS AND DESIGN **9**

Modeling for approximate analysis, Accurate analysis and reduction techniques, Analysis of buildings as total structural system considering overall integrity and major subsystem interaction, Analysis for member forces, drift and twist - Computerized three-dimensional analysis – Assumptions in 3D analysis – Simplified 2D analysis.

UNIT IV STRUCTURAL ELEMENTS **9**

Sectional shapes, properties and resisting capacity, design, deflection, cracking, prestressing, shear flow, Design for differential movement, creep and shrinkage effects, temperature effects and fire resistance.

UNIT V STABILITY OF TALL BUILDINGS **9**

Overall buckling analysis of frames, wall-frames, Approximate methods, second order effects of gravity of loading, P-Delta analysis, simultaneous first-order and P-Delta analysis, Translational, Torsional instability, out of plumb effects, stiffness of member in stability, effect of foundation rotation.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand the design philosophy, loading, different types of frames, types of shear walls.

CO2:Understand different lateral load resisting systems.

CO3:Understand approximate analysis, accurate analysis and reduction techniques

CO4:Design structural elements in tall buildings

CO5:Understand translational – torsional instability.

TEXT BOOKS

1. Beedle.L.S., “Advances in Tall Buildings”, CBS Publishers and Distributors, Delhi, 1986.
2. Bryan Stafford Smith and Alex coull, “Tall Building Structures - Analysis and Design”,John Wiley and Sons, Inc., 2005.
3. Smith B. S. and Coull A., “Tall Building Structures - Analysis and Design”, John Wiley

REFERENCE BOOKS

1. 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.
2. Lin T.Y and Stotes Burry D, “Structural Concepts and systems for Architects and Engineers”, John Wiley, 1988.
3. Taranath B. S., “Structural Analysis and Design of Tall Buildings”, CRC Press, 2011. Sons, Inc., 2011.
4. Holmes, “Wind Loading of Structures”, Third Edition, Spon Press, London, 2017.
5. Schuller W. G., “High rise building structures”, John Wiley,1977.

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3		3	3	3	2

1-Low, 2-Medium, 3-High, “-” – no correlation

24ST2308	DESIGN OF STEEL-CONCRETE COMPOSITE STRUCTURES	L T P C 3 0 0 3

COURSE OBJECTIVES

- To develop an understanding of the behaviour of Steel Composite structures
- To design concrete composite elements and structures.
- To design the Joints of steel and concrete composite structures

UNIT I INTRODUCTION **9**

Types of composite constructions - General behaviour of composite beams, slabs, columns and walls - Material properties of concrete and steel under static and fatigue loads - Codes and standards - Serviceability concepts - Fire resistance requirements and design procedure - Construction techniques.

UNIT II SHEAR CONNECTORS **9**

Methods of shear connection - Properties of shear connectors - Types - Transfer of shear connector forces in concrete elements - Post-cracking dowel strength - Longitudinal force - Embedment force - Partial interaction and full interaction - Design of shear connectors.

UNIT III DESIGN OF COMPOSITE BEAMS AND SLABS **9**

Moment of inertia of composite beams - Design of composite beams - Design of composite profiled slabs and decks - Design of composite beams with composite slabs - Serviceability requirements - behaviour of box girder bridges.

UNIT IV DESIGN OF COMPOSITE COLUMNS **9**

Behaviour under pure axial, eccentric axial loads and moments - Short column and long columns - Axial load-moment interaction curves - Design of encased columns - Design of concrete-filled steel columns - Composite trusses.

UNIT V DESIGN OF JOINTS **9**

Joint configurations - Design of beam-to-beam joints - Design of beam-to-column joints - Column bases - Design of beam and column splices - Design of simple joints and moment-resisting joints.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand properties and behaviour of steel-concrete composites
CO2:Design shear connectors
CO3:Design composite beams and slab for strength and serviceability
CO4:Design encased and concrete-filled composite columns for axial loads and moments
CO5:Design connections in composite structures

TEXT BOOKS

1. Johnson R.P., "Composite Structures of Steel and Concrete Beams, Slabs, Columns and Frames for Buildings", Vol. I, Fourth Edition, Blackwell Scientific Publications, 2018
2. Oehlers D.J. and Bradford M.A., "Composite Steel and Concrete Structural Members, Fundamental behaviour", Revised Edition, Pergamon press, Oxford, 2013.
3. Davison B. and Owens G. W., "Steel Designers Manual", Seventh Edition, Steel Concrete Institute (UK), Wiley Black, 2016.

REFERENCE BOOKS

1. Owens. G.W and Knowles. P," Steel Designers Manual", Seventh Edition, Steel Concrete Institute(UK), Oxford Blackwell Scientific Publications, 2011.
2. Narayanan R, "Composite steel structures – Advances, design and construction", Elsevier, Applied science, UK, 1987
3. Teaching resource for, "Structural Steel Design," Volume 2 of 3, Institute for Steel Development and Growth (INSDAG), 2002.
4. Ghosh, A. "Composite Steel and Concrete Structures", CRC Press, 2020.
5. Bhowmick, A., and Saha, P. "Design of Composite Structures", Springer, 2016.

Mapping of COs and POs

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1-Low, 2-Medium, 3-High, "-" – no correlation

24ST3301 ADVANCED FOUNDATION DESIGN L T P C
3 0 0 3

COURSE OBJECTIVES

- To design various types of foundations.
- To design of piles, pile groups and caissons with respect to vertical and lateral loads for various field conditions.
- To design machine foundations and special foundations.

UNIT I SHALLOW FOUNDATIONS **9**

soil investigation – Types of foundations and their specific applications – depth of foundation – bearing capacity and settlement estimates – structural design of isolated, strip, rectangular and trapezoidal and combined footings – strap – raft foundation.

UNIT II PILE FOUNDATIONS **9**

Types of Pile foundations and their applications – Load Carrying capacity – pile load test – Settlements – Group action – pile cap – structural design of piles and pile caps – undreamed pile foundation.

UNIT III WELL FOUNDATION **9**

Types of well foundations – grip length – load carrying capacity – construction of wells – failure and remedies – structural design of well foundation – lateral stability.

UNIT IV MACHINE FOUNDATIONS **9**

Types – General requirements and design criteria – General analysis of machine foundations-soil system – Stiffness and damping parameters – Tests for design parameters – design of foundation for reciprocating engines, impact type machines and rotary type machines.

UNIT V SPECIAL FOUNDATIONS **9**

General requirements and design criteria – Foundations for towers, Chimneys and Silos – design of anchors

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Design shallow and deep foundations for various types of structures
CO2:Design piles and pile caps
CO3:Design well foundation for bridge piers and related structures
CO4:Gain knowledge on design and construction of machine foundation
CO5:Design foundations for bridges, towers and chimneys

TEXT BOOKS

1. Tomlinson, M.J. and Boorman. R., Foundation Design and Construction, ELBS Longman, Seventh Edition, 2001.
2. Nayak, N.V., Foundation Design manual for Practicing Engineers, Dhanpat Rai and Sons, 2018.
3. Brain J. Bell and M.J. Smith, Reinforced Concrete Foundations, George Godwin Ltd., 1981.

REFERENCE BOOKS

1. Braja M. Das, Principles of Foundations Engineering, Eighth Edition, Thomson Asia (P) Ltd., 2017.

2. Bowels J.E., Foundation Analysis and Design, Fifth Edition, McGraw-Hill International Book Co., 2017.
3. P. C. Varghese, "Foundation Engineering", Prentice-Hall of India, New Delhi, 2005.
4. Swamy Saran, Analysis and Design of Substructures, Oxford and IBH Publishing Co. Pvt. Ltd., 2006.
5. Das, B.M., Principles of Foundation Engineering, Design and Construction, Fourth Edition, PWS Publishing, 1999.

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AVG	3		3	3	3	2

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24ST3302 EARTH RETAINING STRUCTURES L T P C
3 0 0 3

COURSE OBJECTIVES

- To design retaining walls, anchored bulkheads, braced cuts, coffer dams and earth dams.
- To analyze and design rigid, flexible earth retaining structures.
- To design the anchored bulkheads and stability analysis of structures.

UNIT I LATERAL PRESSURE **9**

Basic concepts, Rankine and Coulomb earth pressure theories, graphical methods. Determining active and passive pressures: Culmanns, Rebhan's, logarithmic spiral methods, friction circle method. Consideration of surcharge, seepage, earth quake, wave effect, stratification, type of backfill, wall friction and adhesion.

UNIT II ANCHORED BULKHEADS **9**

Classification of anchored bulkheads, free and fixed earth support methods. Rowe's theory for free earth supports and equivalent beam methods for fixed earth supports. Design of anchored rods and dead man Braced cuts and Cofferdams: Braced excavations and stability of vertical cuts, lateral pressures in sand and clay, Braced and cellular cofferdams: uses, types, components, stability, piping and heaving. Stability of cellular cofferdams, cellular cofferdams in rock and in deep soils.

UNIT III EARTH DAMS- STABILITY ANALYSIS **9**

Classification, seepage control in embankments and foundations, seepage analysis, stability analysis: upstream and downstream for steady seepage, rapid draw down, end of construction, method of slices and Bishop's method.

UNIT IV EARTH DAMS -PROTECTION & CONSTRUCTION **9**

Slope protection, filters, embankment construction materials and construction, quality control, grouting techniques. Instrumentation and performance observations in earth dams.

UNIT V RETAINING WALLS **9**

Different types of Retaining Walls, Proportioning the retaining walls, determining the Lateral earth pressure on Retaining walls, Perform the Stability checks: overturning, sliding, bearing capacity, and settlement, Design the Cantilever and counterfort retaining walls, Provision of joints in retaining wall construction, the drainage of walls from backfill. Special types of retaining walls – Gabion walls.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Understand lateral earth pressure theories and pressure theories

CO2:Design anchored bulkheads by different methods

CO3:Understand pressure envelops and design of various components in braced cuts and cofferdams.

CO4:Understand stability of earth dams and its protection and construction.

CO5:Design of retaining walls

TEXT BOOKS

1. W.C. Huntington (2013), Earth pressure on retaining walls, Literary Licensing.
2. J.E. Bowles (2001), Foundation Analysis and Design, McGraw Hill.
3. Muni Budhu, Soil Mechanics and Foundation, John Wiley and Sons, INC 2007.

REFERENCE BOOKS

1. C.J.F.P. Jones (1996), Earth Reinforcements and Soil structures, Thomas Telford Ltd.
2. S. Prakash, G. Ranjan & S. Swaran (1979), Analysis & Design of Foundations & Retaining Structures, Sarita Prakashan.
3. Winterkorn, H.F. and Fang, H.Y., Foundation Engineering Handbook, Galgotia Book source, 2000.
4. Rowe, R.K., Geotechnical and Geoenvironmental Engineering Handbook, Kluwer Academic Publishers, 2001.
5. McCarthy, D.F., Essentials of Soil Mechanics and Foundations: Basic Geotechnics, Sixth Edition, Prentice Hall, 2002

Mapping of COs and POs

COs	POs					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	3	3	3	2
CO2	3	-	3	3	3	2
CO3	3	-	3	3	3	2
CO4	3	-	3	3	3	2
CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST3303 DESIGN OF OFFSHORE STRUCTURES L T P C
3 0 0 3

COURSE OBJECTIVES

- To impart knowledge about the concept of Wave Theories, Forces, Offshore Foundation, Analysis and Design of Jacket Towers, Pipes and Cables.
- To understand the demand for coastal and offshore structures.
- To be familiar with the problems associated with the material behavior in marine environment and various protection methods.

UNIT I INTRODUCTION TO OFFSHORE ENVIRONMENT 7

Ocean winds - Waves - Wave parameters - Introduction to Airy's wave theory and its applications - Brief introduction about ocean currents - Tides, ice-sea interactions - Need for offshore structures - Introduction to environmental loads - Wind, wave, current and ice loads - Introduction to API and DNV code provisions.

UNIT II TYPES AND COMPONENTS OF OFFSHORE STRUCTURES 6

Types of offshore structures - Functional and structural requirements of an offshore platform - Components of a fixed jacket steel platform, steel jack-up platform, concrete gravity platform, semisubmersible platform and ship structures.

UNIT III LOADS ON OFFSHORE SRUCTURES 8

Wind Loads; Wave and Current Loads; Calculation based on Maximum base, Shear and Overturning Moments; Design Wave heights and Spectral, Definition; Hydrodynamic Coefficients and Marine growth; Fatigue Load, Definition and Joint Probability distribution; Seismic Loads.

UNIT IV ANALYSIS AND DESIGN OF JACKET PLATFORMS **12**

Design considerations - Codes and provisions - Typical preliminary design - Minimum embedment length of piles (of columns) - Top deck analysis for imposed loads - Analysis and design of deck framing members - Truss structures in the top deck - Reassessing sufficiency of vertical column below the top deck - Tubular members in jacket structure - Miscellaneous considerations for jacket platform.

UNIT V ANALYSIS AND DESIGN OF CONCRETE GRAVITY PLATFORMS **12**

Introduction and design environmental conditions - Analysis and design aspects of gravity platform - Salient features to be considered in analysis and design - Bearing capacities of gravity platform foundation - Requirements in design - Drained and undrained bearing capacity of foundation soil - Sliding resistance of foundation soil - Analysis and design of gravity platform subjected to wind and wave loads - Assumptions made in simplified analysis - Additional considerations for dynamic behavior of platform components.

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Develop the concept of wave theories
CO2:Apply the knowledge of wave forces and offshore structures
CO3:Explain the modeling for offshore structure and its foundation
CO4:Analyze offshore structures by means of static and dynamic methods
CO5:Design of jacket towers, mooring cables and pipelines

TEXT BOOKS

1. Graff W. J., “Introduction to Offshore Structures”, Gulf Publ. Co.,1981.
2. Dawson T. H., “Offshore Structural Engineering”, Prentice Hall, 1983.
3. B. C. Gerwick Jr., “Construction of Marine and Offshore Structures”, CRC Press, Florida, 2000.

REFERENCE BOOKS

1. Reddy D. V. and Arockiasamy M., “Offshore Structures” Vol. 1 & 2, Kreiger Publ. Co., 1991.
2. Morgan N., “Marine Technology Reference Book”, Butterworths, 1990.
3. McClelland B. and Reifel M. D., “Planning and Design of fixed Offshore Platforms”, Van Nostrand, 1986.
4. “PI RP 2A - Planning, Designing and Constructing Fixed Offshore Platforms”, API, 2000.
5. Clauss G., Lehmann E. and Ostergaard C., “Offshore Structures”, Vol. 1 & 2, Springer-Verlag, 1992.

Mapping of COs and POs

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CO5	3	-	3	3	3	2
AVG	3	-	3	3	3	2

1-Low, 2-Medium, 3-High, "-" – no correlation

24ST3304 SOIL STRUCTURE INTERACTION L T P C
3 0 0 3

COURSE OBJECTIVES

- To make students understand soil foundation interaction and its importance.
- To study the concept of soil-structure – interaction in the analysis and design of structures.
- To expose students to beams and plates on elastic foundation.

UNIT I INTRODUCTION **9**

Nature and complexities of Soil-Structure Interaction (SSI) problems - Critical study on conventional foundation design - Effect on structural analysis with SSI.

UNIT II TECHNIQUES OF ANALYSIS **9**

Advanced techniques of analysis - Finite element method - Finite differences - Relaxation and interaction for SSI for different types of structures and for various soil conditions.

UNIT III APPLICATION OF SSI **9**

Theory of sub grade reaction - Beams, footings, bulkheads - Shallow foundation - Deep foundation -Grouping of piles and its effects - Effect of soil layer on SSI analysis.

UNIT IV STRUCTURAL ANALYSIS WITH SSI **9**

Analysis of different types of framed structures founded in stratified natural deposits – Determination of stiffness and damping parameters of soil.

UNIT V PRACTICAL APPLICATION **9**

Modeling, analysis and design of building - Real time problem analysis - Case studies

TOTAL: 45 PERIODS

COURSE OUTCOMES

On successful completion of this course, the student will be able to

CO1:Explain the concept of soil structure interaction.

CO2:Do a static analysis of infinite and finite beams resting on elastic foundation

CO3:Analyze finite thin and thick plates

CO4:Do a static and dynamic analysis of soil structure interaction problems

CO5:Analyze ground foundation and structure interaction problems

TEXT BOOKS

1. John P. Wolf, "Soil-Structure Interaction", Prentice Hall, 1987.
2. Bowels J. E., "Analytical and Computer methods in Foundation", McGraw Hill Book Co., New York, 1974.
3. Desai C. S. and Christian J. T., "Numerical Methods in Geotechnical Engineering", McGraw Hill, Book Co., New York, 1977.

REFERENCE BOOKS

1. "Soil Structure Interaction, The Real Behavior of Structures", Institution of Structural Engineers,1989.
2. A. P. S. Selvadurai, "Elastic Analysis of Soil Foundation Interaction, Developments in Geotechnical Engg. Vol - 17", Elsevier Scientific Publishing Co., 1979.
3. Prakash S. and Sharma H. D., "Pile Foundations in Engineering Practice", John Wiley &Sons, New York, 1990.
4. J. W. Bull, Soil-Structure Interaction: Numerical Analysis and Modelling, CRC Press, 1st Edition, 1994.
5. Chandrakant S. Desai, Musharraf Zaman, Advanced Geotechnical Engineering: Soil Structure Interaction using Computer and Material Models, CRC Press, 2013.

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