FACULTY OF ENGINEERING

(Scheme of Instruction & Examination)

PhD Syllabus

In

Civil Engineering

Dean, Faculty of Engineering

Osmania University, Hyderabad – 500 007

2026

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Department of Civil Engineering
Osmania University, Hyderabad.

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S.No	Subject Code	Subject Name	Specialization
1	PHD2001 CE	Research Methodology in Civil Engineering	Mandatory
2	PHD2002 CE	Bridge Engineering	Structural Engineering
3	PHD2003 CE	Retrofitting and Rehabilitation of Structures	Structural Engineering
4	PHD2004 CE	Advanced Concrete Technology	Structural Engineering
5	PHD2005 CE	Fracture Mechanics in Concrete Structures	Structural Engineering
6	PHD2006CE	Composite Constructions	Structural Engineering
7	PHD2007CE	Structural Fire Engineering	Structural Engineering
8	PHD2008CE	Advanced Reinforced Concrete Design	Structural Engineering
9	PHD2010CE	Structural Health Monitoring	Structural Engineering
10	PHD2011CE	Structural Optimization	Structural Engineering
11	PHD2012CE	Structural Design	Structural Engineering
12	PHD2013CE	Water Resources Systems Planning	Water Resources Engineering
13	PHD2014CE	Geospatial Applications in Water Resources	Water Resources Engineering
14	PHD2015CE	Impacts of Climate Change in WRE	Water Resources Engineering
15	PHD2016CE	Traffic Engineering	Transportation Engineering
16	PHD2017CE	Intelligent Transportation Systems	Transportation Engineering
17	PHD2018CE	Transportation Modeling Simulation	Transportation Engineering
18	PHD2019CE	Pavement Systems Engineering	Transportation Engineering
19	PHD2020CE	Statistical Techniques	Transportation Engineering
20	PHD2021CE	Expansive Soil Engineering	Geotechnical Engineering

PHD2001CE	RESEARCH METHODOLOGY in Civil Engineering (RMCE)					
	MANDATORY					
Pre-requisites			L	T	P	C
			3	-	-	3
Evaluation	SEE	100 Marks	CIE			

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Introduce the conceptual and philosophical foundation of research methodology for Scientific and Engineering Research
2	Provide an understanding of the importance of literature review and formulating of a good research problem.
3	Offer procedural instruction on how to plan, design & conduct research projects and interpret the data

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Demonstrate the knowledge of research processes (reading, evaluating, and developing) and formulate a research problem
CO-2	Perform literature reviews, present research ideas, plan research projects, and to explain the rationale for research ethics
CO-3	Data collection, Application of various statistical tools and analysis of the data
CO-4	Develop proficiency in research documentation, including the preparation of research reports, synopsis writing, dissertation writing, and the publication of research papers in academic journals.
CO-5	Apply various research methodologies, including numerical methods, soft computing techniques, genetic algorithms, and other advanced computational approaches, to solve complex research problems and develop innovative solutions."

UNIT-I

Introduction Research Methodology: Objectives and Motivation of Research, Types of Research, Research Approaches, Significance of Research, Research and Scientific Method, Importance of Research Methodology, Research Process, Criteria and characteristics of Good Research, challenges encountered by Researchers, benefits.

Defining the Research Problem: Definition of Research Problem-Problem -Formulation Necessity of defining the Problem-Techniques involved in defining Research Problem.

Literature Review: Importance of Literature Survey, Sources of Information, Assessment of quality of Journals and Articles, Critical appraisal of Literature Review, problem definition.

UNIT-II

Research Design: Meaning of Research Design, need of Research Design, Important concepts related to Research Design, Different Research Designs, Basic Principles of Experimental Design, Developing a Research Plan, Design of Experimental Set-up, Use of Standards and Codes.

Research Tools: Methods to search required information effectively, citation styles, reference management, software's (Zotero/Mendeley/Endnote).

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Plagiarism: plagiarism & self-plagiarism consequence of plagiarism, unintentional plagiarism, copyright infringement. Software's for detection of plagiarism (Turnitin,/ IT thenticate). –Types of Ethics – Patents – Filing of patents at National / International Agencies

UNIT-III

Data Collection: Collection of primary data, Secondary data, Data organization, Methods of data grouping, diagrammatic representation of data, Graphic representation of data,Sample design.

Data Analysis: Mathematical modeling: models in general, mathematical model, model classification, modeling of engineering systems. Probability and its distribution, hypothesis testing, Test for significance: Chi-square, Student t-test, Regression modeling, ANOVA, F-test, Time Series analysis. Analysis of Data- Role of Statistics for Data Analysis- Parametric /non-Parametric methods, Descriptive Statistics.

UNIT-IV

Research Report Writing: Format of the Research report, Synopsis writing, Dissertation and its differentiation, technical writing in peer reviewed journals ethics to be followed related to publishing References/Bibliography research indicators (citations/h-index/i10 index/cite score, etc), research profile building (Orcid-id/Google Scholar/Pub Med/Scopus id/etc.)

Research Proposal Preparation: Funding agencies in India and across the Globe, writing Research Proposal, Writing Research Grant Proposal: Minor and Major Research proposals (UGC and AICTE).

UNIT-V

Research Practices in Civil Engineering: Research paradigms in civil engineering—theoretical, applied, data driven and practice-oriented approaches; Innovation and advancement in materials research- Experimental methodologies covering design and scaling effects, non-destructive testing, and sensor-based data acquisition; Numerical modeling techniques such as FEM, Discrete Element Method, and Computational Fluid Dynamics and non-linear analysis; Recent advancements in AI, ML, deep learning, soft computing techniques, genetic algorithms, and optimization methods; Integrated case studies demonstrating hybrid methodologies combining experimental, numerical, and computational approaches.

References

1. C.R. Kothari, Research Methodology, Methods & Technique; New Age International Publishers, 2004
2. R. Ganesan, Research Methodology for Engineers, MJP Publishers, 2011
3. Vijay Upagade and Aravind Shende, Research Methodology, S. Chand & Company Ltd, New Delhi, 2009
4. P. Ramdass and Wilson Aruni; Research and Writing across the disciplines; MJP Publishers, Chennai, 2009
5. Margaret Cargill and Patrick O' Connor: Writing Scientific Research Articles Strategy and Steps, A John Wiley & Sons, Ltd, Publication, 2009
6. MLA Hand book for Writers of Research Papers, The modern language association of America, New York 2009.

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PHD2002CE	BRIDGE ENGINEERING					
Pre-requisites			L	T	P	C
			3	-	-	3
Evaluation	SEE	100 Marks				

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Learn the high strength materials, IRC loads, planning and lay out of bridges, hydraulic, geological and geo-technical aspects in bridge design.
2	Analyse, design, detailing in bridge deck slabs and box girder systems,
3	Learn steel and composite bridges.
4	Analyse and design the sub-structures and super structures, bearings, joints and retaining walls.
5	Learn the various long span bridges.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamentals, materials and IRC codes of practice of bridge design.
CO-2	Design the bridge deck slabs and box girder systems using appropriate method.
CO-3	Design the steel and composite steel-concrete bridges
CO-4	Propose the sub-structure components such as pier, abutments, retaining walls etc. joints and bridge bearings
CO-5	Design the various types of long span bridges, curved and skew bridges

Correlation rating : Low / Medium / High : 1 / 2 / 3 respectively.

Unit – I
Types of bridges, materials of construction, codes of practice (Railway and Highway Bridges), aesthetics, loading standards (IRC, RDSO, AASHTO), recent developments box girder bridges historical bridges (in India and overseas).
Planning and layout of bridges, hydraulic design, geological and geo-technical considerations; Design aids, computer software, expert systems.

Unit – II
Concrete Bridges: Bridge deck and approach slabs, Slab design methods, design of bridge
deck systems, slab-beam systems (Guyon-Massonet and Hendry Jaeger Methods), box girder systems, analysis and design. Detailing of box girder systems.

Unit – III
Steel and Composite Bridges: Introduction to composite bridges, Advantages and disadvantages, Orthotropic decks, box girders, composite steel-concrete bridges, analysis and design, truss bridges.

Unit – IV

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Sub-Structure: Piers, columns and towers, analysis and design, shallow and deep foundations, caissons,abutments and retaining walls.
Bridge appurtenances: Expansion joints, design of joints, types and functions of bearings, design of elastomeric bearings, railings, drainage system, lighting. Current design practices in Bridge foundations, piers, bridge decks, abutments. Case studies on Industrial area bridges.

Unit – V
Long span bridges: Design principles of continuous box girders, curved and skew bridges, cable stayed and suspension bridges, seismic resistant design, seismic isolation and damping devices. Construction techniques (cast in-situ, prefabricated, incremental launching, free cantilever construction), inspection, maintenance and rehabilitation, current design and construction practices. Heavy loading with bridge bearings, joints, corbels, pile caps. Case studies on live constructions, pre cast- post tensioned slab girders. Design techniques for box girder systems. Case studies on cable stayed and suspension bridges.

Suggested Reading:

1	Wai-Fah Chen Lian Duan "Bridge Engineering Handbook", , CRC Press, USA, 2000.
2	Barker, P.M. and Puckett, J.A "Design of Highway Bridges",., John Wiley & Sons, New York, 1997.
3	Xanthakos, P.P.,"Theory and Design of Bridges", John Wiley & Sons, New York, 1994.
4	Essentials of Bridge Engineering by D. John Victor 2006.
5	Design of Bridge Structures by T.R.Jagadeesh and M.A.Jayaram 2004 .

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PHD2003CE	RETROFITTING AND REHABILITATION OF STRUCTURES					
Pre-requisites			L	T	P	C
			3	-	-	3
Evaluation	SEE	100 Marks				

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Learn the fundamentals of maintenance and repair strategies.
2	Design and detail the deep beams. Study the quality assurance, serviceability and durability of concrete.
3	Know the various materials and techniques used for repair of structures
4	Educate the different repair, strengthening, rehabilitation and retrofitting techniques.
5	Instruct the various health monitoring and demolition techniques.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamentals of maintenance and repair strategies.
CO-2	Diagnose for serviceability and durability aspects of concrete.
CO-3	Know the materials and techniques used for repair of structures
CO-4	Decide the appropriate repair, strengthening, rehabilitation and retrofitting technique required for a case study building.
CO-5	Use an appropriate health monitoring and demolition techniques

Unit – I
Maintenance: Repair and Rehabilitation, Facets of Maintenance, importance of Maintenance various aspects of Inspection, Assessment procedure for evaluating damaged structure, causes of deterioration.
Repair Strategies: Causes of distress in concrete structures, Construction and design failures, Condition assessment and distress-diagnostic techniques, Assessment procedure for Inspection and evaluating a damaged structure.
Unit – II
Serviceability and Durability of Concrete: Quality assurance for concrete construction, concrete properties – strength, permeability, thermal properties and cracking. – Effects due to climate, temperature, chemicals, corrosion – design and construction errors – Effects of cover thickness and cracking.

Unit – III

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Materials and Techniques for Repair: Special concretes and mortar, concrete chemicals, special elements for accelerated strength gain, Expansive cement, polymer concrete, sulphur infiltrated concrete, ferro-cement, Fibre reinforced concrete. Bacterial concrete, Rust eliminators and polymers coating for rebars during repair, foamed concrete, mortar and dry pack, vacuum concrete, Gunite and Shotcrete, Epoxy injection, Mortar repair for cracks, shoring and underpinning. Methods of corrosion protection, corrosion inhibitors, corrosion resistant steels, coating and cathodic protection

Unit – IV

Repair, Rehabilitation and Retrofitting Techniques: Repairs to overcome low member strength, Deflection, Cracking, Chemical disruption, weathering corrosion, wear, fire, leakage and marine exposure, Repair of Structure – Common Types of Repairs – Repair in Concrete Structures – Repairs inUnder Water Structures – Guniting – Shot Create – Underpinning. Strengthening of Structures – Strengthening Methods – Retrofitting – Jacketing.
Retrofitting methods, Techniques, Procedures and their implementation strategies according to the present day needs of the industry. Case studies on repair and rehabilitation of buildings, bridges, post tensioned slabs etc.

Unit – V

Health Monitoring and Demolition Techniques: Long term health monitoring techniques, engineered demolition techniques for dilapidated structures, Use of Sensors – Building Instrumentation-
Machine Foundations: Introduction, Types, Design Principles, Case studies, detailed designs. Identification of repairs on structural elements, diagnosis, techniques, and methodologies for industrial structures. Case studies on industrial buildings with temperatures" etc.

Suggested Reading:

1	A.R. Santakumar Concrete Technology, Oxford University press, 2018 2 nd Edition
2	Barry Richardson Defects and Deterioration in Buildingts, E F & N Spon, London, 1991
3	Bungey Non-Destructive Evaluation of Concrete Structures - Surrey University,1995
4	B.L. Gupta and Amit Gupta Maintenance and Repair of Civil Structures, , Standard Publications, 2009
5	W. H. Ranso,Concrete Repair and Maintenance Illustrated, RS Means Company Inc 1981
6	Ransom Building Failures: Diagnosis and Avoidance, EF & N Spon, London, 1987
7	Mehta, P.K and Montevic. P.J., Concrete- Microstructure, Properties and Materials, ICI, 1997. Jackson, N., Civil Engineering Materials, ELBS, 1983.

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PHD2004CE	ADVANCED CONCRETE TECHNOLOGY					
Pre-requisites			L	T	P	C
			3	-	-	3
Evaluation	SEE	100 Marks				

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Learn the microstructure and material science aspect of concrete.
2	Comprehend the long term and durability properties of concrete.
3	Design high strength and high performance concrete mix by standard guidelines.
4	Study the role of admixtures in concrete.
5	Identify the mix proportion and properties of special concrete

Course Outcomes :	
On completion of this course, the student will be able to do :	
CO-1	Assessment of the hydrated structure and microstructure of concrete.
CO-2	Acquire the knowledge of dimensional stability and durability properties of concrete.
CO-3	Design concrete mixes by various methods of mix design
CO-4	Familiarize with the types of admixtures added to concrete.
CO-5	Carryout the mix design and properties of special concretes.

Unit - I

Concrete as a composite material; advantages-limitations; Materials science aspects of the properties and behavior of Cement Concrete: physical and chemical aspects of cement hydration, type and morphology of hydrates; Structure of concrete-Transition zone-Micro structural engineering.

Modern trends in concrete manufacture and placement techniques-methods of transportation-placing and curing-extreme whether concreting-special concreting methods-vaccum dewatering of concrete-under water concreting.

Unit - II

Strength of Hardened concrete-NDT; Stress-strain relations; Dimensional stability-shrinkage and creep; Durability of concrete -Durability concept- pore structure and transport processes-reinforcement corrosion-chloride attack-carbonation- fire resistance- frost damage- sulphate attack- alkali aggregate reaction- delayed ettringite formation- methods of providing durable concrete- short-term tests to assess
long-term behavior.

Unit - III

Mix design of concrete –Quality control – Principles of concrete mix design-Various methods of mixdesign - IS code method - British and ACI methods-Mix design of special concrete-Design of high
strength and high performance concrete-Design of pumpable concrete

Unit - IV

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Mineral Admixtures – Hydration of Admixtures - Slags – Pozzolanas and Fillers – Dispersing admixtures-Retarding admixtures-Accelerating admixtures-Air entraining admixtures-Water resisting admixtures-Corrosion inhibiting admixtures-Shrinkage reducing admixtures-Under water admixtures-
Sprayed concrete admixtures- Compatibility issues with Chemical Admixtures.
Special materials used in the preparation of concrete-Challenges faced to achieve workability in the field-Field problems related to compaction of concrete-Current techniques of concrete placement in inaccessible locations

Unit - V

Special concrete- Fly ash concrete -Silica fume concrete -Fiber reinforced concrete- Sprayed concrete - Geopolymer concrete-Self compacting concrete- Roller compacted concrete- Ferro cement-Recycled aggregate concrete-Slurry Infiltrated Concrete-Mix design-properties and their applications; Engineered cementitious composites-
Application of admixture in the field-challenges faced-Remedial measures-Case studies related to Special concrete-challenges faced in the field-Remedial measures

Suggested Reading:

1	Neville. A.M "Properties of Concrete", b y ., English Language Book Society-Longman Publications, 1988
2	Neville A.M. & Brooks J.J "Concrete Technology",. Pearson Education, Limited 2010
3	Mehta P.K. and Paulo J.M.M. Concrete – Microstructure – Properties and Material", McGraw-Hill, New York . 1997
4	Zongji Li "Advanced Concrete Technology", , John Wiley & sons, inc. 2011
5	John Newman, "Advanced Concrete Technology", Ban Seng Choo, Elsevier publisher., 2003
6	Thomas Dyer Concrete Durability", CRC Press, Taylor & Francis group, 2014
7	Krishna Raju,N Design of Concrete Mix, CBS Publications, New Delhi, 1985
8	IS 10262-2019- Guidelines for Concrete Mix Design Proportioning

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PHD2005CE	FRACTURE MECHANICS IN CONCRETE STRUCTURES					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks				

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Learn the causes and the effects of cracks in concrete structures based on fracture mechanics.
2	Understand the type of failures in concrete structures.
3	Study the methods for calculating stress intensity factors.
4	Understand the concepts of Fracture Models for Concrete Materials.
5	Develop an understanding of fracture energy determination.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Identify and classify cracking of concrete structures based on fracture mechanics.
CO-2	Know the various fracture mechanics aspects and failure aspects of systems in a structure.
CO-3	Understand stress intensity factor and implement to notched members.
CO-4	Understand the concepts of LEFM and compute fracture parameters for various sections.
CO-5	Apply fracture mechanics models to high strength concrete and FRC structures.

Unit – I
Introduction: Basic fracture mechanics, crack in a structure, characteristics of cracks, fracture, modes of deformation of a cracked body, crack growth mechanisms, mechanisms of fracture and crack growth

Unit – II
Cleavage fracture, ductile fracture, fatigue cracking, fatigue strength of concrete, Fatigue of Reinforcement steel, Fatigue of Reinforced concrete members, fatigue crack growth model, environment assisted cracking, service failure analysis

Unit – III
Linear elastic fracture mechanics, Stress Concentration Effect of Flaws, Griffith"s Criteria, The Energy Release Rate, Stress intensity factors, Stress at crack tip, Concept of R curve, Review of concrete behavior in tension and compression- Fracture Process Zone-Basic frameworks formodeling of quasi-brittle materials, Concept of CTOD and CMD.

Unit – IV

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Mineral Admixtures – Hydration of Admixtures - Slags – Pozzolanas and Fillers – Dispersing admixtures-Retarding admixtures-Accelerating admixtures-Air entraining admixtures-Water resisting admixtures-Corrosion inhibiting admixtures-Shrinkage reducing admixtures-Under water admixtures- Sprayed concrete admixtures- Compatibility issues with Chemical Admixtures. Special materials used in the preparation of concrete-Challenges faced to achieve workability in the field-Field problems related to compaction of concrete-Current techniques of concrete placement in inaccessible locations

Unit - V
Special concrete- Fly ash concrete -Silica fume concrete -Fiber reinforced concrete- Sprayed concrete - Geopolymer concrete-Self compacting concrete- Roller compacted concrete- Ferro cement-Recycled aggregate concrete-Slurry Infiltrated Concrete-Mix design-properties and their applications; Engineered cementitious composites- Application of admixture in the field-challenges faced-Remedial measures-Case studies related to Special concrete-challenges faced in the field-Remedial measures

Suggested Reading:

1	Neville. A.M "Properties of Concrete", b y ., English Language Book Society-Longman Publications, 1988
2	Neville A.M. & Brooks J.J "Concrete Technology",. Pearson Education, Limited 2010
3	Mehta P.K. and Paulo J.M.M. Concrete – Microstructure – Properties and Material", McGraw-Hill, New York . 1997
4	Zongji Li "Advanced Concrete Technology", , John Wiley & sons, inc. 2011
5	John Newman, "Advanced Concrete Technology", Ban Seng Choo, Elsevier publisher., 2003
6	Thomas Dyer Concrete Durability", CRC Press, Taylor & Francis group, 2014
7	Krishna Raju,N Design of Concrete Mix, CBS Publications, New Delhi, 1985
8	IS 10262-2019- Guidelines for Concrete Mix Design Proportioning

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Fracture Models for Concrete Materials-Fictitious crack model- Crack band model-Two parameter fracture model-Size effect model. Concrete Fracture Properties- Direct method-indirect method- Flexural tests on notched beams- Fracture energy & Fracture parameters using three-point bendtest.
Finite element applications in Fracture mechanics and case study on the methodologies for advanced finite element analysis and crack width prediction in RC structures / components and practical aspectsduring its implementation.

Unit – V

Introduction to Damage Mechanics. Applications to High Strength Concrete, Fibre ReinforcedConcrete, Crack Concepts and Numerical Modeling.
Case study on the usage of the XFEM method to study the crack growth in a concrete beam under 3

Suggested Reading:

1	Suri, C.T. and Jin, Z. H Fracture Mechanics Fracture Mechanics,., 1st Edition, Elsevier Academic Press, 2012.
2	Broek David, Elementary Engineering Fracture Mechanics, 3rd Edition, Springer, 1982.
3	Elfgreen, L Fracture Mechanics of Concrete Structures – Theory and Applications,., RILEM Report, Chapman and Hall, 1989.
4	Victor, Li C., Bazant Z. P., Fracture Mechanics – Applications to Concrete, ACI SP118, ACI Detroit, 1989.
5	B.L. Karihaloo, Fracture Mechanics And Structural Concrete, Longman Scientific & Technical, 1995

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PHD2006CE	COMPOSITE CONSTRUCTIONS					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks				

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Study the concepts of composite construction.
2	Learn analysis and designs of composite beams, floors, columns and trusses as per the recommendations of IS codes of practice.
3	Apply the concepts for design of multi-storey composite buildings.
4	Scope of analysis is restricted to skeletal structures subjected to prescribed dynamic loads

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the fundamentals of composite construction, and analysis and designs of composite beams.
CO-2	Analyse and design the composite floors and connection details.
CO-3	Analyse and design the composite columns and connection details
CO-4	Analyse and design the composite trusses and connection details
CO-5	Analyse and design the multi-storey composite buildings.

Unit – I
Introduction of composite constructions: Benefits of composite construction - Introduction to IS - BS and Euro codal provisions.
Composite beams: Elastic behaviour of composite beams - No and full interaction cases - Shear connectors - Ultimate load behaviour - Serviceability limits - Effective breadth of flange - Interaction between shear and moment - Basic design consideration and design of composite beams.

Unit – II
Composite floors: Structural elements - Profiled sheet decking - Bending resistance - Shear resistance - Serviceability criterion - Analysis for internal forces and moments - Design of composite floors.

Unit – III
Composite columns: Materials - Concrete filled circular tubular sections - Non-dimensional slenderness - Local buckling of steel sections - Effective elastic flexural stiffness - Resistance of members to axial compressions - Composite column design - Fire resistance.

Unit – IV

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Composite trusses: Design of truss - Configuration - Truss members - Analysis and design of composite trusses and connection details. Case study on composite trusses.

Unit – V
Design of multi-storey composite buildings: Design basis - Load calculations - Design of composite slabs with profile decks - Composite beam design - Design for compression members - Vertical cross bracings - Design of foundation. Case study on multi-storey composite buildings.

Suggested Reading:

1	R.P. Johnson, "Composite Structures of Steel and Concrete - Beams, Slabs, Columns and Frames in Buildings", Blackwell Publishing, Malden, USA, 2004.
2	" INSDAG Teaching Resources for Structural Steel Design", Vol-2, Institute for Steel Development and Growth Publishers, Calcutta, India.2000
3	"INSDAG Handbook on Composite Construction – Multi-Storey Buildings", Institute for Steel Development and Growth Publishers, Calcutta, India.2000
4	"INSDAG Design of Composite Truss for Building", Institute for Steel Development and Growth Publishers, Calcutta, India-2000
5	"INSDAG Handbook on Composite Construction – Bridges and Flyovers", Institute for Steel Development and Growth Publishers, Calcutta, India.-2000
6	IS: 11384-1985, "Code of Practice for Composite Construction in Structural Steel and Concrete", Bureau of Indian Standards, New Delhi, 1985.

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PHD2007CE	STRUCTURAL FIRE ENGINEERING					
Pre-requisites	-		**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks				

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Understand the impact of fire hazard and the need for fire safety measures
2	Learn the growth of a fire and its severity in a compartment
3	Study the fire resistance evaluation of structural and non-structural members through testing
4	Learn the analysis and design of steel structural members for fire resistance using prescriptive and rational approaches
5	Study the analysis and design of reinforced concrete structural members for fire resistance using prescriptive and rational approaches

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Suggest strategies to mitigate fire hazard and measures for fire safety in buildings
CO-2	Assess the growth of a fire and estimate its severity
CO-3	Determine the fire resistance of structural and non-structural members using test methods
CO-4	Design of steel structural members for fire resistance using prescriptive and rational approaches
CO-5	Design of reinforced concrete members for fire resistance using prescriptive and rational approaches

Unit - I
Fire hazard in built infrastructure: Overview of fire hazard, fire statistics, recent fire incidents, strategies to overcome fire hazard.
Fire safety in buildings: Fire scenarios in buildings, need for fire safety measures, active and passive fire protection systems, codes and standards, limitations of codes and standards.

Unit - II
Fire growth and fire severity: Heat transfer mechanisms, fire development in a compartment, fire calculations: pre-flashover, flashover and post-flashover; time-temperature relations, need for fire severity and estimation of equivalent fire severity.
Material properties at elevated temperature: Thermal and mechanical properties of concrete, steel and insulation.

Unit - III

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Fire resistance evaluation: Test methods: overview of fire tests, standard fire resistance test and its limitations, resistance evaluation under non-standard fire conditions, fire resistance of non-structural members, Calculation methods: Prescriptive and rational engineering approaches.

Unit - IV
Steel structures: Behaviour of steel structures under fire exposure, strategies for achieving required fire resistance, prescriptive and rational approaches for evaluation fire resistance of beams, columns and slabs.

Unit - V	
Reinforced Concrete structures: Behaviour of reinforced concrete structures under fire exposure, strategies for achieving required fire resistance, prescriptive and rational approaches for evaluation fire resistance of beams, columns and slabs.	
SUGGESTED READING	
1	Venkatesh Kodur and Mohannad Naser *Structural Fire Engineering,*. 1st Edition, McGraw-Hill, New York, USA., 2020
2	Andrew H Buchanan and Anthony K Abu. *Structural Design for Fire Safety*2nd Edition, Wiley, Chichester, England.-2017
3	John A Purkiss and Long-yuan Li. *Fire Safety Engineering Design of Structures,* 3rd Edition, CRC Press, Boca Raton, Florida, USA. 2017
4	Jean-Marc Franssen et al. *Designing Steel Structures for Fire Safety,* 1st Edition, CRC Press, Boca Raton, Florida, USA.- 2009
5	Jain V K *Fire Safety in Buildings,*. New Age International, New Delhi.2020
6	Yong Wang et al., *Performance-Based Fire Engineering of Structures,* 1st Edition, CRC Press, Boca Raton, Florida, USA.-2013

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PHD2008CE	ADVANCED REINFORCED CONCRETE DESIGN					
Pre-requisites			L	T	P	C
			3	-	-	3
Evaluation	SEE	100 Marks				

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Learn the analysis and design of beams curved in plan
2	Design and detail the deep beams.
3	Analyse and detail the water tanks.
4	Design and detail Bunkers and silos.
5	Analyse and design the raft, pile and machine foundations.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Design the beams curved in plan
CO-2	Propose and design the deep beams.
CO-3	Design domes and various type water tanks.
CO-4	Differentiate and design the bunkers and silos.
CO-5	Design the raft, pile and machine foundations.

Unit – I

Beams Curved in Plan: Introduction - design principles – Terminologies, structural design of beams curved in plan of circular and rectangular type.

Unit – II

Deep Beams: Introduction to deep beams, Flexural and Shear stresses in deep beams, IS Code provisions - design of deep beams.

Unit – III

Domes: Introduction - Stresses and forces in domes - design of spherical and conical domes. **Water Tanks**: Types, Codal specifications, Design of circular, rectangular and Intze type water tanks.

Unit – IV

Bunkers and Silos: Introduction - Design principles and theories Code provisions - design of square and circular bunkers - design of cylindrical silos. IS specifications.
Advanced design of curved beams, deep beams, and elevated water tanks for industrial Structures, case studies and design and demonstrations on live industrial structures.

Unit – V

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Raft and Pile Foundations: Introduction, need for the design, Design principles - Structural design of raft and pile foundations including the design of pile caps.
Machine Foundations: Introduction, Types, Design Principles, Case studies, detailed designs. Advanced design of silos, Bunkers, Raft foundations, pile foundations and machine foundations. Case studies, design techniques and live design of industrial structures.

Suggested Reading:

1	N. Krishna Raju Advanced Reinforced Concrete Design", , CBS Pub. 1986.
2	H.J. Shah Reinforced Concrete", by, Charotar Pub. 2000. Vol. II.
3	"R.C.C. Designs" by B.C. Punmia, Laxmi Pub. 1998
4	N. Krishna Raju Structural Engineering Design and drawing 2009
5	S Unnikrishna Pillai and Devdas Menon Reinforced concrete design , 2004

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PHD2009CE	STRUCTURAL HEALTH MONITORING					
Pre-requisites			L	T	P	C
			3	-	-	3
Evaluation	SEE	100 Marks	CIE			

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Learn the fundamentals of structural health monitoring.
2	Study the various vibration-based techniques for structural health monitoring.
3	Learn the structural health monitoring using fiber-optic and Piezoelectric sensors.
4	Study the structural health monitoring using electrical resistance and electromagnetic techniques

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	*Understand the fundamentals of maintenance and repair strategies.*
CO-2	*Diagnose for serviceability and durability aspects of concrete.*
CO-3	*Know the materials and techniques used for repair of structures.*
CO-4	*Decide the appropriate repair, strengthening, rehabilitation and retrofitting technique required for a case study building.*
CO-5	*Use an appropriate health monitoring technique and demolition technique.*

Unit – I

Introduction to structural health monitoring: Definition of structural health monitoring (SHM) – Objectives- Need –Steps involved in SHM-Motivation for SHM - SHM as a way of making materials and structures smart - SHM and biomimetics - Process and pre usage monitoring as a part of SHM - SHM as a part of system management - The most remarkable characters of SHM Birth of the SHM community.

Unit - II

Vibration-based techniques for SHM: Basic vibration concepts for SHM -Local and global methods - Damage diagnosis as an inverse problem -Model-based damage assessment - General dynamic behavior-State- space description of mechanical systems - Neural network approach to SHM - The basic idea of neural networks - Detection of delamination in a CFRP plate with stiffeners.

Unit – III

Fiber-optic sensors: Classification of fiber-optic sensors - Intensity-based sensors - Phase-modulated optical fiber sensors - or interferometers -Wavelength based sensors - or Fiber Bragg Gratings (FBG) - The fiber Bragg grating as a strain and temperature sensor - Orientation of the optical fiber optic with respect to the reinforcement fibers - Fiber Bragg gratings as damage sensors for composites - Measurement of strain and stress variations

Unit – IV

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SHM with piezoelectric sensors: The use of embedded sensors as Acoustic Emission (AE) detectors - Available industrial AE systems- New concepts in acoustic emission - State-the-art and main trends in piezoelectric transducer-based acousto-ultrasonic SHM research –The full implementation of SHM of localized damage with guided waves in composite materials - Available industrial acousto-ultrasonic systems with piezoelectric sensors
Health monitoring of residential buildings a case study.

Unit – V

SHM using electrical resistance: Composite damage - Electrical resistance of unloaded composite - Percolation concept - Anisotropic conduction properties in continuous fiber reinforced polymer - Influence of temperature - Composite strain and damage monitoring by electrical resistance -Randomly distributed fiber reinforced polymers - Damage localization.
Low frequency electromagnetic techniques: Theoretical considerations on electromagnetic
Health monitoring of commercial and residential high rise buildings case studies.

Suggested Reading:

1	Daniel Balageas, Claus-Peter Fritzen and Alfredo Güemes "Structural Health Monitoring", John Wiley-ISTE, London, 2006.
2	Douglas E Adams, "Health Monitoring of Structural Materials and Components - Methods with Applications", John Wiley & Sons, New York, 2007.
3	J.P. Ou, H. Li and Z. D. Duan, "Structural Health Monitoring and Intelligent Infrastructure", Vol.-1, Taylor & Francis, London, 2006.
4	Victor Giurglutiu, "Structural Health Monitoring with Wafer Active Sensors", Academic Press Inc., 2007.
5	M.V. Gandhi and B.D. Thompson, "Smart Materials and Structures," Springer, 1992.
6	Fu Ko Chang, "Structural Health Monitoring: Current Status and Perspectives", Technomic, Lancaster, 1997.

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PHD2010CE	STRUCTURAL OPTIMIZATION					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks	**CIE**			

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Understand the basic principles and techniques for optimization
2	Learn to formulate Structural Optimization problems
3	Familiarized with the application of optimization techniques to structural elements.
4	Learn to formulate structural optimization using Dynamic programming concepts
5	Use of SO to various structural components in design

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the basic concepts of optimization and linear programming model.
CO-2	Ability to solve engineering problems using various optimization techniques.
CO-3	Able to formulate and solve nonlinear optimization models.
CO-4	Understand the concept and application of dynamic programming, simulation and decision theory for engineering problems
CO-5	Use the optimization techniques for simple structural elements

Unit – I

Introduction to optimization: Introduction, basic theory and elements of Optimization, Terminology and definitions, Basic principles and procedure of optimization, Engineering applications of Optimization.

Classical Methods of Optimization: Trial and error method, Monte-Carlo method, Lagrangian multiplier method, illustrative examples

Linear Programming: Introduction, terminology, formulation of LPP, graphical and algebraic methods of solving LPP, standard form and canonical form of linear programming, geometrical interpretation, illustrative examples..

Unit - II

Linear Programming: Simplex methods, Artificial variable techniques, solution of simultaneous equations, Dual formulations - illustrative examples.

Network analysis: Modifications and improvements on CPM/PERT

Transportation and Assignment problem: Introduction, terminology, formulation and solution of mathematical models, illustrative examples

Unit – III

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Non-Linear Programming: local and global optimum, problem formulation, Unconstrained and constrained methods of Optimization – Kuhn Tucker conditions. Lagrangian Multiplier methods, graphical method Univariable search method, Steepest Descent Methods, quadratic programming problem, Wolfs modified simplex method, illustrative examples

Unit – IV

Dynamic programming: Introduction, terminology, need and characteristics of dynamic programming, formulation, solution of LPP, applications, illustrative examples Decision theory: Introduction, types, decision trees.
Simulation: Introduction, advantages, limitations, types, applications.:
Case study on Optimization using Linear Programming, Non Linear Programming, Dynamic Programming, Cost Optimization of Civil Engineering Structure.

Unit – V

Structural Optimization: Optimum structural design of rectangular timber beam, reinforced concrete rectangular, T and L beams, concrete mix proportioning, reinforced concrete deep beams, planner trusses, Procedure of optimization for structural grid and slab.
Case study on Optimization of structural members using Linear Programming, Non Linear Programming, Dynamic Programming, Cost Optimization of Civil Engineering Structure.

Suggested Reading:

1	Rao, S.S. Engineering Optimization,. New Age Internationals, New Delhi, 1999
2	Paul, J.O Systems Analysis for Civil Engineers,. john Wiley & Sons., 1988
3	Bhavikatti, S.S.. Fundamentals of Optimum Design in Engineering, New Age International Publications, New Delhi, 2001
4	Kalavathy, S. Operation Research, Vikas Publishing house Pvt Ltd., New Delhi.1998
5	Morris,A. Foundations of Structural Optimization, J. Wiley, New York.1982
6	Arora,J. Introduction to Optimum Design, , 2nd ed., Academic Press, SanDiego., 2004
7	Wilde,D Globally Optimal Design,. J.,Wiley, New York., 1978

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PHD2011CE	STRUCTURAL DESIGN					
Pre-requisites	Structural Analysis		**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks	**CIE**			

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Understand the design concepts of various Structural elements viz. continuous beams, flat slabs, circular slabs, transverse beams using relevant codal provisions.
2	Learn to analyze and design RCC portal frame and multistoried frame for vertical and horizontal loads
3	Understand the basic concepts of plastic design of steel structures and composite Structures.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Analyse and design the continuous beams and flat slab using relevant codes.
CO-2	Comprehend the concepts of design of different types of circular slabs and transverse slab
CO-3	Attain confidence in designing and detailing of RCC portal frame and RCC multistoried frame
CO-4	Analysis and design indeterminate beams and frames using the concepts of plastic analysis.
CO-5	Analyse and design composite constructions system using relevant codes.

Unit - I

Analysis and Design of RC Beams: Introduction, Redistribution of moments in fixed beam, Positions of points of contraflexure, Conditions for moment redistribution, Final shape of redistributed bending moment diagram, Moment redistribution for a two-span continuous beam, Advantages and disadvantages of moment redistribution, Design of Fixed and Continuous beams.

Flat slabs: Introduction – Components - IS code recommendations, Design methods, Design for Flexure and Shear – Openings in Flats Slabs – Moments in Columns.

Unit - II

Circular slabs: Introduction - IS code recommendations - Types of Circular slabs - Analysis and Design of Circular Slabs.

Analysis and Design of Ribbed and Waffle Slabs.

Design of Transverse slab

Unit - III

Reinforced Concrete Portal Frames: Introduction - Analysis and Design of Rectangular Portal Frames for vertical loading – Design of hinge.

Approximate methods of Analysis: Analysis and Design of Multi Storied Frame due to vertical loads by Substitute Frame Method - Analysis and Design of Multi Storied Frame due to horizontal loads by Portal method, Cantilever method and Factor method.

Unit - IV

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Plastic Design of Steel Structures: Introduction, Plasticity in ductile materials, stress-strain for mild steel, Elasto-Plastic behavior of beam in flexure, shape factor for different cross sections, yield zones, concept of plastic hinge, Plastic Analysis and Design of Indeterminate Beams and Portal frames of Single bay two storied and two bay single storied – Minimum weight design.

Case study on the Design of Continuous beams, Flat slab, Circular slabs, RCC multistoried frame and practical aspects during its construction.

Unit - V

Composite construction: Introduction - Design principles - Shear connectors and their types - IS Codal provisions – Design of Slab-Beam type composite construction systems.

Case study on the plastic design of Indeterminate beams, Portal frames, Composite Construction Design and Practical aspects during its construction

Suggested Reading:

1	R.C.C. Design, Punmia, B.C.. 4th Ed., Laxmi Publications, New Delhi, 2015
2	Advanced reinforced concrete design, Varghese, P. C. PHI Learning, New Delhi, 2010
3	Reinforced Concrete, Vol.II, Shah,H.J. . Charotar Publications, New Delhi.
4	Reinforced Concrete Structures, Park, R. and Paulay, T., John Wiley & Sons, Inc., New York., 1995
5	Mechanics of Materials, Popov, E.P., Second edition, Prentice-Hall, Englewood Cliffs, New Jersey, 2015
6	Steel Structures, Ramamrutham, S. 6th Ed., Dhanpat Rai Publications, New Delhi, 2016

Codes books

1	IS 456, (2000), Indian Standard Code of Practice for Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi.
2	SP 22 (S&T), (1982), Explanatory Handbook on Codes for Earthquakes Engineering - IS 1893:1975 and IS 4326:1976, Bureau of Indian Standards, New Delhi.
3	IS 875(1987) (Reaffirmed 2008), Code of practice for design loads (other than earthquake) for buildings and structures(Parts 1-5), Bureau of Indian Standards, New Delhi.
4	IS 11384: Code of Practice for Composite Construction in Structural Steel and Concrete Bureau of Indian Standards, New Delhi.
5	IS 3935 : 1966 (Reaffirmed Year : 2017) Code of practice for composite construction, Technical Committee : CED 38.

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PHD2012CE	WATER RESOURCES SYSTEMS PLANNING					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks	**CIE**			

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Introduction to various steps in water resources systems approach.
2	Economic decision making in water resources.
3	Identification of decision variables for linear and dynamic programming models and solution procedures for simple problems.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Ability to understand water resources systems concepts their stages and procedures.
CO-2	Application of Cash flow diagrams and solution to Water Resources problems based on economical aspects
CO-3	Ability to formulate WRE problems by L.P. and D.P models and solving simple problems.
CO-4	Ability to decide based on economic evaluation criteria for decision making of simple water Resources systems
CO-5	Ability to formulate L.P models for water Resources systems problems

UNIT - I

Introduction: Objectives of water resources development, plan formulation, planning models and solution procedures, basic steps involved in water resources systems approach, cash flow diagrams, annuities, discounting (Net Present Value, Internal Rate of Return, and Benefit Cost Ratio), and non-discounting techniques (urgency, payback, and average rate of return), cost comparison, determination of project benefits, economic and financial analysis of projects.

UNIT - II

Water Resources Planning: Concept of Water Resources Planning, Categories of Water Use, Stages and Flow Activities, Relationship among stages, Data Collection and Processing, Estimation of Future Water Demands for Irrigation, Municipal Use, Industrial and Hydropower, Planning for Operation.

UNIT - III

Optimization techniques: Linear programming (introduction, geometrical approach and interpretation, basic concepts of simplex method), Dynamic Programming (basic concepts, general approach to recursive optimization, formulation of multistate problems), application to water resources engineering problems.

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UNIT - IV
Stochastic optimization: Introduction to stochastic linear and stochastic dynamic programming, two stage linear programming, linear programming with chance constraints. *Simulation:* Basic concepts and application to water resources engineering problems.

UNIT - V
River basin planning models: Irrigation planning model, resource inputs of irrigation, crop diversification, costs of inputs, formulation of linear programming models for single reservoir, multi reservoir cases with single and multiple objectives.

Suggested Reading:

1	Loucks, D. P., Stedinger, J. R., and Douglas, A.H. 'Water Resources Planning and Analysis', Prentice-Hall, New York. 1981
2	Kuiper Edward (1965), 'Water Resources Project Economics', Butterworths and Company Ltd., London.
3	Jain, S.K. and Singh V.P. '*Water Resources Systems Planning and Management*', Elsevier Science, B.V., Amsterdam. 2003
4	Taha, H. A. 'Operations Research an introduction', Prentice-Hall of Indial, New Delhi. 1982
5	Pramod. A. Bhave "*Water Resources Systems*" Narora Publishing House, 22, Medical Association Road, Dharyagunj, New Delhi, 2011

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PHD2013CE	GEOSPATIAL APPLICATIONS TO WATER RESOURCES ENGINEERING					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks	**CIE**			

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Discuss the various spatial and non-spatial data types, and data base management techniques
2	Develop the concepts and professional skills in utility of geospatial techniques
3	Improve the working knowledge of geospatial techniques in field problems
Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understand the geospatial technology relating to the data acquiring and processing that is associated with geographic locations
CO-2	Apply Geospatial techniques in the decision support systems useful for decision makers and community services.
CO-3	Ability to solve the problems related to the natural resource management, environment, Urban planning and Infrastructure development, etc.
CO-4	Able to generate the thematic maps using Geospatial techniques
CO-5	Apply the concept of Geospatial Techniques to the Civil Engineering problems

UNIT - I
Introduction - Basic concepts, socioeconomic challenges, fundamentals of geographical information systems (GIS), history of geographical information system, components of geographical information systems
Projections and Coordinate Systems - Map definitions, representations of point, line, polygon, common coordinate system, geographic coordinate system, map projections, transformations, map analysis.

UNIT - II
Data Acquisition and Data Management - data types, spatial, non-spatial (attribute) data, data structure and database management, data format, vector and raster data representation, object structural model filters and files data in computer, key board entry, manual digitizing, scanner, aerial photographic data, remotely sensed data, digital data, cartographic database, digital elevation data, data compression, data storage and maintenance, data quality and standards, precision, accuracy, error and data uncertainty

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UNIT - III
Data Modeling - Spatial data analysis, data retrieval query, simple analysis, recode overlay, vector data model, raster data model, digital elevation model, cost and path analysis, knowledge based system.
GIS Analysis and Functions - Organizing data for analysis, analysis function, maintenance and analysis of spatial data, buffer analysis, overlay analysis, transformations, conflation, edge matching and editing, maintenance and analysis of spatial and non- spatial data.

UNIT - IV
Applications of GIS - Environmental and natural resource management, soil and water resources, agriculture, land use planning, geology and municipal applications, urban planning and project management, GIS for decision making under uncertainty, software scenario functions, standard GIS packages, introduction to Global Positioning Systems (GPS) and its applications.

UNIT - V
Introduction to Remote Sensing - General background of remote sensing technology, objectives and limitations of remote sensing, electro-magnetic radiation, characteristics, interaction with earth surface and atmosphere, remote sensing platforms and sensors, satellite characteristics, digital image processing, IRS series and high resolution satellites, software scenario functions, remote sensing applications to watershed modeling, environmental modeling, urban planning and management.

Suggested Reading:

1	Burrough, P. A., and McDonnell R. A. *Principles of Geographical Information Systems.* Oxford University Press, New York, Pp.333. 1998
2	Choudhury S., Chakrabarti, D., and Choudhury S. *An Introduction to Geographic Information Technology.* I.K. International Publishing House (P) Ltd, New Delhi, Pp.276. 2009
3	Kang-tsung Chang. *Introduction to Geographical information Systems.* Tata McGraw-Hill Publishing Company Ltd., Third Edition, New Delhi, Pp.432. 2006
4	Lilysand T.M., and Kiefer R.W. *Remote Sensing and Image Interpretation.* John Wiley and Sons, Fourth Edition, New York, Pp.724. 2002
5	Sabins F.F. Jr. (1978). *Remote Sensing Principles and Interpretations.* W.H. Freeman and Company, San Francisco, Pp. 426. 1978
6	Tor Bernhardsen. *Geographical Information System.* Wiley India (P) Ltd., Third Edition, New Delhi, Pp. 428. 2002
7	Hoffman-Wellenhof, B, et al. *GPS Theory and Practice.* Fourth Edition, Springer Wein, New York. 1997.

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PHD2014CE	IMPACT OF CLIMATE CHANGE IN WATER RESOURCES ENGINEERING					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks	**CIE**			

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	Introduction to basic concepts of General Circulation Models and their importance.
2	Features of Indian summer monsoon rainfall (ISMR) and their characteristics
3	Downscaling principles of statistical downscaling and dynamical downscaling.

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Understanding of various components of Climate System.
CO-2	Comprehensive Understanding of Hydrological cycle, water balance, distribution of precipitation
CO-3	Ability to comprehend the monsoon wind patterns, ISMR characteristics, floods and droughts.
CO-4	Analysis and synthesis on the causes of climate change on hydrology using General Circulation Models (GCMs)
CO-5	Modeling of climate variables using various downscaling approaches and Applications of Hydrologic models

UNIT - I
Climate System- Weather and Climate- Overview of earth-atmosphere- vertical structure of atmosphere- Radiation and Temperature- Temperature variation- vertical variation in Air temperature- temperature extremes

UNIT - II
Introduction- Global water balance- cycling of water on land- simple water balance- climate variables affecting precipitation- forms and types of precipitation.

UNIT - III
Monsoon- wind patterns in India- Global wind circulation- clouds- Types of clouds-Indian summer monsoon Rainfall (ISMR) - characteristics- climate variability- Floods- droughts- drought Indicators - climate extremes.

UNIT - IV

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Causes of climate change - Modeling of climate change-General circulation models (GCMs) – IPCC scenarios - IPCC Assessment Report (AR5) - Physical Science basis.

UNIT - V
Bias correction methods -Downscaling – Types of downscaling- Dynamical downscaling- Regional Climate Models - statistical downscaling - Types of statistical downscaling - climate predictors - data reduction techniques -principal component analysis- step wise regression- Lasso- - Kernel Regression - SDSM software - Hydrology models - Introduction on Soil and water assessment tool SWAT and VIC (variable Infiltration capacity models)

Suggested Reading:

1	Bonon G B - *Ecological climatology*- Cambridge University Press Edition- II - ISBN-1107268869, 2008
2	RL Wilby, SP charles, E Zoritaa, B Timbal, P WHetton, LO Mearns - *Guide lines for use of climate science from Statistical Modeling models*. 2004
3	*Physical science basis of AR 5 report of IPCC - working group I contribution to Assessment Report*- https://ipcc.ch/report/ar5/wg1/ 2021
4	*Soil and Water Assessment Tool SWAT- user Manual Report (2005) http://swat.tamu.edu/media/1294/swatuserman.pdf* 2005
5	*VIC model Macro scale Hydrologic Model- http://www.hydro.washington.edu/Lettenmaier/Models/VIC/index.shtml*
6	Rasmus E Benestad, Inger Hanson Baver, Delinag Chen (2008) *Empirical Downscaling* World Scientific Publishing Co. Ltd. 2008.
7	Haan T. C., Statistical Methods in Hydrology, East West Publishers, 1998

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PHD2015CE	TRAFFIC ENGINEERING					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks	**CIE**			

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To understand the basic aspects of traffic Engineering.
2	To describe basic techniques for collecting and analyzing traffic data, diagnosing problems.
3	To learn the traffic control principles and regulations

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Knowledge on traffic stream characteristics and apply the statistical concepts and applications in traffic engineering.
CO-2	Able to conduct traffic studies and Identify traffic problems.
CO-3	Solve the problems related to travel time and delay.
CO-4	Knowledge on traffic capacity and level of service.
CO-5	Design a pre-timed traffic signal and determine the signal splits.

UNIT - I

Basic Aspects of Traffic Engineering Aim of traffic engineering, traffic stream components and characteristics, road user characteristics, vehicle characteristics, acceleration characteristics, measure of quality, measures of separation, relationship among traffic parameters and empirical relationships, mechanics of traffic flow, macroscopic approach, microscopic-approach and human factors approach, discrete distributions, binomial distribution, Poisson's distribution, exponential distribution, normal distribution.

UNIT - II

Traffic Studies, Measurement and Analysis; Volume studies, speed studies, travel forecasting principles and techniques, design hourly volumes and speed, origin and destination studies, presentation of data and analysis, testing of hypothesis relating to improvements.

UNIT - III

Travel Time amid Delay Studies; Various uses, travel time and delay studies, various methods, data collection and analysis, density studies and headways, gap acceptance studies, intersection delay studies, traffic flow theory, queuing theory and simulation models.

UNIT - IV

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Capacity Analysis of Traffic Facilities; Uninterrupted facilities, interrupted facilities, Level of Service, quality of service as per HCM, factors affecting LOS, computation of capacity and LOS, Measure of effectiveness, highway capacity and performance characteristics, intersection design.

Uninterrupted facilities, interrupted facilities, Level of Service, quality of service as per HCM, factors affecting LOS, computation of capacity and LOS,

UNIT - V

Traffic Control, Design and Regulation; Traffic signals, types, principles of phasing, time diagram, signalized intersection, saturation flow, saturation headway, capacity of lane group, concept of critical lane group, signal timing, phase plan, phase diagram, splitting of phase, clearance interval, pedestrian requirement, guidelines for protected movements, signal co-ordination, emerging themes, inter-modalism, access management, congestion management, environmental impact assessment.

Traffic signals, types, principles of phasing, time diagram, signalized intersection, saturation flow, saturation headway, capacity of lane group,

Suggested Reading:

1	McShane, W.R., Roess, R.P. and Prassas, E.S., Traffic Engineering. Prentice Hall, Englewood Cliffs, 1997.
2	Highway Capacity Manual, Transportation Research Board, National Research Council, Washington, D.C., 2000.
3	Daganzo, C.R, Fundamentals of Transportation and Traffic Operations, Pergamon, Elsevier Science Inc., New York, 1997.
4	Salter, R.J., Traffic Engineering: Worked Examples, Macmillan, London, 1989.
5	Pignataro, L.J., Traffic Engineering: Theory and Practice, Prentice Hall, Englewood lifts, 1973.
6	Wohl, M. and Martin, B.V, Traffic System Analysis for Engineers and Planners, McGraw Hill, New York, 1983.
7	Drew, D.R., Traffic Flow Theory, McGraw Hill, New York, 1964.

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PHD2016CE	INTELLIGENT TRANSPORTATION SYSTEMS					
Pre-requisites			L	T	P	C
			3	-	-	3
Evaluation	SEE	100 Marks	CIE			

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To understand theory of problems of traffic flow and definitions of ITS
2	To learn traffic data acquisition techniques, technologies, deployment plans and their usage
3	To learn various applications of ITS

Course Outcomes:	
On completion of this course, the student will be able to:	
CO-1	Understand of the basic definitions and historical developments of ITS.
CO-2	Ability of understand various data collection techniques using various technologies applicable to ITS.
CO-3	Functional areas of ITS and their conceptual uses.
CO-4	Gain knowledge on ITS architecture and its planning.
CO-5	Ability to understand various applications of ITS for solving traffic flow problems.

UNIT - I

Fundamentals of Intelligent Transportation System (ITS): I Introduction to ITS, Definition of ITS, Objectives of ITS, Benefits of ITS, The historical Context of ITS from both public policy and market economic perspectives, Types of ITS, Historical Background.

UNIT - II

Data Requirements for ITS: Basics of ITS, ITS data collection Techniques- Detectors, Automatic Vehicle Location (AVL), Automatic Vehicle Identification (AVI), GIS, data collection using Videos. Importance of telecommunications in the ITS system. Information Management, Traffic Management Centres (TMC). Application of sensors to Traffic management; Data fusion at traffic management centres; Sensor plan and specification requirements; Elements of Vehicle Location and Route Navigation and Guidance concepts.

UNIT - III

Data Requirements for ITS: Basics of ITS, ITS data collection Techniques- Detectors, Automatic Vehicle Location (AVL), Automatic Vehicle Identification (AVI), GIS, data collection using Videos. Importance of telecommunications in the ITS system. Information Management, Traffic Management Centres (TMC). Application of sensors to Traffic management; Data fusion at traffic management centres; Sensor plan and specification requirements; Elements of Vehicle Location and Route Navigation and Guidance concepts.

UNIT - IV

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ITS Architecture: Regional and Project ITS architecture; Concepts of operations; ITS Models and Evaluation Methods; Planning and Human Factors issues for ITS, Case studies on deployment planning and system design and operation; **ITS and safety**; and ITS security. ITS as a technology deployment program, research, development and business models/modules, ITS Planning.

Regional and Project ITS architecture; Concepts of operations; ITS Models and Evaluation Methods;

UNIT - V

ITS Applications: Traffic and Incident Management Systems**; ITS and sustainable mobility**, travel demand management, electronic toll collection, ITS and Road-pricing; Transportation network operations; commercial vehicle operations and intermodal freight; public transportation applications; ITS and regional strategic transportation planning, including regional architectures; ITS and transportation institutions, Automated highway systems-Vehicle in platoons-Integration of Automated Highway System, ITS Programs in the world- Overviews of ITS implementation in developed countries, ITS in developing countries.

requirement, guidelines for protected movements, signal co-ordination, emerging themes, inter-modalism, access management, congestion management, environmental impact assessment.

Traffic and Incident Management Systems, , electronic toll collection, ITS and Road-pricing; Transportation network operations; commercial vehicle operations and intermodal freight; public transportation applications

Suggested Reading:

1	Srinivasa Kumar R, Intelligent Transportation Systems, Universities Press, 2022.
2	Joseph S.S., Perspectives on Intelligent Transportation Systems, Springer, 2017.
3	Chowdhury MA and Sadek A., Fundamentals of Intelligent Transportation Systems Planning, Artech House, USA, 2003.
4	Kan Paul Chen and Jhon Miles, Intelligent Transportation Systems- Hand Book, Recommendations for World Road Association (PIARC), 2000
5	Paolo Pagano (Editor), Intelligent Transportation Systems from Good Practices to Standards, CRC Press, 2016.

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PHD2018CE	TRANSPORTATION MODELLING AND SIMULATION					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	60 Marks	**CIE**		40 Marks	

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Introduction to various models of simulation
2	Describe data processing techniques of simulation
3	Explain exact sampling distributions and testing

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Understand the concepts related to modelling
CO-2	Understand the classification of models
CO-3	Able to perform preliminary data processing
CO-4	Build models for transportation simulation
CO-5	Evaluate and validate the models

UNIT - I

Introduction of Modelling: Fundamentals of systemic approach. System modelling, Model structure, Variables, controllable variables, uncontrollable variables, parameters, coefficients and other statistical methods for testing of models and data.

UNIT - II

Classification of Models; Classification of models - Linear models, Non-linear models, Time-invariant models, Time-variant models, State-space models, Distributed. parameter models. System Synthesis- - Direct and Inverse Problems, Role of optimization and Examples from transportation engineering.

UNIT - III

Preliminary Data Processing: data collection, Regression Analysis-Linear multiple regression analysis; Analysis of residues, Tests of goodness of fit. Spatial Distribution- Polynomial surfaces, Spline functions, Cluster. analysis and Numerical production of contour maps. Time Series Analysis-Auto-cross. correlation analysis, Identification of trend, spectral analysis, Identification of dominant cycles, smoothening techniques, Filters and forecasting.

UNIT - IV

Model Building: Choice of Model Structure- A priori considerations, Selection based upon preliminary data analysis, Comparing model structures. Model Calibration- Role of historical data, Direct and Indirect methods of solving inverse problem-Model Validation.
Choice of Model Structure- A priori considerations, Selection based upon preliminary data analysis,

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UNIT - V
Simulation; Random variables, Basic concepts. Probability density and distribution functions, Expectation and standard deviation of discrete and continuous random variables and their functions, Covariance and correlation, commonly used theoretical Probability distributions: Uniform, Normal, Binomial, Poisson, Negative exponential. Fitting distributions to raw data: Chi-square and Kolmogrov-Smirnov's tests of the goodness of fit. Central limit theorem, various algorithms for generation of Random numbers. Queuing theory: Elements, Deterministic queues. Applications of Monte, Carlo simulation:" Basic concepts. Generation-of synthetic observations, - Statistical interpretation of the output, Evaluation of definite integrals and examples.
Random variables, Basic concepts. Probability density and distribution functions, Expectation and standard deviation of discrete and continuous random variables and their functions, Covariance and correlation, commonly used theoretical Probability distributions

Suggested Reading :

1	Bratley, P., Fox B. L., Schrage, L. E. B., Guide to Simulation, Springer-Verlag, New York 1983.
2	Leigh, J. R., Modelling and Simulation, Peter Peregrinus, London, 1983.
3	Bernard, Z., Theory of Modeling and Simulation, John- Wiley, New York, 1976.
4	Ortuzar, J. and Willumsen, L.G, Modelling Transport, Wiley, Chinchestor, 1994
5	Hansher, D. A., and Button. K. J., Handbook of Transport Modelling, Pergamon, Oxford, UK, 2000

PHD2019CE	PAVEMENT SYSTEMS ENGINEERING					
Pre-requisites			**L**	**T**	**P**	**C**
			3	-	-	3
Evaluation	**SEE**	100 Marks	**CIE**			

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	Introduction to various factors affecting pavements design
2	Analysis of stresses in flexible and rigid pavements
3	Concepts of mechanistic empirical methods of flexible and rigid pavements

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Application of basic principles in pavement design and analyze the inputs for pavement design
CO-2	Analyze stresses in flexible pavement
CO-3	Analyze stresses in rigid pavement and dowel bars
CO-4	Design of flexible pavement including filter and drainage layers
CO-5	Design of rigid pavement including dowels and tie bars

UNIT - I

Introduction to Pavement Design: Types of Pavements, Functions of pavement, types of pavements and functions of their individual Layers, Factors affecting pavement selection, Various Factors affecting pavement design, Traffic factors, Climatic factors, Classification of Axle Types and Articulated Commercial Vehicles, Standard Axle load, Legal Axle and Gross weights on single and multi-units, Methods of measurement of Axle Load and Truck Weight , Tire Pressure, Contact pressure, ESAL concepts, Fourth power rule, factors affecting VDF, Traffic Analysis: ESAL, VDF, 98the percentile axle load, lane distribution, Directional distributions, Effect of Transient & Moving loads.

UNIT - II

Stresses in Flexible Pavement: Vehicle-Pavement Interaction, Stress inducing factors in flexible pavement, Stress in Flexible Pavements: Visco-Elastic Theory and Assumptions. Layered system concepts, Stresses in one and two and Linear Elastic Multi-layered Pavement System. Boussinsq theory and assumptions. Burmister Theory and assumptions. Overview on Softwares used for stress analysis.

UNIT - III

Stresses in Rigid Pavement: Stresses in Rigid Pavements: Westergaard's theory and Assumptions, Stresses due loading, warping and Frictional Stresses, critical locations of wheel loads on a rigid pavement, Equivalent circular contact area considered for rigid pavement design, Influence of Temperature and moisture, Critical Combined stress Due to Warping and load, Critical combination of stresses in India, Friberg's Analysis of Dowel Bars and deflection of dowels at joints. Overview on software/charts for analysis of rigid pavements

UNIT - IV

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Design of Flexible pavement: Empirical Methods and their limitations, overview on Pure Mechanistic Method ,Mechanistic Design Methodology for Pavements: General Methodology, Classification of design methods; Benefits of Pavement Design Based on M–E Method, Pavement Design Concepts; Flexible Pavement Design Concepts, IRC Method as per IRC37-2018, Salient features of IRC:37-2018, Sub-surface drainage considerations and design of drainage and filter layers, Design Criteria, IRC specifications. Empirical Methods and their limitations, overview on Pure Mechanistic Method, Mechanistic Design Methodology for Pavements

UNIT - V

Design of Rigid Pavements: Types of Rigid Pavements, Pavement Joints, Introduction to Mechanistic Design Process, main factors are considered for the design of rigid pavements, Top-down cracking (TDC) and bottom-up cracking (BUC), Critical location of placement of first rear axle considered for determination of max. edge flexural stress for BUC case and max. tensile stress for TDC case. Design Criteria, IRC specifications, Dowel bar design and design of tie bars as per IRC:58-2015.

Types of Rigid Pavements, Pavement Joints, Introduction to Mechanistic Design Process, main factors are considered for the design of rigid pavements, Top-down cracking (TDC) and bottom-up cracking (BUC),

Suggested Reading:

1	Yang H. Huang, *Pavement Analysis & Design*, Prentice Hall Inc.,2008
2	Yoder J. &Witzac, *Principles of Pavement Design*, John Wiley & Sons,2018
3	Srinivasa Kumar R, *Transportation Engineering*, Universities Press, 2019
4	Srinivasa Kumar R, *Pavement Design*, Universities Press, 2012
5	IRC:58-2015, IRC:37-2018 and Other relevant IRC Codes

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PHD2020CE	STATISTICAL TECHNIQUES					
Pre-requisites			L	T	P	C
			3	-	-	3
Evaluation	SEE	100 Marks	CIE			

Course Objectives:	
The course is taught with the objectives of enabling the student to:	
1	To introduce fundamental knowledge of sampling technique.
2	To describe basic statistical techniques such as statistical distributions and correlation methods.
3	To impart knowledge on exact sampling distributions and the tests of significance.

Course Outcomes:	
On completion of this course, the student will be able to :	
CO-1	Use sampling techniques for conducting various surveys related to transportation Engineering
CO-2	Apply the statistical distributions to traffic problems
CO-3	Decide best fit and develop the regression equations for the given variables
CO-4	Apply multi-variant data distributions.
CO-5	Applications of sampling distributions in Highway and Traffic Engineering problems.

UNIT - I

Introduction: Frequency distribution; Measures of central tendency; Measures of dispersion; Standard error, Moments (about mean, arbitrary numbers and origin); Skewness; Kurtosis; Sampling-Definitions and Applications; Simple random sampling; Stratified sampling; Systematic sampling; Sample size determination; Applications in Highway and Traffic Engineering

UNIT - II

Statistical Distribution; Probability, Bayes' Theorem; Binomial, Poisson, Exponential and Normal distributions; Fitting of distributions; Mean and variance; Chi-square test of goodness-of-fit; Applications in Highway and traffic Engineering. Mathematical expectation.

UNIT - III

Regression and Correlation: Linear regression and correlation; Multiple correlation; Multiple correlation coefficient; Standard error of estimate; Analysis of variance; Curvilinear regression; Applications in Transportation Engineering.

UNIT - IV

Multi Variate Data Distributions; Types of data; Basic vectors and matrices; Simple estimate of centroid, Standard deviation Variance and covariance; Correlation matrices; Principal component analysis; Time series analysis. Estimation-Point Estimation interval Estimation, Box Plot, Maximum likelihood estimation, Biased & Non-Biased Estimation.

Types of data; Basic vectors and matrices; Simple estimate of centroid, Standard deviation Variance and covariance

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UNIT - V
Exact Sampling Distributions and Tests of Significance; Chi-square distribution; students t-distribution; Snedectors F-distribution. Large sample and small sample tests; Tests for single mean. Means of two samples, Proportions, two variances, two observed correlation coefficients, paired T-tests, Applications. Intervals for mean, variance and regression Coefficients; Applications in Highway and Traffic Engineering Problems.
Chi-square distribution; students t-distribution; Snedectors F-distribution. Large sample and small sample tests; Tests for single mean. Means of two samples, Proportions, two variances

Suggested Reading:

1	Basic Statistics - Simpson and Kafks; Oxford and IBH Calcutta,1969.
2	Fundamentals of Mathematical Statistics - Gupta, S.C. and Kapoor, K. V. Sultanchand
3	Multivariate Data Analysis – Cootey W.W &Cochens P.R; John Wiley & Sons

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PHD2021CE	EXPANSIVE SOIL ENGINEERING					
Pre-requisites			L	T	P	C
			3	-	-	3
Evaluation	SEE	100 Marks	CIE			

Course Objectives :	
The course is taught with the objectives of enabling the student to:	
1	gain comprehensive understanding about identification and characterization of expansive soils
2	learn the laboratory test procedures for evaluation of expansiveness
3	learn the swell control measures

Course Outcomes :	
On completion of this course, the student will be able to :	
CO-1	Ability to understand the Engineering behavior of Expansive Soils, their presence and identification
CO-2	Acquiring knowledge about Clay mineralogy responsible for expansive behaviour
CO-3	Competence in laboratory and field evaluation of swell potential of expansive soils
CO-4	Appraisal of problems posed by expansive soils on Foundations and competence in providing remediation
CO-5	Understanding about open excavations in expansive soils and the remedial measures to be taken.

UNIT – I

General: Necessity of study and importance. Spread of expansive soils in India and other countries. Various problems encountered for structural safety of structures, remedial measures.

UNIT – II

Clay mineralogy: study of physic- chemical properties of clay mineral including their micro structures, their identification by thermal, x-ray diffraction, Electron Microscopic methods engineering properties.

UNIT – III

Determination of swell and swell potential of soil water systems- laboratory and field estimates of heave. Study of moisture movements- swelling and shrinkage behaviors- cyclic swells- multidimensional swells. Shear strength, consolidation and earth pressure (Characteristic) properties of swelling clays.

UNIT – IV

Problems and remedial measures: Problems encountered in shallow, deep foundations in swelling sub- soil strata- design considerations- study of case histories, methods of alteration or modification of swell properties. Use of under reamed piles and their design criteria – Reliability analysis of foundations on expansive soils- settlement characteristics- hysteresis of deformations

of swelling soils- Inter swelling. Safety factors.

UNIT – V
Open and underground excavations in swelling and shrinkage soils- construction techniques to be adopted. Remedial measures- stabilization methods use of chemical grouts etc.

Suggested Reading :

1	J. D. Nelson et. al., Foundation Engineering for Expansive Soils, , John Wiley & Sons Inc.2015
2	Jphn S. McCartney and L.R. Hoyos (Edts.), Recent Advancements on Expansive Soils, , ISSMGE Conference Proceedings, Springer Publications., 2019
3	F.H.Chen, Foundations on Expansive Soils, , Springer Publications., 2012
4	J.D.Nelson & D.J.Miller, Expansive Soils: Problems and Practice in Foundation and Pavement Engineering, , John Wiley & Sons Inc. 1997

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