CIVIL ENGINEERING DEPARTMENT
SoS, ENGINEERING & TECHNOLOGY
GURU GHASIDAS VISHWAVIDYALAYA, BILASPUR (C.G.), 495009

EVALUATION SCHEME OF Pre-Ph. D COURSE WORK
EFFECTIVE FROM SESSION 2023-24

SN.	Name of the Subject	Subject Code	Periods / Week L–T–P	ESE Duration	ESE MARKS		Credits
					Max.	Min.	
1	Research Methodology in Engineering	ETPHDT00	3–1–0	3 Hrs.	100	50	4
2	Elective-I	CEPHDTXX	3–1–0	3 Hrs.	100	50	4
3	Elective–II	CEPHDTYY	3–1–0	3 Hrs	100	50	4
4.	Seminar	CEPHDS01	-	-	Qualified/Not Qualified		-
Total			**9–3–0**	-	**300**	**150**	**12**

L: Lecture, **T**: Theory, **P**: Practical,

Max.: Maximum Marks in ESE; **Min.**: Minimum Pass Marks in each subject as 50%;

XX and **YY** in the subject code respectively denotes the number value of papers opted by the Scholar from the List of Elective-I & II.

Note:

[1] Duration of the semester will be 6 months.

[2] Candidate has to score minimum 55% of the aggregate marks in the course work in order to be eligible to continue in the program leading to the completion of Ph.D.

[3] The student may opt any two papers as Elective-I and Elective-II from the list of Elective papers

09/02/24 09/02/24

Civil Engineering Department

Programme Outcomes (POs)

PO1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences
PO3	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	**Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions
PO5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Programme Specific Outcomes (PSOs)

PSO1	Graduates will be able to solve the problems related to structural engineering, geotechnical engineering, construction management, transportation engineering, irrigation engineering and environmental engineering by applying the knowledge of mathematical and physical sciences.
PSO2	Graduates will be able handle and apply the technology, modern engineering tools and equipment, software, remote sensing and GIS techniques to solve the problems in the field of civil engineering.
PSO3	Graduates are capable of working in groups by undergoing summer internship in the industry and in laboratories and carrying out minor and major project works.

SYLLABUS OF PRE-Ph.D. COURSE WORK

Course Code	Subject	Credits
ETPHDT00	RESEARCH METHODOLOGY IN ENGINEERING	3-1-0: 4

Course Learning Objectives:

The objective of this Course is

1. To demonstrate the ability to choose an appropriate methodology to research aims and objectives
2. To assess the types of data and techniques for collecting various types of data collection of particular research
3. To develop skills in qualitative and quantitative data analysis and presentation
4. To Develop skills and knowledge related to conducting research and effectively communicating the findings through written reports.
5. To develop a comprehensive understanding of ethics, research integrity, scientific misconduct, publication ethics, and intellectual property rights

Course Outcomes:

At the end of the course, the students shall be able

1. To demonstrate the ability to select an appropriate research methodology that aligns with the aims and objectives of a study.
2. To assess the types of data and techniques required for collecting various forms of data in specific research contexts.
3. To develop skills in qualitative and quantitative data analysis and presentation.
4. To develop skills and knowledge related to conducting research and effectively communicating the findings through written reports.
5. To integrate a comprehensive understanding of ethics, research integrity, scientific misconduct, publication ethics, and intellectual property rights.

Module 1: Introduction and Design of research: Meaning, objectives and significance of research, types and parameters of research, research process, identification and definition of the research problem, definition of construct and variables, pure and applied research design, exploratory and descriptive design methodology, qualitative vs. quantitative research methodology, field studies, field experiments vs. laboratory experiments, research design in social and physical sciences.

Module 2: Data and Methods of Data Collection: Survey, assessment and analysis: data collection, primary and secondary sources of data, Collection of primary data through questionnaire and schedules. Collection of secondary data, processing and analysis of data. Sample survey, simple random sampling, stratified random sampling, systematic sampling, cluster sampling, area sampling and multistage sampling. Pilot survey, scaling techniques, validity & reliability.

Module 3: Data Analysis and Interpretation: Procedure for testing of hypothesis, the null hypothesis, determining levels of significance, Testing of hypothesis, type i and ii errors, grouped data distribution, measures of central tendency, measures of spread/dispersion, normal distribution, analysis of variance: one way, two-way, chi square test, z test and its application, student's 'T' distribution, Univariate and Bivariate analysis, regression analysis.

Module 4: Report writing and presentation: Review of literature: historical survey and its necessity, layout of research plan, meaning, techniques and precautions of interpretation, types of report: technical report, popular report, report writing – layout of research report, mechanics of writing a research report. Writing bibliography and references.

Module 5: Research ethics, IPR and scholarly publishing: Ethics: Definition, moral philosophy, nature of moral judgments and reactions, Ethics with respect to science and research, Intellectual honesty and research integrity, Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). Redundant publication duplicates and overlapping publications, salami slicing, Selective reporting and misrepresentation of data, Publication ethics: definition, introduction and importance, Publication's misconduct: definition, concept, problems that lead to unethical behavior and vice versa, Patents, Designs, Trade and Copyright. Process of Patenting and Development.

Reference Books:

1. Research in education, By J W Best and J V Kahn, Pearson/ Allyn and Bacon.
2. Research Methodology – Methods and Techniques, C K Kothari, New Age International.
3. Design and Analysis of Experiments, D C Montgomery, Wiley.
4. Applied Statistics & Probability for Engineers, D C Montgomery & G C Runger, Wiley.
5. Management Research Methodology: Integration of Principles, Methods and Techniques, K N Krishnaswamy, A I Sivakumar and M Mathiranjan, Pearson Education.
6. Research Methodology- Methods & Tec., CR Kothri CR (1990), Vishva Prakashan, NDL.
7. Research Methodology & Statistical Techniques, S Gupta (1999) Deep & Deep Publications, New Delhi.
8. Research Methodology for Biological Sciences, N Gurumani (2007), MJP Publishers, Chennai.
9. Research Design: Qualitative, Quantitative &Mixed Method Approaches, John W. Creswell (2009), Sage Publication, USA

Course Outcomes and their mapping with Programme Outcomes: RESEARCH METHODOLOGY IN ENGINEERING (ETPHDT00)

CO	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	3	3				3				1	2	2
CO2	3	3	1	2	3			3					2	3	2
CO3	3	3	1	2	3			3		3			2	3	2
CO4	3	3	1	2	3			3		3			2	3	2
CO5	2	2	2	1	1			3	3				2	2	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

LIST OF ELECTIVES

S.N.	SUBJECT CODE	TITLE OF THE SUBJECT
		ELECTIVE-I & II
1	CEPHDT01	OPTIMIZATION TECHNIQUES
2	CEPHDT02	FINITE ELEMENT METHOD
3	CEPHDT03	STRUCTURAL DYNAMICS
4	CEPHDT04	ADVANCED CONCRETE TECHNOLOGY
5	CEPHDT05	CONCRETE FRACTURE MECHANICS
6	CEPHDT06	SPECIAL CONCRETES
7	CEPHDT07	MULTIMODAL TRANSPORTATION SYSTEM
8	CEPHDT08	DESIGN AND CONSTRUCTION OF RURAL ROADS
9	CEPHDT09	ADVANCED PAVEMENT MATERIALS
10	CEPHDT10	TRANSPORTATION GEOTECHNICS
11	CEPHDT11	GEO-ENVIRONMENTAL ENGINEERING
12	CEPHDT12	RIVER HYDRAULICS
13	CEPHDT13	IRRIGATION TECHNOLOGY AND IRRIGATION WATER MANAGEMENT
14	CEPHDT14	OPEN CHANNEL HYDRAULICS
15	CEPHDT15	EARTHQUAKE ENGINEERING
16	CEPHDT16	TRANSPORTATION SYSTEM DESIGN AND MANAGEMENT
17	CEPHDT17	ADVANCE SOIL MECHANICS
18	CEPHDT18	ENVIRONMENTAL GEOTECHNICS
19	CEPHDT19	PRINCIPLES OF GROUND MODIFICATION
20	CEPHDT20	SOIL REMEDIATION

Course Code	Subject	Credits
CEPHDT01	OPTIMIZATION TECHNIQUES	3-1-0: 4

Course Objectives:

1. To develop the knowledge about formulation of structural optimization problem.
2. To define linear programming.
3. To understand application of nonlinear programming.
4. To understand the optimal control and optimality criteria methods.
5. To develop the knowledge of modern methods of optimization.

Unit-I: Formulation of structural optimization Problem: Design Vector, Design Constraints, Constraint Surface, Objective Function, Objective Function Surfaces, Classification of Optimization Problems, Single-Variable Optimization, Multivariable Optimization with No Constraints, with Equality Constraints and with Inequality Constraints

Unit-II: Linear Programming: Simplex Method, Application to structural optimization.

Unit-III: Nonlinear Programming: One-Dimensional Minimization Methods, Unconstrained Optimization Techniques, Constrained Optimization Techniques.

Unit-IV: Optimal Control and Optimality Criteria Methods: Calculus of Variations, Optimal Control Theory, Optimality Criteria Methods, optimization of sections, steel and concrete structures, framed structures, bridge structures.

Unit-V: Modern Methods of Optimization: Genetic Algorithms, Simulated Annealing, Particle Swarm Optimization, Ant Colony Optimization, Optimization of Fuzzy Systems.

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

References

1. J.S. Arora, introduction | to Optimum Design, Elsevier, 2nd Edition, 2004.
2. K. Deb, Optimization for Engineering. Design: Algorithms & Examples, Prentice Hall India, 2006
3. S.S. Rao, Engineering Optimization: Theory & Practice, New Age International (P) Ltd, 3rd Edition,1996, Reprint: June, 2008
4. K. Deb, Multi-Objective Optimization Using Evolutionary Algorithms, John Wiley, 2003

Course Outcomes:

At the end of this course the students will be able to

1. Design formulation of structural optimization problem.
2. Apply the linear programming methods.

3. Apply the nonlinear programming methods.
4. Implement the optimal control and optimality criteria methods.
5. Analysis the modern methods of optimization.

Course Outcomes and their mapping with Programme Outcomes: OPTIMIZATION TECHNIQUES (CEPHDT01)

CO	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1										3	2	1
CO2	3	2	2	1									3	2	1
CO3	3	2	2	1	1								3	2	1
CO4	3	2	1	1	1								3	2	1
CO5	3	2	2	1	2								3	2	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT02	FINITE ELEMENT METHODS	3-1-0: 4

Course objective: The course is aimed

1. To introduce the Finite Element Method for structural analysis.
2. To practice the Finite Element Program/ Software
3. To study the solutions for continuum problems using finite element analysis.

Course Content

Differential equilibrium equations - strain displacement relation - linear constitutive relation - special cases - Principle of stationary potential energy - application to finite element methods. Some numerical techniques in finite element analysis- calculus of variation, the Rayleigh-Ritz and Galerkin methods.

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

Two dimensional iso-parametric elements - Four node quadrilateral elements - triangular elements - Computation of stiffness matrix for iso-parametric elements - numerical integration (Gauss quadrature) – Mess refinement - Convergence criteria for iso-parametric elements.

Assemblage of elements – Direct stiffness method - Special characteristics of stiffness matrix - Boundary condition and reaction - Gauss elimination and LDLT decomposition - Basic steps in finite element analysis.

Analysis of framed Structures - 2D truss element - 2D beam element. Analysis of plate bending: Basic theory of plate bending - displacement functions - plate bending Elements. Plane stress and plane strain analysis: Triangular elements - rectangular elements, Eigen value and time dependent problems - discussion about pre-processors, postprocessors and finite element packages.

Reference Books

1. Krishnamoorthy, C. S, Finite Element Analysis - Theory and Programming, McGraw - Hill, 1995.
2. R. T. Chandrupatla and A. D. Belegundu, Introduction to Finite Elements in Engineering, PHI Learning Pvt Ltd, New Delhi, 1997.
3. S. S. Bhavikatti, Finite Element Analysis, New Age Publishers, 2007.
4. David Hutton, Fundamentals of Finite Element Analysis, Tata McGraw Hill Publishing Company Limited, New Delhi, 2005.
5. Chennakesava R. Alavala Finite Element Methods: Basic Concepts and Applications, Prentice Hall Inc., 2010.
6. J. N. Reddy, An introduction to the Finite Element Method, McGraw-Hill, New York, 2006
7. R. D. Cook, D. S. Malkus and M. E. Plesha, Concepts and Applications of Finite Element Analysis, Fourth Edition, Wiley, India, 2003.

8. K. J. Bathe, Finite Element Procedures in Engineering Analysis, Prentice-Hall, Englewood Cliffs, NJ, 1996
9. Fish and Belytschko, A First Course in Finite Elements, John Wiley, 2007.

Course outcomes: At the end of the course, students will be able to

1 Use Finite Element Method for structural analysis.

2 Execute the Finite Element Program/ Software

3 Solve continuum problems using finite element analysis.

Course Outcomes and their mapping with Programme Outcomes: FINITE ELEMENT METHODS (CEPHDT02)

CO	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1		2							2	3		2
CO2	2	2	2		3							3	3		1
CO3	3	1	1		2							1	3		3

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT03	STRUCTURAL DYNAMICS	3-1-0: 4

Course Objectives: The course is aimed

1 To Introduction the dynamic analysis of SDOF for blast and earthquake loads

2 To evaluate the structural property matrices, natural vibration and solution of eigen value problems.

3 To carryout deterministic analysis of earthquake response - lumped SDOF system, evaluate beam flexure including shear deformation and ductile design and detailing of buildings. .

Course Content

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

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

Unit-V: Differential equation of motion - Beam flexure including shear deformation.

Basics of Earthquake Engineering Indian standards, Response Spectrum Concepts, Different analysis methods, Ductile detailing of buildings, Examples

Reference Books

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

Course Outcomes:

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

1 To carry out the dynamic analysis of SDOF for blast and earthquake loads

2 To determine the structural property matrices and evaluate natural vibration and solution of eigen value problems.

3 To perform deterministic analysis of earthquake response - lumped SDOF system, and evaluate beam flexure including shear deformation and ductile design and detailing of buildings. .

Course Outcomes and their mapping with Programme Outcomes: STRUCTURAL DYNAMICS (CEPHDT03)

CO	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	2	1	1					1	3	2	1
CO2	3	3	3	1	2	1	1					1	3	2	1
CO3	3	3	3	1	2	1	1					1	3	2	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT04	ADVANCED CONCRETE TECHNOLOGY	3-1-0: 4

Course Content

Unit I: Structure of hydrated cement paste, Micro structure, air & void ratio, mechanical strength of cement gel, water held in hydrated paste and heat of hydration, pore structure and transport process. Transition zone in concrete, Concrete: segregation, bleeding, Effect of water quality.

Unit II: Concrete quality control, Green Concrete, Concrete properties, Factors affecting Workability, Performance of concrete in hardened state, Strength-Porosity relationship, maturity concept for curing duration, Behaviour of Concrete under different stress Conditions. Mix Design for High Strength Concrete.

Unit III: Concrete deterioration, Strength properties, Elastic Modulus, Permeability, shrinkage, creep, plastic & thermal cracking, corrosion, carbonation, freezing-thawing. Alkali-aggregate reactivity, Durability, Self-healing concrete.

Unit IV: Fibre reinforced concrete: Types & Mechanism, Aspect ratio, Fibres: Types, Volume & orientation, balling effect, properties & applications of fibre reinforced concrete. Ready mix concrete: Concept, plants, use of admixtures in RMC, quality control aspects.

Unit V: Recycled aggregates and recycled aggregate concrete properties. Concrete from Industrial wastes: Blast furnace slag cement concrete; Fly-ash concrete and. Silica fume concrete

References

1. A.M. Neville, J.J. Brooks, Concrete Technology, Low Priced Edition, Pearson Education, 2015.
2. M.S. Shetty, Concrete Technology- Theory & Practice, S. Chand & Comp., 2015
3. N. Krishna Raju, Design of Concrete Mixes, CBS Publishers & distributers
4. Irving Kett, Engineered Concrete: Mix Design & Test Methods, CRC press, Taylor & Francis group, 2010
5. P. Mehta and P.J.M. Monteiro, Concrete: Microstructure, Properties and Materials, Mc Graw Hill, 2001
6. Kumar Mehta. P, Paul J.N. Monterio: Microstructure, Properties & Materials, Tata McGraw Hill
7. Chakradhara Rao, M, Bhattacharyya SK and Barai SV. A Systematic approach of characterisation and behaviour of recycled aggregate concrete. Springer Nature, 2019.
8. Jongjin Li, Advanced Concrete Technology, John Wiley & Sons, Inc, 201.

Course outcomes:

At the end of the course, students will be able to:

1. To understand concrete technology, admixtures, non-destructive testing, semi destructive testing, special concrete.
2. To be familiar with structure of hydrated cement paste, types of cement, cement production quality control.
3. To learn transition zone in concrete, measurement of workability, properties of concrete,

rheological behaviour of concrete, economic concrete mix design.

4. To be exposed to strength-porosity relationship, failure modes in concrete, elastic behaviour in concrete, ageing properties and long-term behavior
5. To better understand the causes of concrete deterioration, permeability of concrete, durability of concrete, alkali aggregation reaction.

Course Outcomes and their mapping with Programme Outcomes: ADVANCED CONCRETE TECHNOLOGY (CEPHDT04)

CO	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	3	2	1	1	1	1	-	-	-	3	3	2
CO2	3	2	2	3	1	1	1	1	-	-	-	-	3	2	1
CO3	3	3	2	3	2	2	1	1	1	-	-	-	2	3	2
CO4	3	3	2	2	2	2	1	1	1	-	-	-	3	3	2
CO5	3	3	2	2	2	2	1	1	1	-	-	-	3	2	2

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT05	CONCRETE FRACTURE MECHANICS	3-1-0: 4

Course Objectives: The course is aimed

1 To study the Identification and the classification of cracking of concrete structures based on fracture mechanics.

2 To study the Implementation of stress intensity factor for notched members

3 To introduce the application of fracture mechanics models to high strength concrete and FRC structures.

Course Content

Unit I: Review of theory of elasticity: Body and surface forces, strain and strain tensors, equilibrium equation, compatibility condition, plane stress, plane strain, Airy stress function, polar coordinate system.

Unit II: Basic modes of fracture, an atomic view of fracture, stress concentration effect of flaws, Griffith theory of brittle fracture, Irwin's modifications for elastic-plastic materials, dimensional analysis of fracture mechanics.

Unit III: Theories of linear elastic fracture mechanics, stress intensity factors, Fracture toughness, Energy release rate, Critical Energy release rate, Crack mouth opening displacement, R-Curve and J integral.

Unit IV: Tensile Behavior of Concrete, Strain localization effect, Fracture process zone, nonlinear behavior of concrete, softening function of concrete, Fracture energy.

Unit V: Definition and brief introduction of fracture parameters of various nonlinear concrete fracture models: cohesive crack model (CCM) or fictitious crack model (FCM), crack band model (CBM), two parameter fracture model (TPFM), size effect model (SEM), effective crack model (ECM), double-K fracture model (DKFM) and double-G fracture model (DGFM).

Reference Books

1. David Broek, Elementary Engineering Fracture Mechanics, Sijthoff and Noordhaff, Alphen Aan Den Rijn, The Netherlands, 2001.
2. Ed L. Elfgren and S.P. Shah, Analysis of Concrete Structure by Fracture Mechanics, , Proc of Rilem Workshop, Chapman and Hall, London, 2001.
3. Prashant Kumar, Elements of Fracture Mechanics, Tata McGraw Hill, New
4. Hertzberg, Deformation and Fracture Mechanics of Engineering Materials, Wiley, India, 5th Edition, 2014.
5. Anderson: Fracture Mechanics: Fundamentals and Applications, CRC press, 3rd Ed., 2005
6. Kumar S and Barai SV (2011) Concrete Fracture Models and Applications. ISBN 9783642167638 (Hard Cover), Springer.

7. Bazant ZP, Planas J (1998) Fracture and size effect in concrete and other quasibrittle materials, Florida, CRC Press.
8. Surendra P. Shah, Stuart E. Swartz, Chengsheng Ouyang. Fracture Mechanics of Concrete: Applications of Fracture Mechanics to Concrete, Rock and Other Quasi-Brittle Materials. John Wiley & Sons.

Course outcomes: At the end of the course, students will be able to

1 Identify and classify cracking of concrete structures based on fracture mechanics.

2 Implement stress intensity factor for notched members

3 Apply fracture mechanics models to high strength concrete and FRC structures.

4 Compute J-integral for various sections understanding the concepts of LEFM.

Course Outcomes and their mapping with Programme Outcomes: CONCRETE FRACTURE MECHANICS (CEPHDT05)

CO	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	2	2	1	1	1	-	-	-	-	3	2	2
CO2	3	3	3	2	2	-	-	-	-	-	-	-	2	2	1
CO3	3	3	3	3	2	1	-	-	-	-	-	-	3	2	2
CO4	3	2	2	2	1	1	-	-	-	-	-	-	2	2	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT06	SPECIAL CONCRETES	3-1-0: 4

Course Objective:

1. To impart the knowledge of various method for manufacturing and the mechanical properties of High Performance Concrete.
2. To make aware with durability properties of High Performance Concrete.
3. To familiarize the mix design of High Performance Concrete using different methods.
4. Explain the performance of High Performance Concrete under various conditions in which it is used.
5. To impart the knowledge of method of manufacturing, properties, mix design and behavior/performance under various working condition of Self-Compacting Concrete.

Course Content

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

Unit-II: Durability of HPC - Acid Attack – Permeability – Scaling resistance – Chloride penetration – Resistance to sea water – sulphate attack – Alkali-aggregate reaction – Fire resistance

Unit-III: Mix design methods of HPC.

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

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

Reference Books

1. P. C. Aitcin, High Performance Concrete, E & FN SPON, 1998.
2. E. G. Nawy, Fundamentals of High-Performance Concrete, John Wiley and Sons., 2nd Edition, 2000.
3. High Performance Concrete Structural Designers Guide published by FHWA, USA, 2005.
4. Geert De Schutter, Peter J. M. Bartos, Peter Domone, John Gibbs, Self-Compacting Concrete, Whittles Publishing, 2008.
5. Shetty M. S., Concrete Technology, S. Chand and Company Ltd. Delhi, 2003.

Course outcomes:

At the end of the course, students will be able to:

1. Apply various method for manufacturing of High Performance Concrete and analyze the mechanical properties of High Performance Concrete.
2. Familiar with durability properties of High Performance Concrete.
3. Mix design High Performance Concrete using different methods.
4. Understand the performance of High Performance Concrete under various conditions in which it is used.
5. Understand method of manufacturing, properties, mix design and behavior/performance under various working condition of Self-Compacting Concrete.

Course Outcomes and their mapping with Programme Outcomes: SPECIAL CONCRETES (CEPHDT06)

CO	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2										2	3	3	
CO2	3	2		2	2							2	3	3	
CO3	3		3									2	3	3	
CO4	3			2								2	3	3	
CO5	3	2	3	2								2	3	3	

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT07	MULTIMODAL TRANSPORTATION SYSTEM	3-1-0: 4

Course Objectives:

1. To develop the basic knowledge about role of Artificial Intelligence in optimization of Transportation system.
2. To define role of GIS in Transportation system.
3. To understand Application of Image Processing in Urban Transportation Systems.
4. To understand the planning of Non-Motorized Transportation (NMT) Systems.
5. To develop the knowledge of Urban Pedestrian Safety.

Course Content

Unit-I: Artificial Intelligence based Transportation System: Urbanization and transportation, Travel demand impacts of urbanization, Modal share, Motorization, Introduction to AI, components of transportation system that require optimization, role of AI in optimization of these components, congestion control, accident avoidance, active alert system design

Unit-II: Geographic information system-based transportation system: Introduction to GIS, sources of GIS, role of GIS in transportation, assessment of roads, and railways using GIS, case study of smart city GIS

Unit-III: Introduction of signal processing: Overview of Signal processing, Fundamentals of Image processing; Fundamental signals (1-D, 2-D and 3-D); Classification of systems; Characteristics of LTI/LSI systems. Application of Image Processing in Urban Transportation Systems

Unit-IV: Non-Motorized Transportation (NMT) Systems: Components of NMT, categories of NMT, planning smart cities to facilitate NMT, effect of NMT planning on healthcare

Unit-V: Pedestrian Safety: Urban Pedestrian Safety- Skyways, Intersection subways, halt stations, crossing measures, flexibility in accessibility, design of collision control systems for intersections to improve pedestrian safety

Reference Books

1. O. Flaherty C.A., "Traffic Engineering and Transport Planning", Butterworth Heinemann, Elsevier, Burlington, MA 2006.
2. M.A. Chowdhury and A. Sadek, Fundamentals of Intelligent Transportation Systems Planning, Artech House, 2010.
3. Gonzalez R. C. and Woods R. C., "Digital Image Processing", 2nd Ed., Pearson Education, 2007.
4. Jain A. K, "Fundamentals of Digital Image Processing", Prentice Hall, 2007.

Course Outcomes:

At the end of this course the students will be able to

1. Design the artificial intelligence-based transportation system.
2. Analysis the geographic information system-based transportation system.
3. Implement the application of image processing in urban transportation systems.
4. Design and planning of non-motorized transportation Systems.
5. Analysis the urban pedestrian safety.

Course Outcomes and their mapping with Programme Outcomes: MULTIMODAL TRANSPORTATION SYSTEM (CEPHDT07)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2	1	1								3	2	1
CO2	3	2		1									3	3	1
CO3	3	2	1	1	1								3	2	1
CO4	3	2	2	1									2	1	1
CO5	3	2											3	1	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT08	DESIGN AND CONSTRUCTION OF RURAL ROADS	3-1-0: 4

Course Objectives:

1. To develop the basic knowledge of rural roads.
2. To understand geometric design and road materials.
3. To understand construction of rural roads.
4. To understand use of recycle or waste material in rural roads.
5. To develop the knowledge of quality control and maintenance of rural roads.

Course Content

Unit-I: Introduction about Rural Roads and Planning and Alignment: Importance of Rural roads, Classification of rural roads, Terrain classification, Socio-economic impact of rural roads. Data base for master plan, Concept of network planning, Rural Roads plan, Road alignment, Governing factors for route selection, Factors controlling alignment, Special considerations while aligning hill roads, Surveys, Detailed project report, Environmental issues.

Unit-II: Geometric Design and Road Materials: Introduction, Design speed, Basic principles of geometric design, Elements, Horizontal and vertical alignment, Alignment compatibility, Lateral and vertical clearances. General, Soil and material surveys, Soil as road construction material, Aggregates for pavement courses, Materials for bituminous construction, Materials for semi-rigid and rigid pavement, Materials for special pavements Climatic suitability of concrete materials

Unit-III: Pavement Design, Specifications and Construction of Rural Roads: Introduction, Design parameters, Pavement components, Design of flexible pavement, Design of semi-rigid pavement, Design of rigid pavement, Drainage and Shoulders. General, Selection of construction materials and methodology, Earthwork, Sub-base, Base course, Bituminous constructions, Semi-rigid pavement construction, Concrete pavements, Equipment required for different operations.

Unit-IV: Use of Waste Materials in Rural Road Construction: Introduction, Significance of green roads, fly ash for road construction, Iron & steel and copper slags, Recycled concrete aggregate, other waste materials.

Unit-V: Quality Control Tests & Maintenance: General, Pre-requisite, Specifications and codes of practice, Quality control tests during pavement construction. Distresses/defects in pavements, Types of maintenance, Classification of maintenance activities, Maintenance norms of maintenance cost.

References:

1. Rural Roads Manual, IRC: SP 20-2002
2. Guidelines for the design of flexible pavements for low volume rural roads, IRC: SP: 72-2007
3. Geometric design standards for Rural (Non-Urban) Highways, IRC: 73-1980.
4. Guidelines for quality systems for road construction, IRC: SP: 57-2000.

Course Outcomes:

At the end of this course the students will be able to

1. Estimate the planning and alignment of rural roads.
2. Apply the knowledge of the geometric design and road materials.
3. Pavement design, specification and construction of rural roads.
4. Plan use of recycle or waste material in rural roads.
5. Analysis quality control and maintenance of rural roads.

Course Outcomes and their mapping with Programme Outcomes: DESIGN AND CONSTRUCTION OF RURAL ROADS (CEPHDT08)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1										2	2	1
CO2	3	2	2	1									3	2	1
CO3	3	2	2	1	1								3	2	1
CO4	3	2											2	2	1
CO5	3	2											3	2	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT09	ADVANCED PAVEMENT MATERIALS	3-1-0: 4

Course Learning Objective:

1. To develop knowledge of different type of materials used in different layers of pavement.
2. To define natural materials used in pavement.
3. To understand the pavement plastics and geosynthetic materials.

To understand recycled waste materials in pavement.

Course Content

Unit-I: Aggregate: Nature and properties – aggregate requirements – types and processing – aggregates for pavement base – aggregate for bituminous mixture – aggregate for Portland Cement Concrete – lightweight aggregate – tests on aggregate – specification.

Unit-II: Bituminous Materials: conventional and modified binders – production – types and grade – physical and chemical properties and uses – types of asphalt pavement construction – principles of bituminous pavement construction – tests on bituminous materials. Bituminous Mix design – modified mixtures – temperature susceptibility and performance.

Unit-III: Cement /concrete-based materials: Cement – properties – PCC mix design and properties – modified PCC – Mix Design – Behaviour – Performance – Tests on Cement and Concrete mixes. High Performance Concrete – low shrinkage – increased strength. Composites,

Unit-IV: Plastics and Geosynthetics: Plastics and polymerization process – properties – durability and chemical composition – Reinforced Polymer Composites – Geosynthetics – Dry Powdered Polymers – Enzymes.

Unit-V: Reclaimed / Recycled Waste Products: Reclaimed Materials – waste products in highway engineering and its applications – effect of waste products on materials, structure and properties – self healing and smart materials – locally available materials.

References:

1. P. T. Sherwood, Alternative Materials in Road Construction, Thomas Telford Publication, London,1997.
2. RRL, DSIR, Soil Mechanics for Road Engineers, HMSO, London, 1995
3. Koerner, R. M. Designing with Geosynthetics, Prentice Hall, Englewood Cliffs, New Jersey, U.S.A.
4. Shan Somayaji, Civil Engineering Materials, second edition, Prentice Hall Inc., 2001.

Course Outcomes:

At the end of this course the students will be able to

1. Estimate the basic characteristics of pavement materials.
2. Analysis the natural and basic materials used in pavement.
3. Implement the plastics and geosynthetic materials in pavement.
4. Analysis the recycled waste materials.

Course Outcomes and their mapping with Programme Outcomes: ADVANCED PAVEMENT MATERIALS (CEPHDT09)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2											3	2	1
CO2	3	2		1									3	2	1
CO3	3	2				1	1						3	2	1
CO4	3	2	1										2	1	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT10	TRANSPORTATION GEOTECHNICS	3-1-0: 4

Course Learning Objective:

1. To develop knowledge of different type of materials and technics for subgrade materials.
2. To define subgrade soil and ground improvement technics.
3. To understand the pavement design.
4. To understand subgrade improvement and strengthening.

Course Content

Subgrade Soil: Classification, desirable properties, determination of soil strength, Swelling and Shrinkage characteristics, Road aggregates: classification, properties of aggregates, design of aggregate gradation; Cyclic response of soils, resilient and plastic behaviour of soils and aggregates, Effects of traffic loads, natural forces, and material quality. Current design practices; Principles and theoretical concepts of rigid and flexible pavements for highways and airfields;

Ground Improvement technics: Need for ground improvement, column methods: sand, stone and lime columns, soil nailing: root piles, soil reinforcement, functions of geosynthetics in soil, soil grouting: electro-chemical stabilization

Pavement evaluation and performance; Utilization of recycled materials for sustainable pavements; Life cycle cost analysis. Highway embankments; Design and construction of embankments; Stage construction; Introduction to reinforced earth design and construction.

Subgrade Improvement and Strengthening

Objectives of Soil Stabilization, Characteristics of Stabilized Soils, Thick Granular Layers, Geotextiles and Geogrids, Admixture Stabilization, Soil Encapsulation, Light-weight Fill, Deep Foundations & Other Foundation Improvement Method

References:

1. Rajib B. Mallick, Tahar El-Korchi, Pavement Engineering: Principles and Practice. CRC Press, 2017.
2. Chakraborty P. and Das, A. Principles of Transportation Engg., PHI Publication, 1st Edition 2005
3. Papagiannakis A. T. and Masad, E. A. Pavement Design and Materials. Willey,2017

Course Outcomes:

At the end of this course the students will be able to

1. Estimate the basic characteristics of subgrade materials.
2. Analysis the subgrade soil characteristics.
3. Implement the ground improvement technics.
4. Design the different type of pavement.
5. Analysis the Subgrade Improvement and Strengthening.

Course Outcomes and their mapping with Programme Outcomes: TRANSPORTATION GEOTECHNICS (CEPHDT10)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1										3	2	1
CO2	3	2											3	2	1
CO3	3	2	1	1									3	2	1
CO4	1	2	3	1									2	1	1
CO5	3	2											3	1	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT11	GEO-ENVIRONMENTAL ENGINEERING	3-1-0: 4

Course Learning Objective:

1. To develop knowledge role of soil in geo-environmental application in various field.
2. To define soil mineralogy and soil-water interaction.
3. To understand design of waste containment facilities.
4. To understand remediation methods for soil and groundwater.
5. To define advanced soil characterization.

Course Content

Unit-I: Fundamentals of Geoenviromental Engineering: Scope of geoenvironmental engineering - multiphase behaviour of soil – role of soil in geoenvironmental applications – importance of soil physics, soil chemistry, hydrogeology, biological process – sources and type of ground contamination – impact of ground contamination on geoenvironment - case histories on geoenvironmental problems.

Unit-II: Soil-Water-Contaminant Interaction: Soil mineralogy characterization and its significance in determining soil behaviour – soil-water interaction and concepts of double layer –forces of interaction between soil particles. Concepts of unsaturated soil–importance of unsaturated soil in geoenvironmental problems - measurement of soil suction - water retention curves - water flow in saturated and unsaturated zone. Soil-water-contaminant interactions and its implications – Factors effecting retention and transport of contaminants.

Unit-III: Waste Containment System: Evolution of waste containment facilities and disposal practices – Site selection based on environmental impact assessment –different role of soil in waste containment – different components of waste containment system and its stability issues – property evaluation for checking soil suitability for waste containment – design of waste containment facilities.

Unit-IV: Contaminant Site Remediation: Site characterization – risk assessment of contaminated site - remediation methods for soil and groundwater – selection and planning of remediation methods – some examples of in-situ remediation.

Unit-V: Advanced Soil Characterization: Contaminant analysis - water content and permeability measurements – electrical and thermal property evaluation – use of GPR for site evaluation - introduction to geotechnical centrifuge modeling.

References:

1. Rowe R.K., "Geotechnical and Geoenvironmental Engineering Handbook" Kluwer Academic Publications, London, 2000.

2. Sharma H.D. and Reddy K.R.,"Geoenvironmental Engineering: Site Remediation, Waste Containment, and Emerging Waste Management Technologies" John Wiley & Sons, Inc., USA, 2004.
3. Yong, R. N.,"Geoenvironmental Engineering, Contaminated Soils, Pollutant Fate, and Mitigation" CRC Press, New York, 2001.
4. Alvarez-Benedi J. and Munoz-Carpena, R., "Soil-Water Solute Process Characterization: An Integrated Approach" CRC Press, New York, 2005.
5. Mitchell, J.K.,"Fundamentals of Soil Behavior" Wiley, 2005.

Course Outcomes:

At the end of this course the students will be able to

1. Importance of soil in geo-environmental application in various field.
2. Analysis soil mineralogy and soil-water interaction.
3. Design of waste containment facilities.
4. Analysis the remediation methods for soil and groundwater ground.
5. Analysis the advanced soil characterization.

Course Outcomes and their mapping with Programme Outcomes: GEO-ENVIRONMENTAL ENGINEERING (CEPHDT11)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2					1						3	2	1
CO2	3	2	1										3	2	1
CO3	3	2	1										3	2	1
CO4	2	2	1	1									2	1	1
CO5	3	2	1	1			1						3	2	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT12	RIVER HYDRAULICS	3-1-0: 4

Course Learning Objectives:

The objective of this Course is to

1. Understand the fundamental principles and concepts of river mechanics, including the mechanical properties of flow and the basic principles of free surface flow.
2. Learn the characteristics of flow profiles in steady gradually varied flow and apply appropriate computation methods.
3. Study hydraulic structures such as spillways, energy dissipaters, and channel transitions for steady and unsteady rapid varied flow conditions.
4. Understand the characteristics of river beds and sediments, including the initiation of motion and the different types of sediment loads.
5. Learn stable channels for different flow conditions, considering erosion and sediment transport, and apply similitude principles for model testing.

Course Content

Unit-1: Introduction to river mechanics, Mechanical properties of flow, Aggrading rivers, Degrading rivers, Meandering rivers, Basic concepts of free surface flow, Flow regimes, Velocity and Pressure distribution, Energy principles and its applications, Specific energy, Critical flow computations, Momentum equations and its applications, Specific force diagram.

Unit-2: Steady gradually varied flow, Dynamic equation, Characteristics of flow profile and methods of computation, Practical problems, gradually varied flow classification, analysis and computations

Unit-3: Steady rapid varied flow, Hydraulic jump analysis and location, Jump in sloping channels and Oblique jump, Surge analysis, Design of spillways, Energy dissipaters, Channel transitions. Unsteady rapidly varied flow, Dam break problem, Moving hydraulic jump, Positive and Negative surges.

Unit-4: Fluvial hydraulics, Basic characteristics of river beds and sediments, Initiation of motion, Bed load, suspended load, total load and sediment measurements, Regimes of flow, Plan form and stream bed variations of rivers, Sediment control.

Unit-5: Design of stable channels, Design of erodible and lined channels for clear and sediment – laden flows, Regime method, Tractive force methods, Reservoir sedimentation, Erosion and deposition, Sediment transport in pipes Similitude and models.

Reference Books

1. Chow V.T. "Open Channel Hydraulics", McGraw Hill, Inc. New York.
2. Henderson "Open channel flow", McMillan Pub. London

3. Subramanya K. "Flow in Open Channels", Tata McGraw Hill Pub.
4. Garde and Ranga Raju K.G. "Mechanics of sediment transportation and Alluvial Stream Problems", Wiley Eastern, New Delhi
5. Chaudhry M.H. "Open – Channel Flow", Prentice Hall of India, New Delhi
6. French R.H. "Open Channel Hydraulics", McGraw Hill Pub Co., New York

Course Outcomes:

At the end of the course the students shall be able to

1. Explain the concept of critical flow and apply the energy principles to analyze and compute specific energy in river systems.
2. Solve practical problems related to gradually varied flow, such as determining flow profiles and predicting flow behavior in river systems.
3. Apply the principles of hydraulic jump analysis and surge analysis to solve problems and design appropriate structures in river systems.
4. Analyze and predict stream bed variations and sediment transport regimes in rivers and propose strategies for sediment control.
5. Develop design solutions for erodible and lined channels that can handle both clear and sediment-laden flows, while considering sediment transport and similitude principles for model testing.

Course Outcomes and their mapping with Programme Outcomes: RIVER HYDRAULICS (CEPHDT12)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	2										3	1	2
CO2	3	1	1			2							2	2	1
CO3	3	2		2									3	3	1
CO4	3		2	2									2	1	2
CO5	3	2	2	2									2	1	3

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT13	IRRIGATION TECHNOLOGY AND WATER MANAGEMENT	3-1-0: 4

Course Learning Objectives:

The objective of this Course is

1. To understand the Types & Techniques of Irrigation.
2. To develop the basic understanding of Soil and Land Management in Agriculture.
3. To understand the Crop requirements and irrigation scheduling.
4. To learn the Water conveyance and computing the capacity of canals.
5. To learn the Reclamation of Water Logged and Saline Soils.

Course Content

Unit-1

Introduction: Types & Techniques of Irrigation including advanced techniques, Present situation of irrigation in India Soil-Moisture Irrigation Relationship, Estimating depth and frequency of irrigation.

Unit-2

Soil and Land Management in Agriculture: classification and surveys-land capability farm development, grading-equipment, land management techniques.

Unit-3

Crop requirements and irrigation scheduling: Major Indian crops times of sowing and harvesting –critical periods of growth moisture stress, Duty & delta of crops, Irrigation scheduling, Consumptive use of Crop- Blanney-Criddle, Thornth wait penman, Christiansen methods, Water-use efficiency, scope of computerization in irrigation.

Unit-4

Water conveyance Computing the capacity of canals, Losses in water canals, Distribution of water into the fields through water courses, Lined canals.

Unit-5

Reclamation of Water Logged and Saline Soils: Glances of water logging- design of surface and subsurface drains, Saline and alkaline lands reclamation and management of Salt affected lands.

Reference Books

1. Modi. P. N., "Irrigation, Water Resources & Water Power Engineering", Standard Publishers, New Delhi.
2. Punmia B. C., Pande Ashok kumar and Jain Arun kumar, "Irrigation and water power engineering", Laxmi Publications Pvt. Ltd.

3. Chaturvedi M.C., "Water Resources Systems Planning and Management", Tata McGraw Hill. NY.
4. Linsley, R. K.and Frazinini, J. B., "Water Resources Engineering", 2nd Ed. McGraw Hill, NY
5. James L.D and Lee R.R., "Economics of Water Resources Systems Planning, McGraw Hill. NY

Course Outcomes:

At the end of the course the students shall be able

1. To have an understanding about Types & Techniques of Irrigation
2. To have an understanding about Soil and Land Management in Agriculture.
3. To have an idea about Crop requirements and irrigation scheduling.
4. Ability to analyse and calculate the capacity of canals.
5. To have an idea Reclamation of Water Logged and Saline Soils.

Course Outcomes and their mapping with Programme Outcomes: IRRIGATION TECHNOLOGY AND WATER MANAGEMENT (CEPHDT13)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	1									3	2	1
CO2	3	2	1	2									2	2	2
CO3	3	2	2	1									2	2	2
CO4	3	2	2	2									3	3	3
CO5	3	2	1	1									2	2	2

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT14	OPEN CHANNEL HYDRAULICS	3-1-0: 4

Course Learning Objectives:

The objective of this Course is

1. To understand the concepts of free surface flow and equations hydraulics to uniform and non-uniform open channel flows.
2. To develop the basic understanding for flow resistance and compound channel.
3. To learn to apply conservation laws to gradually varied and rapidly varied unsteady flows.
4. To analyse hydraulics of mobile bed channel.
5. To learn the significance of Bridge Hydraulics.

Course Content

Unit-1: Basic Concepts of Free Surface Flow, classification of flow, velocity & pressure distribution. Conservation laws, continuity equation, momentum equation, Specific energy, Application of momentum & energy equation, Channel transition, Hydraulic jump. Critical flow.

Unit-2: Uniform flow: flow resistance, equation of flow resistance, compound channel, Computation of normal flow depth.

Unit-3: Gradually varied flow, Governing equation, classification of water surface profiles, and computation of GVF. Unsteady Rapidly Varied Flow. Application of conservation laws. Spillways, Energy dissipaters. Critical slope and limit slope.

Unit-4: Initiation of Motion of sediment, Critical analysis of Shield's diagram, Bed forms, and Predication of bed form. Sediment load: Suspended load, Bed load, total bed material load, measurement and estimation of sediment load. Design of Stable Channels: Regime and Tractive force Methods.

Unit-5: Introduction to Bridge Hydraulics: Water ways, Afflux, Scour: Local scour, abutment scour, Indian practice of design for scour.

Books and References

1. Flow through Open Channel by Ranga Raju, K.G., Tata McGraw Hill, New Delhi.
2. Open Channel Hydraulics by Chow, V.T, McGraw Hill, New York.
3. Open Channel Flow by Hendersen, F.M., McGraw Hill, New York.
4. Open Channel Flow by Chaudhry, M. H., Prentice Hall of India.
5. River Behavior Management and Training, Vol. I & II by Central Board of Irrigation & Power (CBIP), New Delhi.
6. River processes: An Introduction to Alluvial dynamics by Andre Rober, ARNOLD, London.

Course Outcomes:

At the end of the course the students shall be able

1. Ability to apply continuity, momentum and energy equations to uniform and non-uniform open channel flows.
2. Ability to apply flow resistance equation for uniform flow in open channel and compound channel.
3. Ability to apply conservation laws to gradually varied and rapidly varied unsteady flows.
4. Ability to analyse hydraulics of bed load sediment in open channel.
5. To have an idea of bridge hydraulics

Course Outcomes and their mapping with Programme Outcomes: OPEN CHANNEL HYDRAULICS (CEPHDT14)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	3									3	2	1
CO2	3	2	2	2									2	3	2
CO3	3	2	2	2									3	3	2
CO4	3	2	3	3									2	2	1
CO5	3	2	2	2									2	2	2

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT15	EARTHQUAKE ENGINEERING	3-1-0: 4

Course Objectives: The course is aimed

1 To Introduction the Seismology and Earthquakes, Strong Ground Motion, Seismic Hazard Analysis.

2 To study the Wave propagation and evaluate the Ground Response Analysis (1D, Linear Non-Linear) with Local site effects,

3 To introduce Liquefaction, Soil Improvement for Remediation of Seismic Hazards:

Unit-I: Seismology and Earthquakes; Introduction, Seismic Hazards, seismic waves, internal structure of earth, Continental drift and plate tectonics, faults, elastics rebound theory, geometric notations, location of earthquakes, size of earthquakes.

Strong Ground Motion: Strong ground motion measurement, ground motion parameters, estimation of ground motion parameters.

Unit-II: Seismic Hazard Analysis; Identification and Evaluation of Earthquake Sources, deterministic seismic hazard analysis, probabilistic seismic hazard analysis.

Unit-III: Wave propagation; Waves in unbounded media, waves in a semi – infinite body, waves in a layered media, attenuation of stress waves.

Unit-IV: Ground Response Analysis; One – Dimensional Ground response Analysis – Linear and Non-Linear Approaches.

Local Site Effects: Effect of local site conditions on ground motion, design parameters, development of design parameters.

Unit-V Liquefaction: Flow liquefaction, cyclic mobility, evaluation of liquefaction hazards, liquefaction susceptibility, initiation of liquefaction, effects of liquefaction.

Soil Improvement for Remediation of Seismic Hazards: Densification techniques, Reinforcement Techniques, Grouting and Mixing techniques, Drainage techniques.

TEXT BOOK:

1. Geotechnical Earthquake Engineering by Steven L. Kramer, prentice Hall, 1st edition, 1996.
2. Fundamentals of Earthquake Engineering: An Innovative Approach by Amr S. Elnashai and Luigi Di Sarno, Wiley–Blackwell,2008.

REFERENCE BOOK:

1. Geotechnical Earthquake Engineering Handbook by Robert W. Day, McGraw-Hill.2nd edition, 2010.
2. Earthquake Engineering: Theory and Implementation with the 2015 International Building Codeby by Nazzal Armouti,2015.

Course Outcomes:

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

1 Implement the effects of Seismology and Earthquakes and use Strong Ground Motion for the Seismic Hazard Analysis.

2 Carryout the wave propagation and evaluate the Ground Response Analysis (1D, Linear Non-Linear) with Local site effects,

3 Evaluate the Liquefaction of soils and carryout the Soil Improvement for Remediation of Seismic Hazards:

Course Outcomes and their mapping with Programme Outcomes: EARTHQUAKE ENGINEERING (CEPHDT15)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	1	1	1	1					1	3	2	1
CO2	3	3	2	1	1	1	1					1	3	2	1
CO3	3	3	2	1	1	1	1					1	3	2	1

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT16	TRANSPORTATION SYSTEM DESIGN AND MANAGEMENT	3-1-0: 4

Course Learning Objectives:

- To provide a comprehensive scientific insight of transportation system planning.
- To learn travel survey and analysis using econometric methods.
- To learn various travel demand modelling.
- To understand the concepts of transportation system management.
- To understand the sustainability aspects of transport system design for green mobility.

Course Content:

UNIT-I

Introduction: Basic concepts in transportation planning; accessibility and mobility; Characteristics of travel and transport problems.

UNIT- II

Travel Survey and Analysis: Transportation survey and data collection; planning, design and Implementation, Econometric methods for transportation data analysis (Regression Analysis); travel analysis zone (TAZ) development.

UNIT-III

Travel Demand Modelling: Travel demand and supply analysis, Trip generation, Trip distribution (Spatial and Temporal), Mode choice, Traffic assignment.

UNIT-IV

Demand Management: Transportation demand management (TDM); Transportation system management (TSM), Transit-oriented development (TOD); pedestrian-oriented development, liveable street planning, Multimodal transportation planning; shared mobility concept; integrated transportation management and planning.

UNIT-V

Sustainability: Sustainable Transport Planning, Transportation and energy; climate change, fuel choice and green mobility.

Text Books:

1. Sarkar, P.K., Maitri, V., and Joshi, G.J. Transportation Planning, Principles, Practices and Policies, PHI Pvt. Ltd., 2016

2. Papacosta, C.S., and Prevedouros Transportation Engineering and Planning, PHI Pvt.Ltd.,2004

Reference Books:

1. De Dios Ortuzar, J., and Willumsen, L. G. Modelling transport. John Wiley & Sons., 2011
2. Hutchinson B.G; Principles of Urban Transport Systems Planning; McGraw-Hill Book Company, 1974.
3. Chakroborty, P. and Das, A. Principles of Transportation Engineering, PHI Pvt. Ltd., 2012
4. Train, K. E. Discrete choice methods with simulation. Cambridge university press, 2009
5. Kadiyali, L. R. Traffic Engineering and Transport Planning, Khanna Publishers, 20

Course Outcomes- At the end of the course students will be able to:

CO1: Develop an understanding of transportation planning to measure transportation demand.

CO2: Design various travel behavior surveys to collect transportation planning related data and analyze the data for calibration and validation of various types of models involved in the traditional four-step travel demand forecasting process.

CO3: Develop in-depth knowledge on the classic four stage demand models including: 1) trip generation, 2) trip distribution, 3) mode choice, and 4) trip assignment.

CO4: Able to understand econometric models and use statistical packages.

CO5: Learn the concepts of sustainable transportation planning and land-use transport.

Course Outcomes and their mapping with Programme Outcomes: TRANSPORTATION SYSTEM DESIGN AND MANAGEMENT (CEPHDT16)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	2	1	3		2							3	1	1
CO2	3	3	2	2		2							2	3	2
CO3	3	2	3	2		1							3	3	2
CO4	3	2	3	3	2	1							2	3	1
CO5	3	2	2	2		2	3						2	2	2

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT17	Advance Soil Mechanics	3-1-0: 4

Course Learning Objectives:

The objective of this Course is

- To understand soil composition, index properties, and forces governing soil structure, fostering a comprehensive grasp of soil nature.
- To analyze dry soil behavior, shear strength, and stress-strain relationships for practical application in civil engineering projects and designs.
- To assess the principles of saturated soil behavior, including permeability, stress-strain characteristics, and stability analysis in diverse conditions.
- To analyze undrained shear behavior, consolidation, and stability under varying conditions for informed geotechnical design decisions.
- To Analyze and Design the Retaining Wall and Foundations with Different field Conditions

Module 1: Nature of Soil: Soil Problems in Civil Engineering, A Preview of Soil Behaviour, Conduct of the Subject. Soil Composition, Index Properties, Soil Classification, Soil Structure: Clay-Water Forces, Interparticle Forces: Normal Stresses and Shear Stresses, Soil Formation.

Module 2: Dry Soil: Stresses Within a Soil Mass: Geostatic Stress & Stresses due to applied load, Tests, to Measure Stress-Strain Properties, General Aspects of Stress-Strain Behaviour, Shear Strength of Cohesionless Soil, Stress-Strain Relationships.

Module 3: Saturated Soil (No or Steady State Flow): Effective Stress Principle, Capillarity, Soil Suction, One- and Two-Dimensional Flow, Coefficient of Permeability (Theory and Practice), Stress-Strain and Strength Behaviour of Clays, 1-D Behaviour (Theory and Practice), Drained Shear Behaviour, Strength Principles, Lateral Earth Pressures, and Slope Stability.

Module 4: Saturated Soil (Transient Flow): Pore Pressure Parameters, Undrained Shear Behaviour of Clays, and Strength Principles, Consolidation of Cohesive Soils, Evaluation of Stability (Loading vs. Unloading and Undrained vs. Drained Conditions), Estimation of Undrained Strength for Design.

Module 5: Slopes and Foundations: Finite & Infinite Slopes, Rankine Earth Pressures, Retaining Walls: Analysis and Behaviour of Shallow Foundation: Analysis and Design, Settlement, Deep Foundations: Analysis and Design

Reference Books:

1. Lambe, T. W., & Whitman, R. V. (1991). Soil mechanics (Vol. 10). John Wiley & Sons.
2. Das, B. M. (2019). Advanced soil mechanics. CRC press.
3. Terzaghi, K., & Peck, R. B. (1948). Soil mechanics. Engineering Practice. John Wiley and Sons, Inc., New York.

4. Terzaghi, K., Peck, R. B., & Mesri, G. (1996). Soil mechanics in engineering practice. John Wiley & sons.

5. Mitchell, J. K., & Soga, K. (2005). Fundamentals of soil behavior (Vol. 3, p. USA). New York: John Wiley & Sons.

Course Outcomes:

At the end of the course, the students shall be able

CO1: To Characterize soil composition, index properties, and structure for engineering applications.

CO2: To Analyze dry soil properties to determine stress-strain behavior, shear strength, and stability in civil engineering applications.

CO3: To Apply principles of effective stress, capillarity, permeability, stress-strain, and strength behavior to assess and design for stability in saturated soil under no or steady-state flow conditions.

CO4: To Analyze pore pressure parameters, undrained shear behavior, consolidation, and stability to make informed engineering decisions in saturated soil under transient flow conditions.

CO5: To Analyze and Design the retaining wall and foundations for different field conditions.

Course Outcomes and their mapping with Programme Outcomes: Advance Soil Mechanics (CEPHDT17)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	3	3	3					2	3	2	3
CO2	3	3	3	3	3	3	3					3	3	2	3
CO3	3	3	3	2	3	3	3					2	3	2	3
CO4	3	3	3	3	3	3	3					3	3	2	3
CO5	3	3	3	3	3	3	3					3	3	2	3

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT18	Environmental Geotechnics	3-1-0: 4

Course Learning Objectives:

The objective of this Course is

- To develop an understanding of geoenvironmental engineering, emphasizing soil's multifaceted role in diverse applications and addressing contamination impact through case studies
- To explore soil-water-contaminant interactions, understanding factors influencing the retention and transport of contaminants in soil for geoenvironmental problem-solving.
- To evaluate soil properties for waste containment, ensuring stability and suitability, guiding the design of adequate waste containment facilities
- To develop skills for effective site characterization, risk assessment, and selection of remediation methods for contaminated sites.
- To enhance expertise in advanced soil characterization through contaminant analysis, property evaluation, and innovative geotechnical techniques like GPR and centrifuge modelling.

Module 1: Fundamentals of Environmental Geotechnics: Scope of geoenvironmental engineering- multiphase behaviour of soil – role of soil in geoenvironmental applications – importance of soil physics, soil chemistry, hydrogeology, biological process – sources and type of ground contamination – impact of ground contamination on geoenvironmental - case histories on geoenvironmental problems.

Module 2: Soil-Water-Contaminant Interaction: Soil mineralogy characterization and its significance in determining soil behaviour – soil-water interaction and concepts of double layer – forces of interaction between soil particles.

Concepts of unsaturated soil – the importance of unsaturated soil in geoenvironmental problems - measurement of soil suction - water retention curves - water flow in the saturated and unsaturated zone. Soil-water-contaminant interactions and its implications – Factors affecting retention and transport of contaminants.

Module 3: Waste Containment System: Evolution of waste containment facilities and disposal practices – Site selection based on environmental impact assessment –different role of soil in waste containment – different components of waste containment system and its stability issues – property evaluation for checking soil suitability for waste containment – design of waste containment facilities.

Module 4: Contaminant Site Remediation: Site characterization – risk assessment of contaminated site - remediation methods for soil and groundwater – selection and planning of remediation methods – some examples of in-situ remediation.

Module 5: Advanced Soil Characterization: Contaminant analysis - water content and permeability measurements – electrical and thermal property evaluation – use of GPR for site evaluation - introduction to geotechnical centrifuge modeling.

Reference Books:

1. Rowe, R. K. (Ed.). (2012). Geotechnical and geo-environmental engineering handbook. Springer Science & Business Media.
2. Reddi, L., & Inyang, H. I. (2000). Geo-environmental engineering: principles and applications. CRC Press.
3. Yong, R. N. (2000). Geo-environmental engineering: Contaminated soils, pollutant fate, and mitigation. CRC press.
4. Sharma, H. D., & Reddy, K. R. (2004). Geo-environmental engineering: site remediation, waste containment, and emerging waste management technologies. John Wiley & Sons.
5. Fredlund, D. G., & Rahardjo, H. (1993). Soil mechanics for unsaturated soils. John Wiley & Sons.

Course Outcomes:

At the end of the course, the students shall be able
CO1: To understand geo-environmental engineering, analyzing soil's multiphase behavior and its role in environmental applications, supported by case histories.
CO2: To comprehend soil-water-contaminant interactions, assessing implications, and factors affecting retention and transport of contaminants in geo-environmental scenarios.
CO3: To evaluate waste containment system stability, soil suitability, and design, considering environmental impact, evolving disposal practices, and facility components.
CO4: To develop expertise in assessing and planning contaminant site remediation, integrating site characterization, risk assessment, and remediation method selection.
CO5: To apply advanced techniques, including contaminant analysis, GPR, and geotechnical centrifuge modeling, for comprehensive soil characterization in practice.

Course Outcomes and their mapping with Programme Outcomes: Environmental Geotechnics (CEPHDT18)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	3	2	3	3	3					2	3	2	3
CO2	3	3	3	3	3	3	3					3	3	2	3
CO3	3	3	3	2	3	3	3					2	3	2	3
CO4	3	3	3	3	3	3	3					3	3	2	3
CO5	3	3	3	3	3	3	3					3	3	2	3

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT19	Principles of Ground Modification	3-1-0: 4

Course Learning Objectives:

The objective of this Course is

- To analyze ground modification methods, including recent trends and emerging developments in geotechnical engineering.
- To understand soil compaction principles for effective ground modification in engineering applications.
- To design and implement effective hydraulic modifications for soil dewatering, drainage, and seepage control.
- To apply chemical, thermal, and admixture methods for soil modification in geotechnical engineering practices.
- To understand soil reinforcement techniques, including geosynthetics and stone columns, for practical ground modification applications.

Module 1: Introduction to Engineering Ground Modification: The ground modification option in dealing with difficult soil, Recent forums, Traditional objectives, Emerging Trends, and Current and Future Developments.

Module 2: Mechanical modification: Analysis and Design: Mechanical Modification, Principles of Soil Densification, Properties of Compacted Soil, Compaction Control Tests, Specifications of Compaction Requirements and Design.

Module 3: Hydraulic Modifications: Introduction to Hydraulic Modification; Design of Dewatering System; Filtration, Drainage and Seepage Control with Geosynthetics; Analysis and Design: Preloading and Use of Vertical Drain; Electrokinetic Dewatering and Stabilization.

Module 4: Physical and Chemical Modification: Analysis and Design: Modifications by Admixtures; Modification at Depth by Grouting; Thermal Modifications.

Module 5: Modification by Inclusion and Confinement: Analysis and Design Using Soil Reinforcement; Mechanical Models of Soil Reinforcement, Flexible Geosynthetics Sheet reinforcement, Stone Columns; Encased Stone Columns; Soil Confinement by Formwork.

Reference Books:

6. Hausmann, M. R. (1990). Engineering principles of ground modification. McGraw Hill Education (India) Private Limited.
7. Han, J. (2015). Principles and practice of ground improvement. John Wiley & Sons.
8. Nicholson, P. G. (2014). Soil improvement and ground modification methods. Butterworth-Heinemann.
9. Moseley, M. P., & Kirsch, K. (Eds.). (2004). Ground improvement. CRC Press.

10. Datye, K. R. (1982). Simpler technique for ground improvements. Fourth IGS Annual Lectures, IGJ, 12, 1-82.

11. Chu, J. J., & Rujikiatkamjorn, C. (2005). Ground improvement: case histories. Elsevier.

Course Outcomes:

At the end of the course, the students shall be able

CO1: To recall and articulate the historical evolution and diverse objectives of ground modification practices.

CO2: To apply principles of soil densification, compaction control, and specifications for effective mechanical modification.

CO3: To design dewatering system, filtration, and drainage with geosynthetics for effective hydraulic modifications.

CO4: To design and implement effective ground modifications using admixtures, grouting, and thermal techniques at various depths.

CO5: To apply advanced soil reinforcement techniques, demonstrating expertise in inclusion and confinement methods for stabilization and their design.

Course Outcomes and their mapping with Programme Outcomes: Principles of Ground Modification (CEPHDT19)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1	1	3	1	3					2	3	2	1
CO2	3	3	3	3	3	2	2					2	3	2	3
CO3	3	3	3	3	3	2	3					2	3	2	3
CO4	3	3	3	3	3	2	2					2	3	2	3
CO5	3	3	3	3	3	2	3					2	3	2	3

Weightage: 1-Sightly; 2-Moderately; 3-Strongly

Course Code	Subject	Credits
CEPHDT20	Soil Remediation	3-1-0: 4

Course Learning Objectives:

The objective of this Course is

- To analyze soil origin, constituents, properties, and degradation to comprehend soil dynamics and its environmental impact.
- To comprehend soil pollution sources, mechanisms, and effective monitoring strategies for sustainable environmental management.
- To master electrokinetic and thermal soil remediation principles, processes, and applications for effective environmental restoration.
- To understand and apply bioremediation principles and phytoremediation for effective soil pollutant removal.
- To apply spatial and mathematical models to understand fluid flow, enhancing proficiency in soil pollution prediction and management.

Module 1: Soil-Its Nature and Origin: Origin of Soil: Formation and Morphology, Soil Constituents: As Three Phase System, Organic Matter and Soil Organisms; Soil properties and Classification: Physical and Chemical Properties, Criteria of Soil Classification, Different system of classification along with FAO-UNESCO Soil Classification system; Soil Degradation.

Module 2: Soil Pollution and Monitoring: Major Types of Soil Pollutants, Source of Soil Pollution, Pollution Mechanism and Soil-Pollution Interaction, Pollutant's Alteration and Initiation of Chemical Change within Soil, Monitoring of Soil Pollution.

Module 3: Electrokinetic and Thermal Remediation: Electrokinetic Remediation: Introduction, Fundamentals, Important Processes and Case study; Thermal Remediation: Thermal processes, Fundamentals, Incineration, Thermal Desperation, Aqueous Oxidation and Case study.

Module 4: Bioremediation and Plant-Based Remediation: Overview of Phytoremediation, Phytoremediation of Metal-Contaminated, Lead-Contaminated, Heavy Metal Polluted and Salt Affected Soils, Phytoremediation Towards Future; Bioremediation: Introduction, Fundamentals, Important Processes and Case study.

Module 5: Modelling of Soil Pollution: Model and Their Construction, Types of Models: Space Analogue and Mathematical Modelling of Fluid Flow in Soil.

Reference Books:

1. Ibrahim, A.M. "Soil Pollution: Origin, Monitoring and Remediation" Springer New York, 2008.
2. Brian, J.A. and Jack, T.T. "Soil Remediation and Rehabilitation: Treatment of Contaminated

and Disturbed land" Springer New York, 2013.

3. William, C.B. "Basic Hazardous Waste Management" Lewis Publishers, New York, 2001.

Course Outcomes:

At the end of the course, the students shall be able

CO1: To demonstrate a comprehensive understanding of soil science fundamentals and environmental implications.

CO2: To effectively monitor and mitigate soil pollution, demonstrating proficiency in pollutant identification and monitoring techniques.

CO3: To apply electrokinetic and thermal remediation principles to address soil contamination effectively in practice.

CO4: To apply bioremediation principles to design effective strategies for diverse soil contamination challenges.

CO5: To model soil pollution using space analogy and mathematical methods for practical environmental analysis.

Course Outcomes and their mapping with Programme Outcomes: Soil Remediation (CEPHDT20)

COs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	2	3	2	3	3					2	3	2	3
CO2	3	3	3	2	3	3	3					2	3	2	3
CO3	3	3	2	3	2	3	3					2	3	2	3
CO4	3	3	3	2	3	3	3					2	3	2	3
CO5	3	3	3	2	3	3	3					2	3	2	3

Weightage: 1-Sightly; 2-Moderately; 3-Strongly