DR. A.P.J. ABDUL KALAM TECHNICAL UNIVERSITY

UTTAR PRADESH, LUCKNOW

SYLLABUS

FOR

B.Tech. Civil Engineering

(5th Semester)

BASED ON

AICTE MODEL CURRICULUM & NEP2020

[Effective from the Session: 2024-25]

PLEASE NOTE: The Mini Project or internship (4 weeks) will be done during summer break after 6th Semester and will be assessed during 7th semester.

B.Tech. Civil Engineering, III[rd] Year (V Semester)
Course Structure

FIFTH SEMESTER CIVIL ENGINEERING SESSION 2024-25

S. No.	Subject Code	Subject	Periods			Evaluation Scheme				End Semester		Total	Credit
			L	T	P	CT	TA	Total	PS	TE	PE		
1	BCE-501	Geotechnical Engineering	3	1	0	20	10	30		70		100	4
2	BCE -502	Structural Analysis	3	1	0	20	10	30		70		100	4
3	BCE-503	Quantity Estimation and Construction Management	3	1	0	20	10	30		70		100	4
4		**Departmental Elective-I**	3	0	0	20	10	30		70		100	3
	BCE-051	Concrete Technology											
	BCE-052	Modern Construction Materials											
	BCE-053	Open Channel Flow											
	BCE-054	Engineering Geology											
5		**Departmental Elective-II**	3	0	0	20	10	30		70		100	3
	BCE-055	Engineering Hydrology											
	BCE-056	Sensor and Instrumentation Technologies for Civil Engineering Applications											
	BCE-057	Air and Noise Pollution Control											
	BCE-058	GIS and Advance Remote Sensing											
6	BCE-551	CAD Lab	0	0	2				50		50	100	1
7	BCE-552	Geotechnical Engineering Lab	0	0	2				50		50	100	1
8	BCE-553	Quantity Estimation and Management Lab	0	0	2				50		50	100	1
9	BCE-554	Mini Project or Internship Assessment*	0	0	2				100			100	1
10	BNC501/ BNC502	Constitution of India / Essence Of Indian Traditional Knowledge	2	0	0	20	10	30		70			NC
11		Minor/Honors Degree Track Subjects											
		Total	**17**	**3**	**8**							**900**	**22**

*The Mini Project or Internship (4 weeks) conducted during semester break after IV semester and will be assessed during V semester.

NOTE:

1. Regular classroom interaction with industry experts is to be ensured in all theory courses (minimum two expert talks from relevant Industry).
2. Working on experiments using virtual labs is to be ensured in lab courses.
3. Student's visit to Industry/Industry Expert's project site must be arranged as & when possible.

BCE-501 Geotechnical Engineering

Course Outcomes: After completion of the course student will be able to:

CO1. Classify the soil and determine its Index properties.

CO2. Evaluate permeability and seepage properties of soil.

CO3. Interpret the compaction and consolidation characteristics & effective stress concept of soil.

CO4. Determine the vertical and shear stress under different loading conditions and explain the phenomenon of soil liquefaction.

CO5. Interpret the earth pressure and related slope failures.

Syllabus:

Unit-1	**ORIGIN AND CLASSIFICATION:** Preview of Geotechnical field problems in Civil Engineering, Soil formation, transport and deposit, Soil composition, Basic definitions, Weight volume relationships, Clay minerals, Soil structure, Index properties, sensitivity and thixotropy, Particle size analysis, Unified and Indian standard soil classification system.	8
Unit-2	**SOIL HYDRAULICS:** Stress conditions in soil- total, effective and neutral stresses and relationships. Permeability - Darcy's Law, hydraulic conductivity, equivalent hydraulic conductivity in stratified soil. Seepage, flow nets, seepage calculation from a flow net, flow nets in anisotropic soils, seepage through earth dam, capillarity, critical hydraulic gradient and quick sand condition, uplift pressure, piping.	8
Unit-3	Soil compaction, water content - dry unit weight relationships. Factors controlling compaction. Field compaction equipment; field compaction control; Proctor needle method. **CONSOLIDATION:** Primary and secondary consolidation, Terzaghi's one dimensional theory of consolidation, Consolidation test, Normal and Over Consolidated soils, Over Consolidation Ratio, determination of coefficient of consolidation.	8
Unit-4	**STRESS DISTRIBUTION IN SOIL:** Elastic constants of soils and their determination, Boussinesq equation for vertical stress, The Westergaard equation, Stress distribution under loaded areas, Concept of pressure bulb, contact pressure. **SHEAR STRENGTH:** Mohr-Coulomb failure criterion, shear strength parameters and determination; direct and tri-axial shear test; unconfined compression test; pore pressure, Skempton's pore pressure coefficients, and Soil liquefaction.	8
Unit-5	**EARTH PRESSURE:** Classical theories, Coulomb and Rankine's approaches for frictional and c-φ soils, inclined backfill, Graphical methods of earth pressure determination. Stability of slopes - finite and infinite slopes, types of slope failure, Culmann's method & Method of slices, Stability number & chart, Bishop's method.	8

Text & References Books:

1. V.N.S. Murthy – Soil Mechanics and Foundation Engineering (Fifth Edition).
2. K.R. Arora – Soil Mechanics and Foundation Engineering.
3. Narasinga Rao, B.N.D, "Soil Mechanics & Foundation Engineering", John Wiley &Sons, Wiley India Pvt. Ltd., Daryaganj, New Delhi – 110002.
4. Alam Singh – Modern Geotechnical Engineering.
5. Brij Mohan Das – Geotechnical Engineering, CENGAGE Learning.
6. I.H. Khan – Text Book of Geotechnical Engineering.

7. C. Venkataramaiah – Geotechnical Engineering.
8. Gopal Ranjan and A.S.R. Rao – Basic and Applied Soil Mechanics.
9. G.V. Rao & G.V.S.S. Raju – Engineering with Geosynthetics.
10. P. Purushottam Raj- Soil Mechanics and Foundation Engineering, Pearson Education in South Asia, New Delhi.
11. Shenbaga R Kaniraj- Design Aids in Soil Mechanics and Foundation Engineering.
12. Gulati, S.K., "Geotechnical Engineering" McGraw Hill Education (India), Pvt. Ltd., Noida.

BCE-502 Structural Analysis

Course Outcomes: After completion of the course student will be able to:

CO1. Explain type of structures **and method for their analysis.**

CO2. Analyze different types of trusses for member forces.

CO3. Compute slope and deflection in determinate structures using different methods.

CO4. Apply the concept of influence lines and moving loads to compute bending moment and shear force at different sections.

CO5. Analyze determinate arches for different loading conditions.

Syllabus:

Unit-1	Classification of Structures, Types of structural frameworks and Load transfer Mechanisms, stress resultants, degrees of freedom, Static and Kinematic Indeterminacy for beams, trusses and building frames. Analysis of cables with concentrated and continuous loadings, Effect of Temperature upon length of cable.	8
Unit-2	Classification of Pin jointed determinate trusses, Analysis of determinate plane trusses (compound and complex). Method of Substitution, Method of tension coefficient for analysis of plane trusses.	8
Unit-3	Strain Energy of deformable systems, Maxwell's reciprocal & Betti's theorem, Castigliano's theorems, Calculations of deflections: Strain Energy Method and unit load method for statically determinate beams, frames and trusses. Deflection of determinate beams by Conjugate beam method.	8
Unit-4	Rolling loads and influence line diagrams for determinate beams and trusses, Absolute maximum bending moment and shear force. Muller-Breslau's principle & its applications for determinate structures.	8
Unit-5	Arches, Types of Arches, Analysis of three hinged parabolic and circular Arches. Linear arch, Eddy's theorem, spandrel braced arch, moving load & influence lines for three hinged parabolic arch.	8

References:

1. Hibbler, "Structural Analysis", Pearson Education.
2. Mau, "Introduction to Structural Analysis" CRC Press Taylor & Francis Group.
3. Ghali, " Structural Analysis: A Unified Classical and Matrix Approach" 5/e, CRC Press Taylor & Francis Group.
4. T S Thandavmorthy, "Analysis of Structures", Oxford University Press 5.Wilbur and Norris, "Elementary Structural Analysis", Tata McGraw Hill.
5. Temoshenko & Young "Theory of Structure" Tata Mc Grew Hill.
6. Reddy, CS, "Basic Structural Analysis", Tata McGraw Hill.
7. Jain, OP and Jain, BK, "Theory & Analysis of Structures". Vol.I & II Nem Chand.
8. Vazirani & Ratwani et al , "Analysis of Structures", Khanna PublishersCoates, RC, Coutie, M.G. & Kong, F.K., "Structural Analysis", English Language Book Society & Nelson, 1980.

9. SP Gupta & Gupta "Theory of Structure Vol.1 & 2" TMH.
10. DS Prakash Rao "Structural Analysis: A Unified Approach" Universities Press.
11. S Ramamurtham "Theory of Structure" Dhanpat Rai.
12. Devdas Menon "Advanced Structural Analysis" Narosa.
13. Wang, CK, "Intermediate Structural Analysis", Tata Mc-Graw Hill.
14. Hsieh, "Elementary Theory of Structures" 4/e, Pearson Education, Noida.
15. Mckenzie, "Examples in Structural Analysis" 2/e, CRC Press Taylor & Francis Group.
16. Bibek Kumar Mukherjee, "Theory and Analysis of Structures" Satya Prakashan, New Delhi.
17. Jacques Heyman, "Structural Analysis" Cambridge University Press.

BCE-503 Quantity Estimation and Construction Management

Course Outcomes: After completion of the course student will be able to:

CO1. Understand the importance of units of measurement and preliminary estimate for administrative approval of projects.

CO2. Understand the contracts and tender documents in construction projects.

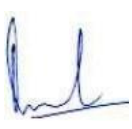
CO3. Analyze and assess the quantity of materials required for civil engineering works as per specifications.

CO4. Evaluate and estimate the cost of expenditure and prepare a detailed rate analysis report.

CO5. Analyze and choose cost effective approach for civil engineering projects.

Syllabus:

Unit-1	**QUANTITY ESTIMATION FOR BUILDINGS:** Measurement units for various building materials, Centreline method, Long and short wall method of estimates, Types of estimates, PWD schedule of rate.	8
Unit-2	**RATE ANALYSIS, SPECIFICATION AND TENDERS:** Analysis of rates knowing cost of material, labour, equipment, overheads, profit, taxes etc, Specifications – Preparation of detailed and general specifications, Legal aspects of contracts, laws related to contracts, land acquisition, labour safety and welfare. Different types of contracts, their relative advantages and disadvantages. Elements of tender preparation, process of tendering, pre-qualification of contracts, Evaluation of tenders, contract negotiation and award of work, monitoring of contract extra items.	8
Unit-3	**ELEMENTS OF MANAGEMENT & NETWORK TECHNIQUES:** Project cycle, Organization, planning, scheduling**,** monitoring, updating and management system in construction, Bar charts, milestone charts, work break down structure and preparation of networks. Network Techniques like PERT & CPM in construction management. Project monitoring and resource allocation through network techniques.	8
Unit-4	**EQUIPMENT MANAGEMENT:** Productivity, operational cost, owning and hiring cost and the work motion study. Simulation techniques for resource scheduling. Construction Equipment for earth moving, earth compaction, Hauling Equipment, Hoisting Equipment, Conveying Equipment, Concrete Production Equipment, Tunnelling Equipment	8
Unit-5	**PROJECT COST MANAGEMENT:** Budgeting, Cost planning, Direct Cost, Indirect cost, Total Cost Curve, Cost Slope. Time value of money, Present economy studies, Equivalence concept, financing of projects, economic comparison, present worthmethod Equivalent annual cost method, discounted cash flow method, Depreciation and its type, depletion, Arbitration, and break even cost analysis.	8



References:

1. Dutta, B.N., "Estimating and Costing in Civil Engineering", UBS Publishers & Distributors Pvt. Ltd., 2003.
2. Srinath, L.S., "PERT and CPM Principals and applications" Affiliated East-West Press Pvt. Ltd., New Delhi.
3. Patil, B.S., "Civil Engineering Contracts and Estimates" University Press India, Pvt. Ltd. Hyderabad –500004.
4. Construction Management by Ojha.
5. Srivastava, U.K., "Construction Planning and Management", Galgotia Publications Pvt. Ltd., New Delhi.
6. Construction Technology by Sarkar, Oxford.
7. Delhi Schedule of Rates (latest version).

BCE-551 CAD Lab

Course Outcomes: After completion of the course student will be able to:

CO1. Students will be able to work on Geo 5 /PLAXIS/STAAD Pro /Etabs software.

CO2. Students will be able to work on QGIS software.

CO3. Students will be able to design and analyze Cantilever ,Gravity wall retaining wall using geotechnical engineering software/design and analysis of multistory building using Structural analysis and design software.

CO4. Students will be able to Geo reference a given map using QGIS softwares.

CO5. Students will be able to Prepare maps using QGIS.

1. Working on latest version of geotechnical engineering software, structural engineering software (Open source/commercial software).

2. Working on latest version of surveying software (Open source/commercial software).

NOTE:-

For open source software the following link of FOSSEE may be used apart from other available resources:
https://fossee.in
FOSSEE: (Free/Libre and Open Source Software for Education), National mission on education through ICT, MHRD, Govt. of India.

BCE-552 Geotechnical Engineering Lab

Course Outcomes: After completion of the course student will be able to:

CO1. Calculate and explain the water content and specific gravity of soil.

CO2. Measure and analyze the in-situ density and relative density of soil.

CO3. Analyze and evaluate the grain size distribution and consistency limits of soil.

CO4. Determine and evaluate the dry density of soil through compaction processes and assess the permeability of soil.

CO5. Perform and evaluate shear strength tests (direct shear and triaxial) to assess soil stability under various conditions.

PART -A (To be performed in lab)

1. Determination of water content of a given moist soil sample by (i) oven drying method, (ii) pycnometer method.
2. Determination of specific gravity of a given soil sample by (i) density bottle, (ii) pycnometer method.
3. Determination of in situ dry density of soil mass by (i) core-cutter method, (ii) sand replacement method.
4. Determination of relative density of a given soil sample.
5. Determination of complete grain size distribution of a given soil sample by sieve analysis and sedimentation (hydrometer) analysis.
6. Determination of consistency limits (liquid, plastic and shrinkage limits) of the soil sample used in experiment no. 5 (grain-size analysis).
7. Determination of shear strength of soil by Direct shear test.
8. Determination of compaction characteristics (OMC & MDD) of a given soil sample.
9. Determination of permeability of a remoulded soil sample by constant head &/or falling head method.
10. Determination of consolidation characteristics of a remoulded soil sample by an odometer test.
11. Determination of shear strength characteristics of a given soil sample by U/U test from Triaxial Compression Machine.
12. Retrieving soil samples and conducting SPT tests by advancing boreholes through hand-held auger.

Note: Any 8 experiments are to be performed from the list of experiments.

PART-B

It is mandatory to perform experiments using virtual lab wherever applicable.

References:

1. Bowles, Joseph E., "Engineering Properties of Soil and Their Measurement" Fourth Edition, Indian Edition, McGraw Hill Education (India) Pvt. Ltd, New Delhi-110032.

BCE-553 Quantity Estimation and Management Lab

Course Outcomes: After completion of the course student will be able to:

CO1. Interpret and analyze DSR (Delhi Schedule of Rates), CPWD (Central Public Works Department) specifications.
CO2. Estimate and analyze quantities of various items of work of a building.
CO3. Develop and prepare a Bill of Quantities (BOQ) for a project.
CO4. Utilize and apply MS Project to manage a project.
CO5. Evaluate a complete set of tender documents of a building.

1. Study of DSR, CPWD specifications and NBC.
2. Estimation of quantities for any one of the following: Building/ Septic tank/Water supply pipe line/road/bridge.
3. Preparation of Bill of Quantities (BOQ) for above project.
4. Practice on open source project management software / MS Project/Primavera software for same problem.
5. Study of any full set of tender documents (Institute shall provide the set from ongoing/ completed tenders).

NOTE:-

1. Suitable software must be used to complete the above exercises in 8-10 hours.
2. For open source software the following link of FOSSEE may be used apart from other available resources:
   https://fossee.in

References:

1. FOSSEE: (Free/Libre and Open Source Software for Education), National mission on education through ICT, MHRD, Govt. of India.
2. Dutta, B.N., "Estimating and Costing in Civil Engineering", UBS Publishers & Distributors Pvt. Ltd., 2003.
3. Srinath, L.S., "PERT and CPM Principals and applications" Affiliated East-West Press Pvt. Ltd., New Delhi.
4. Patil, B.S., "Civil Engineering Contracts and Estimates" University Press India, Pvt. Ltd. Hyderabad –500004.
5. Construction Management by Ojha.
6. Srivastava, U.K., "Construction Planning and Management", Galgotia Publications Pvt. Ltd., New Delhi.
7. Construction Technology by Sarkar, Oxford.
8. S V Deodhar and SC Sharma, "Construction engineering and Management", Khanna Publishing House.
9. Delhi Schedule of Rates (latest version).

BCE-051 Concrete Technology

Course Outcomes: After completion of the course student will be able to:

CO1. Understand the properties of constituent material of concrete.
CO2. Apply admixtures to enhance the properties of concrete.
CO3. Evaluate the strength and durability parameters of concrete.
CO4. Design the concrete mix for various strengths using difference methods.
CO5. Use advanced concrete types in the construction industry.

Syllabus:

Unit-1	**CEMENT:** Types and cement chemistry. Aggregates: mineralogy, properties, test and standards. Quality of water for use in concrete.	8
Unit-2	Introduction & study of accelerators, retarders, water reducers, air entrainers, water proofers, super plasticizers. Study of supplementary cementing materials like fly ash, silica fume , ground granulated blast furnace slag, metakaoline and pozzolana; their production, properties and effect on concrete properties.	8
Unit-3	**CONCERT PRODUCTION:** batching, mixing and transportation of concrete. Workability test: slump test, compacting factor test and Vee Bee test. Segregation, bleeding and Laitance in concrete, curing of concrete and its methods. Determination of compressive and flexural strength as per BIS. Mechanical properties of concrete: elastic modules, poisson's ratio, creep, shrinkage and durability of concrete.	8
Unit-4	Principle of mix proportioning, properties related to mix design, Mix design method (IS method and ACI method). Mix design of concrete, Rheology and its Application in 3D Printing in construction, mix design examples.	8
Unit-5	Study and uses of high strength concrete, self-compacting concrete, fibre reinforced concrete, ferro cement, ready Mix Concrete, recycled aggregate concrete and status in India.	8

References:

1. Neville, A.M. and Brooks, J.J.," CONCRETE TECHNOLOGY", ELBS .1990.
2. Shetty, M.S, "Concrete Technology, Theory and Practice", S. Chand and Company Ltd, New Delhi, 2008.
3. Gambhir, M.L, "Concrete Technology", Tata McGraw Hill Publishing Company Ltd, New Delhi, 2004.
4. Santhakumar, A.R; "Concrete Technology" , Oxford University Press, New Delhi, 2007.
5. Gupta B.L., Amit Gupta, "Concrete Technology", Jain Book Agency, 2010.
6. Newman, K., "CONCRETE SYSTEMS in COMPOSITE MATERIALS".EDT BY L. Holliday. Elsevier Publishing Company. 1966.
7. Popovics. S., "FUNDAMENTALS OF PORTLAND CEMENT CONCRETE: A Quantitative Approach VOL 1 FRESH CONCRETE" JOHN WILEY & SONS.1982.
8. P.K. Mehta and Paulo J.M. Monteiro, "Concrete: microstructure, properties and materials", The Mcgraw Hill Companies.
9. Jayant D. Bapat (2013),Mineral admixtures in cement and concrete, Taylor and Francis group.
10. Concrete mix proportioning as per IS 10262:2009 – Comparison with IS 10262:1982 and ACI 211.1-91 M.C. Nataraja and Lelin Das
11. IS 10262-1982 Recommended Guidelines for Concrete Mix Design, Bureau of Indian Standards, New Delhi, 1998.
12. IS 456-2000 Plain and Reinforced Concrete- Code of Practice, Bureau of Indian Standards, New Delhi, 2000.

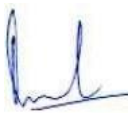
BCE-052 Modern Construction Materials

Course Outcomes: After completion of the course student will be able to:

CO1. Understand the use of modern construction materials.
CO2. Use geosynthetics and bituminous materials in constructions.
CO3. Apply knowledge of modern materials in production of variety of concrete.
CO4. Apply knowledge of composites and chemicals in production of modern concrete.
CO5. Use modern water proofing and insulating materials in constructions.

Syllabus:

Unit-1	**INTRODUCTION, PROPERTIES AND USES OF MODERN BUILDING MATERIALS:** fly ash bricks, soil – cement blocks, calcium silicate bricks, red mud jute fibre polymer composite (RFPC), glass reinforced gypsum.	8
Unit-2	**INTRODUCTION , PROPERTIES AND USE OF:** geosynthetics, bituminous material, fire resistant materials (chemicals ,paints ,tiles ,bricks, glass),metals, light - weight concrete, mass concrete, waste material based concrete.	8
Unit-3	**INTRODUCTION, PROPERTIES AND USE OF:** Ferro cement &fibre reinforced concrete, different types of fibres, high density concrete, Nuclear concrete, heat resisting & refractory concretes, prefabricated systems.	8
Unit-4	**INTRODUCTION, PROPERTIES AND USE OF:** Polymers, fibre reinforced polymers, polymer concrete composites (PCCs), sulphur concrete and sulphur - infiltrated concrete.	8
Unit-5	**INTRODUCTION, PROPERTIES AND USE OF:** Conventional and modern water proofing materials, Conventional and modern insulating materials (thermal, sound and electrical insulating materials).Concept of polymer floor finishes.	8



References:

3. Gambhir ML."Concrete Technology" Tata McGraw Hill education private Limited.
4. A.R. Santhakumar, Concrete Technology, Oxford University Press.
5. Building Materials, P.C. Varghese, Prentice-Hall India.
6. Shetty, M. S., "Concrete Technology" S. Chand Publication.
7. Krishnaraju .N., Advanced Concrete Technology, CBS Published.
8. Materials Science and Engineering: An introduction, W.D. Callister, John Wiley.
9. Nevile. A.M., Concrete Technology, Prentice Hall, Newyork.
10. Dr. U. K. Shrivastava, Building Materials Technology, Galgotia Publication pvt.ltd.
11. Materials Science and Engineering, V. Raghavan, Prentice Hall.
12. Properties of Engineering Materials, R.A. Higgins, Industrial Press.
13. Construction materials: Their nature and behaviour, Eds. J.M. Illston and P.L.J. Domone, 3rd ed., Spon Press.
14. The Science and Technology of Civil Engineering Materials, J.F. Young, S. Mindess,R.J. Gray & A. Bentur, Prentice Hall.
15. Engineering Materials 1: An introduction to their properties & applications, M.F. Ashby and D.R.H. Jones, Butterworth Heinemann.
16. The Science and Design of Engineering Materials, J.P. Schaffer, A. Saxena, S.D. Antolovich, T.H. Sanders and S.B. Warner, Irwin.
17. Concrete: Microstructure, properties and materials, P.K. Mehta and P.J.M. Monteiro, McGraw Hill.
18. S K Sharma, "Civil Engineering and construction material," Khanna Publishing House.
19. Properties of concrete, A.M. Neville, Pearson.

BCE-053 Open Channel Flow

Course Outcomes: After completion of the course student will be able to:

CO1. Apply knowledge of fluid flow for designing of channel sections.
CO2. Analyze the gradually varied flow in channel section.
CO3. Analyze the rapidly varied flow in channel sections.
CO4. Apply numerical methods for profile computation in channels.
CO5. Design channels for sub critical and super critical flows.

Syllabus:

Unit-1	**INTRODUCTION:** Basic concepts of free surface flows, velocity and pressure distribution, Mass, energy and momentum principle for prismatic and non-prismatic channels, Review of Uniform flow: Standard equations, hydraulically efficient channel sections, compound sections	8
Unit-2	**GRADUALLY VARIED FLOW (GVF):** Equation of gradually varied flow and its limitations, flow classification and surface profiles, Control sections, Computation methods and analysis: Integration of varied flow equation by analytical, graphical and advanced numerical methods, Transitions of subcritical and supercritical flow, flow in curved channels.	8
Unit-3	**RAPIDLY VARIED FLOW (RVF):** Characteristics of rapidly varied flow, Classical hydraulic jump, Evaluation of the jump elements in rectangular and non-rectangular channels on horizontal and sloping beds, Hydraulic jump in gradually and suddenly expanding channels, submerged hydraulic jump, rolling and sky jump, use of jump as an energy dissipater. **RAPIDLY VARIED UNSTEADY FLOW:** Equation of motion for unsteady flow, "Celerity" of the gravity wave, deep and shallow water waves, open channel positive and negative surge.	8

Unit-4	**SPATIALLY VARIED FLOW (SVF):** Basic principles, Differential SVF equations for increasing and decreasing discharge, Classifications and solutions, Numerical methods for profile computation, low over side-weir and Bottom-rack.	8
Unit-5	Flow in channel of non-linear alignment and non-prismatic channel sections, Design considerations for sub critical and super critical flows, Design of culvert.	8

References:

1. Chow, V.T., Open channel Hydraulics, McGraw Hill International.
2. Henderson, F.M., Open Channel Flow, McGraw Hill International.
3. Subramanya, K., Flow in Open Channels, Tata McGraw Hill.
4. Ranga Raju, K.G., Flow through open channels, T.M.H.
5. M. Hanif Chaudhry, Open Channel Flow, PHI.
6. French, R.H., Open channel Hydraulics, McGraw Hill International.
7. Srivastava, Flow through Open Channels, Oxford University Press.
8. Open Channel Flow by Madan Mohan Das.

BCE-054 Engineering Geology

Course Outcomes: After completion of the course student will be able to:

CO1. Understand the scope of geological studies.

CO2. Understand the rocks and its engineering properties.

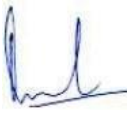
CO3. Understand the minerals and constituents of rocks.

CO4. Understand the rock deformations, their causes effects and preventive measures.

CO5. Understand the ground water reserves, Geophysical exploration methods and site selection for mega projects.

Syllabus:

Unit-1	**INTRODUCTION:** Branches of geology useful to civil engineering, scope of geological studies in various civil engineering projects. Department dealing with this subject in India and their scope of work- GSI, Granite Dimension Stone Cell, NIRM. Mineralogy-Mineral, Origin and composition. Physical properties of minerals, susceptibility of minerals to alteration, basic of optical mineralogy, SEM, XRD., Rock forming minerals, mega scopic identification of common primary & secondary minerals.	8
Unit-2	**STUDY OF ROCKS:** Introduction and importance of Geological knowledge. Rocks: their origin, structure and texture. Classification of igneous, sedimentary and metamorphic rocks and their suitability as engineering materials, Weathering and erosion of rocks, Stratification, Lamination bedding.Outcrop-its relation to topography. Dip and Strike of bed. Overlap, outlier and Inlier. Building stones and their engineering properties.	8
Unit-3	**STUDY OF MINERALS**: Physical properties of minerals. Detailed study of certain rock forming minerals. Alkaliaggregate reaction. Grouting. Pozzolonic materials.	8
Unit-4	**ROCK DEFORMATION & EARTHQUAKE:** Folds, Faults, Joints and unconformities: Their classification, causes and relation to engineering behavior of rock masses. Landslides, its causes and preventive measures. Earthquake, its causes, classification, seismic zones of India and its geological consideration.	8
Unit-5	**GEOPHYSICAL EXPLORATION AND GEOLOGICAL INVESTIGATION:** Geophysical exploration methods for sub-surface structure. Underground water and its origin. Aquifer & Aquiclude. Artesian wells. Underground provinces and its role as geological hazard. Site selection for dam, reservoir, tunnel, bridge and highway.	8



References:

1. D Venkat Reddy: Engg. Geology, Vikas Publication.
2. Tony Waltham: Foundations of Engg. Geology, Spon Press.
3. Tony Waltham: Foundations of Engineering Geology, SPON Press.
4. D Venkat Reddy: Engineering Geology, Vikas Publishing House Pvt. Ltd.
5. J M Treteth: Geology of Engineers, Princeton, Von. Nostrand.
6. K V G K Gokhale: Text book of Engineering Geology, B S Publication.
7. Prabin Singh: Engg. and General Geology, Katson Publishing House.
8. D S Arora: Geology for Engineers, Mohindra Capital Publishers, Chandigarh.
9. F G Bell: Fundamental of Engineering Geology, B S Publication.
10. Leggot R F: Geology and Engineering, McGraw Hill, New York.
11. P K Mukerjee: A Text book of Geology, Calcuta Word Publishers.
12. B S Sathya Narayanswami: Engineering Geology, Dhanpat Rai & Co.
13. Prakash Rao : Engineering Geology, Nirali Prakashan, Pune.

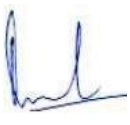
BCE-055 Engineering Hydrology

Course Outcomes: After completion of the course student will be able to:

CO1. Understand the basic concept of hydrological cycle and its various phases.
CO2. Understand the concept of runoff and apply the knowledge to construct the hydrograph.
CO3. Apply the various methods to assess the flood.
CO4. Assess the quality of various forms of water and their aquifer properties.
CO5. Understand the well hydraulics and apply ground water modelling techniques.

Syllabus:

Unit-1	**INTRODUCTION:** hydrologic cycle, water budget equations, world water balance. Precipitation types, measurements, analysis, mean precipitation, IDF and DAD analysis. Introduction to characteristics of storm. Abstraction from Precipitation: Evaporation – process, measurement and estimation; Evapotranspiration- measurement and estimation; Initial Losses- Interception & Depression storage; Infiltration- process, capacities indices, measurement & estimation.	8
Unit-2	**RUNOFF AND HYDROGRAPHS:** Runoff characteristics of stream, mass curve. Hydrograph, Factors affecting flood hydrographs, unit hydrograph and its analysis, s-curve hydrograph, synthetic and instantaneous unit hydrographs.	8
Unit-3	**FLOOD:** Rational method, empirical formulae, flood frequency studies, statistical analysis, regional flood frequency analysis, design storm & design flood, risk/reliability and safety factor. **FLOOD ROUTING:** Governing equations, Hydrologic routing: Reservoir flood routing, Muskingum method.	8
Unit-4	**GROUNDWATER:** Introduction, forms of subsurface water, aquifers & its properties, Occurrence of ground water, hydro-geology& aquifers, Ground water movement. Steady and unsteady flow through confined and unconfined aquifers. Well Hydraulics: Single& Multiple well system, partially penetrating wells, Image wells, Mutual interference of wells, well losses, specific capacity.	8
Unit-5	**WATER WELLS:** Introduction to Well construction, completion and Development. Pumping equipment for water wells, maintenance of wells. Ground Water quality, Contamination of groundwater and its Control, Ground Water Modelling Techniques and exploration, artificial discharge and Recharge of Ground Water.	8



Text Books:

1. 'Groundwater Hydrology' by Todd D. K., Wiley.
2. 'Groundwater Resource Evaluation' by Walton W. C., McGraw Hill.
3. 'Groundwater' by Raghunath H. M., New Age Publisher.
4. 'Engineering Hydrology' by K. Subramanya, Mc Graw Hill Education.
5. 'Hydrology: Principles. Analysis. Design' by Raghunath H. M., New Age Publisher.
6. 'Handbook of Applied Hydrology' by Chow V. T., Mc Graw Hill Education.

References:

1. 'Irrigation: Theory & Practice' by Michael A. M., Vikas Publication House.
2. 'Groundwater' by S.Ramakrishnan, Scitech Publications.
3. 'Irrigation: Theory & Practice' by Michael A. M., Vikas Publication House.
4. 'Engineering Hydrology' by Ojha, Oxford University Press.
5. 'Introduction to Hydrology' by Viessman& Lewis by Pearson Publication.
6. 'Applied Hydrology' by Fetter, by Pearson Publication.

BCE-056 Sensor and Instrumentation Technologies for Civil Engineering Applications

Course Outcomes: After completion of the course student will be able to:

CO1. Analyze the errors during measurements.
CO2. Describe the measurement of electrical variables.
CO3. Describe the requirements during the transmission of measured signals.
CO4. Construct Instrumentation/Computer Networks.
CO5. Suggest proper sensor technologies for specific applications.
CO6. Design and set up measurement systems and do the studies.

Syllabus:

Unit-1	Fundamentals of Measurement, Sensing and Instrumentation covering definition of measurement and instrumentation, physical variables, common types of sensors; Describe the function of these sensors; Use appropriate terminology to discuss sensor applications; and qualitatively interpret signals from a known sensor type, types of instrumentation, Sensor Specifics, Permanent installations, Temporary installations;	8
Unit-2	Sensor Installation and Operation covering to: i) Predict the response of sensors to various inputs; ii) Construct a conceptual instrumentation and monitoring program; iii) Describe the order and methodology for sensor installation; and iv) Differentiate between types of sensors and their modes of operation and measurement and v) Approach to Planning Monitoring Programs, Define target, Sensor selection, Sensor siting, Sensor Installation & Configuration, Advanced topic, Sensor design, Measurement uncertainty	8
Unit-3	Data Analysis and Interpretation covering a) Fundamental statistical concepts, b) Data reduction and interpretation, c) Piezometer, Inclinometer, Strain gauge, etc. d) Time domain signal processing, e) Discrete signals, Signals and noise and f) a few examples of statistical information to calculate are: Average value (mean), On average, how much each measurement deviates from the mean (standard deviation), Midpoint between the lowest and highest value of the set (median), Most frequently occurring value (mode), Span of values over which your data set occurs (range)	8
Unit-4	Frequency Domain Signal Processing and Analysis covering Explain the need for frequency domain analysis and its principles; Draw conclusions about physical processes based on analysis of sensor data; Combine signals in a meaningful way to gain deeper insight into physical phenomena, Basic concepts in frequency domain signal processing and analysis, Fourier Transform, FFT (Fast Fourier Transform),	8

	Example problems: Noise reduction with filters, Leakage, Frequency resolution.	

Text/Reference Books:

1. Alan S Morris (2001), Measurement and Instrumentation Principles, 3rd/e, Butterworth Hienemann.
2. David A. Bell (2007), Electronic Instrumentation and Measurements 2nd/e, Oxford Press.
3. S. Tumanski (2006), Principle of Electrical Measurement, Taylor & Francis Ilya Gertsbakh (2010), Measurement Theory for Engineers, Springer.

BCE-057 Air & Noise Pollution Control

Course Outcomes: After completion of the course student will be able to:

CO1. Understand air pollutants and their impacts.

CO2. Explain air pollution chemistry and meteorological aspects of air pollutants.

CO3. Demonstrate methods for controlling particulate air pollutants.

CO4. Demonstrate methods for controlling gaseous air pollutants.

CO5. Understand automotive emission standards.

CO6. Apply methods for controlling noise pollution.

Syllabus:

Unit-1	**AIR POLLUTION:** composition and structure of atmosphere, global implications of air pollution, classification of air pollutants: particulates, hydrocarbon, carbon monoxide, oxides of sulphur, oxides of nitrogen and photochemical oxidants. Indoor air pollution. Effects of air pollutants on humans, animals, property and plants.	8
Unit-2	Air pollution chemistry, meteorological aspects of air pollution dispersion; temperature lapse rate and stability, wind velocity and turbulence, plume behaviour, dispersion of air pollutants, the Gaussian Plume Model, stack height and dispersion.	8
Unit-3	Ambient air quality and standards, air sampling and measurements. Air Quality Index (AQI), Control of particulate air pollutants using gravitational settling chambers, cyclone separators, wet collectors, fabric filters (Bag-house filter), electrostatic precipitators (ESP).	8
Unit-4	Control of gaseous contaminants: Absorption, Adsorption, Condensation and Combustion, Control of sulphur oxides, nitrogen oxides, carbon monoxide, and hydrocarbons. Automotive emission control, catalytic convertor, Euro-I, Euro-II and Euro-III specifications, Indian specifications. Impact of Lockdown on Air Quality, National Policies for Managing the Ambient Air Quality (AAQ)	8
Unit-5	**NOISE POLLUTION:** Basics of acoustics and specification of sound; sound power, sound intensity and sound pressure levels; plane, point and line sources, multiple sources; outdoor and indoor noise propagation; psychoacoustics and noise criteria, effects of noise on health, annoyance rating schemes; special noise environments: Infrasound, ultrasound, impulsive sound and sonic boom; noise standards and limit values; noise instrumentation and monitoring procedure. Noise indices. Noise control methods.	8

References:

1. Peavy, Rowe and Tchobanoglous: Environmental Engineering.
2. Martin Crawford: Air Pollution Control Theory.
3. Wark and Warner: Air Pollution: Its Origin and Control.
4. Rao and Rao: Air Pollution Control Engineering.
5. Nevers: Air Pollution Control Engineering.
6. Mycock, McKenna and Theodore: Handbook of Air Pollution Control Engineering and Technology.Suess and Craxford: W.H.O. Manual on Urban Air Quality Management.
7. C.S. Rao, Air pollution and control.

8. Advanced Air and Noise Pollution Control by Lawrence K. Wang, Norman C. Pereira & Yung IseHung.
9. Noise Pollution and Control by S. P.Singhal , Narosa Pub House.
10. Textbook of Noise Pollution and Its Control by S. C. Bhatia, Atlantic; Edition.

BCE-058 GIS and Advance Remote Sensing

Course Outcomes: After completion of the course student will be able to:

CO1. Understand the concepts of Photogrametry and compute the heights of objects.

CO2. Understand the principles of aerial and satellite remote sensing, Able to comprehend the energy interactions with earth surface features, spectral properties of water bodies.

CO3. Understand the basic concept of GIS and its applications, know different types of data representation in GIS.

CO4. Understand and Develop models for GIS spatial Analysis and will be able to know what the questions that GIS can answer are.

CO5. Illustrate spatial and non-spatial data features in GIS and understand the map projections and coordinates systems.

CO6. Apply knowledge of GIS and understand the integration of Remote Sensing and GIS.

Syllabus:

Unit-1	**INTRODUCTION TO PHOTOGRAMMETRY:** Principles and types of aerial photographs, geometry of vertical and aerial photograph, Scale and Height measurement on single and vertical aerial photograph, Height measurement based on relief displacement, Fundamentals of Stereoscopy, fiducial points, parallax measurement using fiducial line.	8
Unit-2	Remote sensing Basic concepts and foundation of Remote Sensing elements, Data information, Remote sensing data collection, Remote sensing advantages and Limitations, Remote sensing process. Electromagnetic spectrum, Energy interaction with atmosphere and with earth surface features (soil, water, and vegetation) Indian Satellites and Sensors characteristics, Map and Image false color composite, introduction to digital data, elements of visual interpretations techniques.	8
Unit-3	Geographic Information Systems Introduction to GIS, Components of GIS, Geospatial data: Spatial Data – Attribute Data- Joining Spatial and Attribute Data, GIS Operations: Spatial Data input- Attribute Data Management-Data Display-Data Exploration-Data Analysis. COORDINATE SYSTEMS: Geographic Coordinate system; Approximation of Earth, Datum: Map Projections; Types of Map Projections-Map Projection Parameters-Commonly used Map Projections – Projected Coordinate Systems.	8
Unit-4	Vector data model Representation of simple features- Topology and its importance: coverage and its data structure, shape file:, data models for composite features Object Based Vector Data Model; Classes and their Relationships: The geobased data model: Geometric representation of Spatial feature and data structure: Topology rules.	8
Unit-5	Raster data model Elements of Raster data model: Types of Raster data: Raster data structure: Data conversion, Integration of Raster and Vector data. Data Input: Metadata: Conversion of Existing data, Creating new data, Remote sensing data, Field data, Digitizing, Scanning, on screen digitizing, importance of source map, Data Editing.	8

Text Books:

1. Remote Sensing of the environment- An earth resource perspective- 2nd edition- by John R. Jensen, Pearson Education.
2. Introduction to geographic information system- kang – Tsung Chang, Tata McGraw- Hill

Education Private Limited.

References:

1. Concepts & Techniques of GIS by C.P.Lo Albert, K.W. Yonng, Prentice Hall (India) Publications.
2. Remote Sensing and Geographical Information systems by M.Anji Reddy JNTU Hyderabad 2001, B.S. Publications.
3. Principals of Geo physical Information System- Peter A Burragh and Rachael A. Mc Donnell, Oxford Publishers 2004
4. Basics of Remote Sensing and GIS by S. Kumar, laxmi Publications.

DR. A.P.J. ABDUL KALAM TECHNICAL UNIVERSITY

UTTAR PRADESH, LUCKNOW

SYLLABUS
FOR

B.TECH. THIRD YEAR

CIVIL ENGINEERING

BASED ON

AICTE MODEL CURRICULUM & NEP2020

[Effective from the Session: 2024-25]

B.TECH. CIVIL ENGINEERING, IIIrd YEAR (VIth SEMESTER)

COURSE STRUCTURE

SIXTH SEMESTER CIVIL ENGINEERING SESSION 2024-25

S.No	Subject Code	Subject	Periods			Evaluation Scheme				End Semester		Total	Credit
			L	T	P	CT	TA	Total	PS	TE	PE		
1	BCE601	Design of Concrete Structures	3	1	0	20	10	30		70		100	4
2	BCE602	Transportation Engineering	3	1	0	20	10	30		70		100	4
3	BCE603	Environmental Engineering	3	1	0	20	10	30		70		100	4
4		**Departmental Elective-III**	**3**	**0**	**0**	**20**	**10**	**30**		**70**		**100**	**3**
	BCE061	Advanced Structural Analysis											
	BCE062	River Engineering											
	BCE063	Repair and Rehabilitation of Structures											
	BCE064	Foundation Design											
5		**Open Elective-I**	**3**	**0**	**0**	**20**	**10**	**30**		**70**		**100**	**3**
6	BCE651	Structural Detailing Lab	0	0	2				50		50	100	1
7	BCE652	Transportation Engineering Lab	0	0	2				50		50	100	1
8	BCE653	Environmental Engineering Lab	0	0	2				50		50	100	1
9	BNC60/ BNC602	Constitution of India, Law and Engineering / Indian Tradition, Culture and Society	2	0	0	20	10	30		70		100	Non-Credit
		Total	17	3	6							900	21

NOTE:

1. Regular classroom interaction with industry experts is to be ensured in all theory courses. (minimum two expert talks from relevant Industry)
2. Working on experiments using virtual labs is to be ensured in lab courses.
3. Student's visit to Industry/Industry Expert's project site must be arranged as & when possible.

BCE 601: Design of Concrete Structures

(L-T-P: 3-1-0) Credits: 4
Total Contact Hours: 40

Course Objectives:

- To introduce the fundamental principles of reinforced concrete design based on Indian Standards.
- To develop the ability to apply IS Codes in the design and detailing of structural elements.
- To enable students to analyze, evaluate, and create safe and economical RCC structural designs.

Course Outcomes (COs) with Bloom's Taxonomy Knowledge Levels (1–6):

CO	Course Outcome	Knowledge Level
CO1	Recall key IS codes, design philosophies, and basic RCC terminologies & learn WSM Method	*K1, K2*
CO2	Apply IS code provisions for designing beams and understanding shear behavior.	*K2, K3*
CO3	Analyze structural behavior and design of slabs and staircases.	*K3, K4*
CO4	Evaluate the design efficiency of columns for axial and biaxial loading conditions.	*K4, K5*
CO5	Designs for footings, retaining walls, and structural drawings with bar bending schedules.	*K4, K5*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Unit 1: Introduction to Design Philosophies (8 Hours)

- Design Philosophies: Working Stress Method (WSM) vs. Limit State Method (LSM)
- Basic Assumptions in RCC Design, Stress-Strain Relationships in Concrete and Steel
- Introduction to IS 456:2000 and Design Aids (SP-16)
- Design of RCC Beam by Working Stress Method

Unit 2: Design of RCC Beams by Limit State Method (LSM) (8 Hours)

- Design of Rectangular Singly and Doubly Reinforced Beams
- Design of T-Beams and L-Beams as per Limit State Method
- Analysis of Shear Strength, Design of Shear Reinforcement
- Development Length, Anchorage Bond, and Flexural Bond

Unit 3: Design of Slabs and Staircases by LSM (8 Hours)

- Design of One-Way, Two-Way, Continuous, and Cantilever Slabs
- Serviceability Limit States: Deflection, Cracking, and Vibration Control
- Design of Dog-Legged Staircases and Open-Well Staircases

Unit 4: Design of Compression Members (8 Hours)

- Classification of Columns: Short and Long Columns
- Design of Columns under Axial Load and Biaxial Bending
- Effective Length of Columns, Slenderness Ratio
- Ductile Detailing as per IS 13920:2016 for Seismic Design

Unit 5: Design of Footings and Retaining Walls (8 Hours)

- Design of Isolated, Combined, and Strap Footings
- Structural Behavior of cantilever and counterfort RW and Design of Retaining Walls (Cantilever Type)
- Stability Analysis: Overturning, Sliding, and Bearing Capacity Considerations

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suggested Reading Materials:

1. IS 456:2000 – Code of Practice for Plain and Reinforced Concrete
2. IS 13920:2016 – Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces
3. IS 1893:2016 – Criteria for Earthquake Resistant Design of Structures
4. SP-16 – Design Aids for Reinforced Concrete to IS 456:2000
5. SP-34 – Handbook on Concrete Reinforcement and Detailing
6. Reinforced Concrete Design by S. Unnikrishna Pillai & Devdas Menon
7. Limit State Design of Reinforced Concrete by A.K. Jain
8. Reinforced Concrete Structures by B.C. Punmia, Ashok Kumar Jain, Arun Kumar Jain
9. Design of Reinforced Concrete Structures by N. Krishna Raju
10. Reinforced Concrete Design by M.L. Gambhir
11. Fundamentals of Reinforced Concrete Design by S.N. Sinha

KCE 651: Structural Detailing Lab

(L-T-P: 0-0-2) Credits: 1
Total Contact Hours: 20 (10 Practical × 2 Hours Each)

Lab Objectives:

- To provide hands-on experience in reinforcement detailing of RCC structural elements as per IS codes.
- To develop the ability to prepare bar bending schedules (BBS) and interpret structural drawings.
- To enable students to apply seismic detailing practices as per IS 13920 and use basic BIM software tools for detailing.

Lab Outcomes (LOs) with Bloom's Taxonomy Knowledge Levels (1–6):

LO	Lab Outcome	Knowledge Level
LO1	Recall key IS codes (IS 456, IS 13920, SP-34, IS1893) related to reinforcement detailing.	*K1, K2*
LO2	Apply IS code provisions to prepare detailed drawings of beams, slabs, columns, and footings.	*K1, K2, K3*
LO3	Analyze structural drawings to identify detailing errors and suggest corrections.	*K2, K4*
LO4	Evaluate structural detailing for compliance with IS codes and seismic design standards.	*K2, K3, K5*
LO5	Create bar bending schedules (BBS) and detailed reinforcement drawings using BIM or drafting software.	*K2, K3, K6*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Experiments (Minimum 10 to be Performed):

1. Study and recall of IS codes (IS 456:2000, IS 13920:2016, SP-34, IS1893) for RCC detailing.
2. Preparation of hand sketches for detailing of simply supported and continuous RCC beams.
3. Detailing of RCC slabs (one-way and two-way) with reinforcement placement.
4. Detailing of RCC columns (tied and spirally reinforced) with lap splices and anchorage.
5. Detailing of isolated, combined, and strap footings as per IS codes.
6. Preparation of bar bending schedules (BBS) for beams, slabs, and columns.
7. Seismic detailing of RCC beams and columns as per IS 13920:2016.
8. Detailing of Masonry structures as per the IS codes.
9. Detailing of shear walls and understanding boundary elements for seismic resistance.
10. Introduction to structural detailing software (AutoCAD/Revit/Tekla/FOSSEE tools).
11. Structural modeling and reinforcement detailing using BIM tools for a simple RCC structure.

Suggested Reading Materials:

1. IS 456:2000 – Code of Practice for Plain and Reinforced Concrete
2. IS 13920:2016 – Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces
3. SP-34 – Handbook on Concrete Reinforcement and Detailing
4. SP-16 – Design Aids for Reinforced Concrete to IS 456:2000
5. Detailing of Reinforced Concrete Structures by S. S. Bhavikatti
6. Reinforced Concrete Detailing Manual by S. N. Sinha
7. AutoCAD/Revit Manuals for Practical Learning
8. FOSSEE Virtual Labs – https://fossee.in for open-source structural detailing tools

BCE 602: Transportation Engineering

(L-T-P: 3-1-0) Credits: 4
Total Contact Hours: 40

Course Objectives:

- To understand the fundamentals of road development, alignment, and highway planning.
- To analyze geometric design, traffic engineering principles, and highway material properties.
- To apply pavement design concepts, mix design, and construction techniques as per IRC guidelines.

Course Outcomes (COs) with Bloom's Taxonomy Knowledge Levels (1–6):

CO	Course Outcome	Knowledge Level
CO1	Recall the history of road development, road alignment principles, and water demand assessment methods.	*K1, K3*
CO2	Apply geometric design principles and IRC guidelines for highway design.	*K2, k3, K4*
CO3	Analyze traffic flow characteristics, intersection design, and traffic signal systems.	*K3, k4*
CO4	Evaluate pavement materials, design flexible and rigid pavements, and assess performance efficiency.	*K2, K4, K5*
CO5	Learn highway construction plans integrating modern technologies and sustainable practices.	*K4, K5*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Unit 1: Introduction to Transportation Systems (8 Hours)

- Role of Transportation in Economic Development
- Modes of Transportation: Road, Rail, Air, and Water
- History of Road Development: Nagpur, Bombay, and 20-Year Road Plans
- Highway Alignment: Factors, Surveys, and Route Selection

Unit 2: Geometric Design of Highways (8 Hours)

- Geometric Design Standards (IRC:73-Latest Revision)
- Cross-Sectional Elements, Camber, Super-elevation, and Extra Widening
- Design of Horizontal and Vertical Curves
- Application of AutoCAD Civil 3D for Highway Design

Unit 3: Traffic Engineering and Management (8 Hours)

- Traffic Characteristics: Volume, Speed, Flow, Density

- Traffic Studies: O-D Surveys, Speed Studies, Accident Analysis
- Design of Traffic Signals: Webster's Method, IRC Guidelines
- Introduction to Intelligent Transportation Systems (ITS) and Traffic Simulation (SuMo/OTS/MatSim/VISSIM/Synchro/Free Open Sourced Softwares)
- Design of Intersections (At-grade and Grade-separated), Roundabouts (IRC:65-2017)

Unit 4: Pavement Materials, Mix Design, and Pavement Design (8 Hours)

- Properties and Testing of Subgrade, Aggregates, and Bituminous Materials
- Introduction to Mix Design Concepts and Job Mix Formula (JMF)
- Mix Design for WMM, WBM, BC, DBM as per IRC and MORTH Guidelines
- Design of Flexible Pavement (IRC:37) & Rigid Pavement (IRC:58)
- Introduction to Pavement Management Systems (PMS)

Unit 5: Highway Construction and Sustainable Practices (8 Hours)

- Construction of WBM, WMM, Bituminous, and Cement Concrete Roads
- Green Highway Concepts, Sustainable Road Construction, and Use of Recycled Materials
- Quality Control Measures in Highway Construction
- Case Studies: National Highway Projects and Metro Rail Systems in India

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Suggested Reading Materials:

Textbooks:

1. Khanna, S.K., Justo, C.E.G., & Veeraragavan, A. - *Highway Engineering*
2. Khanna, S.K., Justo, C.E.G. - *Highway Materials and Pavement Testing*

References:

1. Kadiyali, L.R. - *Principles and Practices of Highway Engineering*
2. Saxena, Subhash C. - *Highway and Traffic Engineering*
3. Chakraborty, Partha & Das, Animesh - *Principles of Transportation Engineering*

IRC Codes (Latest Revisions):

- IRC:37 (Flexible Pavement Design)
- IRC:58 (Rigid Pavement Design)
- IRC:65 (Design of Roundabouts)
- IRC:106 (Urban Road Capacity Guidelines)
- MORTH Specifications

BCE 652: Transportation Engineering Lab

(L-T-P: 0-0-2) Credits: 1
Total Contact Hours: 20 (10 Practical × 2 Hours Each)

Lab Objectives:

- To provide hands-on experience with standard testing procedures for highway materials.
- To develop practical skills in conducting traffic studies and analyzing data.
- To understand the application of Job Mix Formula (JMF) and mix design in pavement construction.
- To evaluate material performance through laboratory tests as per IRC guidelines.
- To apply laboratory findings for real-world highway engineering solutions.

Lab Outcomes (LOs):

LO	Lab Outcome	Knowledge Level
LO1	Recall standard procedures for material testing as per IRC guidelines.	*K1, K2*
LO2	Apply standard methods to test aggregates, bitumen, and subgrade materials.	*K1, K2, K3*
LO3	Analyze traffic survey data, material test results, and mix designs.	*K1, K2, K4*
LO4	Evaluate pavement quality based on laboratory and field test data.	*K2, K4, K5*
LO5	Create Job Mix Formulas (JMF) and comprehensive lab reports for highway materials.	*K3, K6*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Experiments (Minimum 10 to be Performed):

1. Determination of Crushing & Impact Value of Aggregates
2. Determination of Density and specific gravity of Aggregates
3. Flakiness and Elongation Index of Aggregates
4. Los Angeles Abrasion Test
5. Penetration and viscosity grade Test on Bitumen
6. Marshall Mix Design for Bituminous Concrete (BC) as per IRC:111-2009
7. Job Mix Formula (JMF) for Wet Mix Macadam (WMM)
8. Mix Design for Dense Bituminous Macadam (DBM) and Derivation of JMF
9. California Bearing Ratio (CBR) Test (Lab and Field)
10. Traffic Volume Study Using Manual and Automated Counters
11. Traffic Speed Study Using Radar Speed Gun

Lab References:

1. Khanna, S.K., Justo, C.E.G. - *Highway Materials and Pavement Testing*
2. Duggal, Ajay K. - *Laboratory Manual in Highway Engineering*
3. Gambhir, M.L. - *Lab Manual for Construction Materials Testing*
4. FOSSEE Virtual Labs for Traffic Simulation Experiments
5. IRC:111-2009 - *Specifications for Bituminous Concrete Mix Design*
6. MORTH Specifications for Road and Bridge Works

BCE 603: Environmental Engineering

(L-T-P: 3-1-0) Credits: 4
Total Contact Hours: 40

Course Objectives:

- To understand the principles of water supply, treatment, and wastewater management.
- To develop skills in the design of water distribution systems and wastewater treatment plants.
- To assess the environmental impact of water-related projects and promote sustainable practices.

Course Outcomes (COs) with Bloom's Taxonomy Knowledge Levels (1–6):

CO	Course Outcome	Knowledge Level
CO1	Recall basic concepts of freshwater resources, water demand, and transmission systems.	*K1, K2*
CO2	Apply principles of water storage and distribution system design.	*K2, K3*
CO3	Analyze physical, chemical, and biological parameters of water and wastewater.	*K3, K4*
CO4	Evaluate the efficiency of water and wastewater treatment processes.	*K4, K5*
CO5	Apply sustainable wastewater treatment solutions using emerging technologies.	*K3,K4, K5*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Unit 1: Introduction to Water Supply Systems (8 Hours)

- Freshwater resources, water demand assessment, factors affecting consumption
- Population forecasting methods
- Design period, variation in demand
- Transmission of water: Types of conduits, economical sizes, structural requirements
- Laying, testing, and leakage control in water supply pipelines

Unit 2: Water Storage and Distribution Systems (8 Hours)

- Storage methods, service reservoirs, balancing reservoirs
- Design and layout of water distribution systems (gravity, pumping, and combined systems)
- General guidelines for the design of distribution networks
- Use of SCADA/WaterGEM/Open Source Free Software in water distribution monitoring
- Study of GIS based water distribution analysis, important aspect of Smart City.

Unit 3: Water Quality Assessment (8 Hours)

- Physical, chemical, and bacteriological examination of water and wastewater

- Key parameters: pH, turbidity, BOD, COD, TDS, heavy metals, nutrients
- Water quality standards (IS 10500, WHO guidelines)
- Impact of wastewater disposal on land and water bodies

Unit 4: Water Treatment Processes (8 Hours)

- Objectives of water treatment: Unit operations and flow diagrams
- Sedimentation, coagulation, filtration, and disinfection
- Design of sedimentation tanks, grit chambers, and filters
- Disinfection techniques (chlorination, ozonation, UV)
- Advanced treatment: Membrane filtration, ion exchange, and desalination techniques

Unit 5: Wastewater Treatment and Emerging Technologies (8 Hours)

- Primary, secondary, and tertiary treatment processes
- Activated sludge process, trickling filters, anaerobic digesters
- Design of septic tanks and UASB reactors
- Emerging technologies: MBR, MBBR, constructed wetlands, and AOPs
- Basics of Environmental Impact Assessment (EIA) for water projects

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Suggested Reading Materials:

Textbooks:

1. Peavy, Howard S., Rowe, Donald R., & Tchobanoglous, George - *Environmental Engineering*, McGraw Hill.
2. Metcalf & Eddy - *Wastewater Engineering: Treatment & Reuse*, Tata McGraw Hill.
3. Garg, S.K. - *Water Supply Engineering* (Environmental Engineering Vol. I)
4. Garg, S.K. - *Sewage Disposal and Air Pollution Engineering* (Environmental Engineering Vol. II)
5. Davis, M.L., & Cornwell, D.A. - *Introduction to Environmental Engineering*, McGraw Hill.

References:

1. Manual on Water Supply and Treatment, CPHEEO, Govt. of India
2. Manual on Sewerage and Sewage Treatment, CPHEEO, Govt. of India
3. Steel & McGhee - *Water Supply and Sewerage*
4. Hammer & Hammer Jr. - *Water and Wastewater Technology*
5. Punmia - *Water Supply and Wastewater Engineering*
6. Davis & Cornwell - *Introduction to Environmental Engineering*

BCE 653: Environmental Engineering Lab

(L-T-P: 0-0-2) Credits: 1
Total Contact Hours: 20 (10 Practical × 2 Hours Each)

Lab Objectives:

- To provide hands-on training in water and wastewater quality analysis.
- To develop skills for environmental monitoring using standard equipment.
- To enable students to interpret laboratory data for water treatment design.

Lab Outcomes (LOs) with Bloom's Knowledge Taxonomy Levels (1–6):

LO	Lab Outcome	Knowledge Level
LO1	Recall standard procedures for water and wastewater quality analysis.	*K1, K2*
LO2	Apply standard methods to determine physical, chemical, and biological parameters.	*K3, k4*
LO3	Analyze environmental data from water and wastewater samples.	*K4, k5*
LO4	Evaluate water quality against national and international standards.	*K4, k5*
LO5	Design laboratory protocols for advanced water and wastewater testing.	*K5*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Experiments (Minimum 10 to be Performed):

1. Determination of turbidity and conductivity
2. Determination of pH, alkalinity, and acidity
3. Determination of hardness and chloride content
4. Determination of residual chlorine
5. Determination of MPN (Most Probable Number) of coliforms
6. Measurement of Suspended Particulate Matter (SPM) and PM10 using a high-volume sampler
7. Measurement of noise levels using a sound level meter
8. Determination of total, suspended, and dissolved solids
9. Determination of Biochemical Oxygen Demand (BOD)
10. Determination of Chemical Oxygen Demand (COD)
11. Determination of Kjeldahl nitrogen
12. Determination of fluoride content
13. Jar Test for determination of optimum coagulant dose
14. Field Visit to nearby Water/Sewage Treatment Plant if not available then Jal Jeevan Mission Site *(Mandatory)*

Suggested Lab References:

1. APHA - *Standard Methods for the Examination of Water and Wastewater*
2. Sawyer, C.N., McCarty, P.L., & Parkin, G.F. - *Chemistry for Environmental Engineering*, McGraw Hill
3. Mathur, R.P. - *Water & Wastewater Testing: Lab Manual*, Roorkee
4. O.P. Gupta - *Environmental Chemistry*, Khanna Publishing
5. FOSSEE Virtual Labs for Environmental Monitoring

BCE061: Advanced Structural Analysis

(L-T-P: 3-0-0) Credits: 3
Total Contact Hours: 40

Course Objectives:

- To understand the analysis of indeterminate structures using classical and modern methods.
- To apply influence line principles in the analysis of beams, arches, and cable structures.
- To introduce matrix methods for analyzing structural systems.
- To develop the ability to perform plastic analysis of structures for advanced design scenarios.

Course Outcomes (COs) with Knowledge Levels (K1–K6):

CO	Course Outcome	Knowledge Level
CO1	Analyze indeterminate structures to calculate unknown forces, slopes, and deflections using different methods.	*K2, K3, K4*
CO2	Apply the principle of influence lines to analyze indeterminate beams and arches.	*K2, K3, K4*
CO3	Analyze and design cable structures along with their influence line diagrams.	*K3, K4, K5*
CO4	Apply basics of force and stiffness methods of matrix analysis for beams, frames, and trusses.	*K2, K3, K4*
CO5	Apply the basics of plastic analysis to analyze structures using different mechanisms.	*K3, K4, K5*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Unit 1: Analysis of Indeterminate Structures (8 Hours)

- Analysis of Fixed Beams and Continuous Beams
- Analysis of Simple Frames with and without Joint Translation
- Methods: Slope-Deflection Method, Moment Distribution Method, Strain Energy Method

Unit 2: Influence Lines and Arch Analysis (8 Hours)

- Muller-Breslau's Principle and Applications
- Drawing Influence Lines for Indeterminate Beams
- Analysis of Two-Hinged and Fixed Arches
- Influence Line Diagrams for Maximum Bending Moment, Shear Force, and Thrust
- Analysis of Two- and Three-Hinged Stiffening Girders

Unit 3: Suspension Bridges and Cable Structures (8 Hours)

- Introduction to Suspension Bridges
- Analysis of Two- and Three-Hinged Stiffening Girders

- Influence Line Diagrams for Maximum Bending Moment and Shear Force
- Design Principles for Cable Structures

Unit 4: Matrix Methods of Structural Analysis (8 Hours)

- Basic Concepts of Force and Displacement Matrix Methods
- Matrix Analysis of Beams, Frames, and Trusses
- Application of Stiffness and Flexibility Methods

Unit 5: Plastic Analysis of Structures (8 Hours)

- Basics of Plastic Analysis
- Applications of Static and Kinematic Theorems
- Plastic Analysis of Beams and Single-Storey Frames
- Mechanism Methods for Determining Collapse Loads

Suggested Reading Materials:

1. Jain, A. K. - *Advanced Structural Analysis*, Nem Chand & Bros., Roorkee
2. Hibbeler, R.C. - *Structural Analysis*, Pearson Prentice Hall
3. C. S. Reddy - *Structural Analysis*, Tata McGraw Hill
4. Timoshenko, S. P. & D. Young - *Theory of Structures*, Tata McGraw Hill
5. Dayaratnam, P. - *Analysis of Statically Indeterminate Structures*, Affiliated East-West Press
6. Wang, C. K. - *Intermediate Structural Analysis*, McGraw-Hill
7. Thandavamoorthy, T.S. - *Structural Analysis*, Oxford University Press
8. Martin, H. C. - *Introduction to Matrix Methods of Structural Analysis*, McGraw-Hill
9. Mau - *Introduction to Structural Analysis*, CRC Press
10. Ghali - *Structural Analysis: A Unified Classical and Matrix Approach*, CRC Press
11. Wilbur and Norris - *Elementary Structural Analysis*, Tata McGraw Hill
12. Vazirani & Ratwani - *Analysis of Structures*, Khanna Publishers
13. SP Gupta & Gupta - *Theory of Structure Vol.1 & 2*, TMH
14. DS Prakash Rao - *Structural Analysis: A Unified Approach*, Universities Press
15. S Ramamurtham - *Theory of Structure*, Dhanpat Rai
16. Devdas Menon - *Advanced Structural Analysis*, Narosa
17. Hsieh - *Elementary Theory of Structures*, Pearson Education
18. McKenzie - *Examples in Structural Analysis*, CRC Press
19. R Agor - *Structural Analysis*, Khanna Book Publishing
20. Jacques Heyman - *Structural Analysis*, Cambridge University Press

BCE062: River Engineering

(L-T-P: 3-0-0) Credits: 3
Total Contact Hours: 40

Course Objectives:

- To understand the fundamentals of river morphology and classification.
- To analyze river behavior, sediment transport, and channel dynamics.
- To develop skills in river restoration techniques, socio-cultural considerations, and ethical practices.
- To apply engineering principles for the design of river training and flood protection structures.

Course Outcomes (COs) with Knowledge Levels (K1–K6):

CO	Course Outcome	Knowledge Level
CO1	Explain river morphology, classification, and mechanics of alluvial rivers.	*K1, K2*
CO2	Describe hydraulic geometry, river channel behavior, and sediment transport mechanisms.	*K2, K3*
CO3	Explain socio-cultural influences, ethical considerations, and river restoration techniques.	*K2, K4*
CO4	Analyze flow patterns, sediment transport, and channel geometry using bio-engineering techniques.	*K3, K4, K5*
CO5	Design guide bands, embankments, and flood protection systems for river training and management.	*K4, K5*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Unit 1: Introduction to River Morphology (8 Hours)

- Classification of Rivers
- Mechanics of Alluvial Rivers
- Channel and Floodplain Features
- Sediment Transport and Budgets
- River Morphology and Classification Schemes

Unit 2: River Behavior and Hydraulic Geometry (8 Hours)

- River Channel Patterns
- Straight River Channels: Causes, Characteristics, and Control
- Meanders: Formation, Characteristics, and Control
- Braided Rivers, Bedforms, and Instability of Rivers
- Hydraulic Geometry and Delta Formation

Unit 3: Socio-Cultural Influences and River Restoration (8 Hours)

- Mechanics of Alluvial Rivers in Restoration
- Introduction to River Restoration Structures
- Socio-Cultural Influences and Ethics in Stream Restoration
- Case Studies of Successful River Restoration Projects

Unit 4: Bio-Engineering Techniques and Data Analysis (8 Hours)

- Bio-Engineering Techniques for River Management
- Natural Channel Design and Classification Review
- Time Series Analysis of Flow, Sediment, and Channel Geometry
- Modeling Tools for River Dynamics

Unit 5: River Training and Protection Works (8 Hours)

- Introduction to River Training Works
- Classification and Types of Training Works
- Bridge Protection with Reduced Waterways
- Design of Guide Bands, Embankments, Spurs/Dampeners
- Flood Protection Structures and Case Studies

Suggested Reading Materials:

1. *River Behavior Management and Training (Vol. I & II)*, CBI&P, New Delhi
2. *Irrigation & Water Power Engineering* by B.C. Punmia and Pande B.B. Lal
3. *River Engineering* by Margaret Peterson
4. *Principles of River Engineering (The Non-Tidal Alluvial Rivers)* by P.H. Jameen

BCE063: Repair and Rehabilitation of Structures

(L-T-P: 3-0-0) Credits: 3
Total Contact Hours: 40

Course Objectives:

- To understand the fundamentals of structural maintenance, repair, and rehabilitation.
- To identify factors affecting serviceability and durability of concrete structures.
- To explore various materials and advanced techniques used in repair works.
- To select appropriate repair, rehabilitation, and retrofitting methods based on the structural condition.
- To apply health monitoring techniques and demolition methods for deteriorated structures.

Course Outcomes (COs) with Knowledge Levels (K1–K6):

CO	Course Outcome	Knowledge Level
CO1	Understand the fundamentals of maintenance, repair strategies, and causes of deterioration.	*K1, K2*
CO2	Identify serviceability and durability issues related to concrete structures.	*K2, K4*
CO3	Know the materials and techniques used for repair of structures, including specialized concretes.	*K2, K3*
CO4	Decide on appropriate repair, rehabilitation, and retrofitting techniques based on structural conditions.	*K3, K5*
CO5	Use suitable health monitoring techniques and engineered demolition methods for dilapidated structures.	*K4, K5*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Unit 1: Maintenance and Repair Strategies (8 Hours)

- Introduction to Maintenance, Repair, and Rehabilitation
- Importance of Maintenance and Causes of Deterioration
- Various Aspects of Inspection and Assessment Procedures
- Causes of Distress: Design Failures, Construction Defects
- Diagnostic Techniques and Condition Assessment Methods

Unit 2: Serviceability and Durability of Concrete (8 Hours)

- Quality Assurance in Concrete Construction
- Concrete Properties: Strength, Permeability, Thermal Effects, Cracking
- Environmental Impacts: Climate, Temperature, Chemical Exposure, Corrosion
- Durability Concerns for Long-Term Serviceability

Unit 3: Materials and Techniques for Repair (8 Hours)

- Special Concretes: Polymer Concrete, Fiber-Reinforced Concrete, Bacterial Concrete
- Advanced Repair Materials: Expansive Cement, Sulphur-Infiltrated Concrete
- Repair Techniques: Epoxy Injection, Mortar Repair, Shoring, Underpinning
- Specialized Methods: Gunite, Shotcrete, Vacuum Concrete, Dry Pack, Foamed Concrete
- Coating Techniques for Rebars: Rust Eliminators, Polymer Coatings

Unit 4: Repair, Rehabilitation, and Retrofitting Techniques (8 Hours)

- Repairs for Structural Issues: Low Strength, Cracking, Deflection, Corrosion, Chemical Disruption
- Rehabilitation Methods for Concrete Structures and Underwater Repairs
- Strengthening Techniques: Jacketing, Retrofitting, Load Redistribution
- Techniques for Marine Exposure and Fire-Damaged Structures

Unit 5: Health Monitoring and Demolition Techniques (8 Hours)

- Long-Term Structural Health Monitoring Systems
- Use of Sensors for Building Instrumentation and Condition Monitoring
- Engineered Demolition Techniques for Dilapidated Structures
- Advanced Monitoring Methods: Non-Destructive Testing (NDT) and Instrumentation

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Suggested Reading Materials:

1. *Concrete Technology* by A.R. Santakumar, Oxford University Press
2. *Defects and Deterioration in Buildings*, E F & N Spon, London
3. *Non-Destructive Evaluation of Concrete Structures* by Bungey, Surrey University
4. *Maintenance and Repair of Civil Structures* by B.L. Gupta and Amit Gupta, Standard Publications
5. *Concrete Repair and Maintenance Illustrated* by W.H. Ranso, RS Means Company Inc.
6. *Building Failures: Diagnosis and Avoidance*, E F & N Spon, London
7. *Concrete: Microstructure, Properties, and Materials* by P.K. Mehta and P.J. Montevic, ICI
8. *Civil Engineering Materials* by N. Jackson, ELBS

BCE064: Foundation Design

(L-T-P: 3-0-0) Credits: 3
Total Contact Hours: 40

Course Objectives:

- To understand the methods of soil exploration and its importance in foundation engineering.
- To analyze bearing capacity and settlement for shallow foundations.
- To design various types of shallow foundations and understand the basics of deep foundations.
- To understand the characteristics of well foundations and retaining walls.
- To explore the concept and application of soil reinforcement in foundation design.

Course Outcomes (COs) with Knowledge Levels (K1–K6):

CO	Course Outcome	Knowledge Level
CO1	Understand various methods of soil exploration, including boring, drilling, and in-situ tests.	*K1, K2*
CO2	Analyze bearing capacity and settlement of soil for shallow foundations using established theories.	*K2, K4*
CO3	Design different types of shallow foundations and understand the basics of deep foundations.	*K3, K5*
CO4	Understand the characteristics, forces, and construction techniques of well foundations and retaining walls.	*K2, K4*
CO5	Understand the concept of soil reinforcement and its application in foundation design.	*K3, K5*

K1- Remember, K2- Understand, K3- Apply, K4- Analyze, K5- Evaluate, K6- Create

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Unit 1: Soil Exploration and In-Situ Testing (8 Hours)

- Introduction to Soil Exploration
- Methods of Boring and Drilling
- Soil Sampling Techniques and Sampler Types
- In-Situ Tests: Standard Penetration Test (SPT), Cone Penetration Test (CPT), Dynamic Cone Penetration Test (DCPT)
- Geophysical Methods: Soil Resistivity, Seismic Refraction

Unit 2: Bearing Capacity and Settlement of Shallow Foundations (8 Hours)

- Bearing Capacity: Design Criteria and Factors Affecting Bearing Capacity
- Selection of Foundation Depth
- Modes of Shear Failures
- Theories of Bearing Capacity: Terzaghi's, Meyerhof, Hansen's, and IS Code Methods
- Settlement of Shallow Foundations: Immediate, Consolidation, and Differential Settlement

Unit 3: Design of Shallow and Deep Foundations (8 Hours)

- Principles of Shallow Foundation Design
- Design of Isolated and Strip Footings
- Introduction to Deep Foundations: Necessity and Applications
- Pile Foundations: Installation, Group Action in Sand and Clay, Group Efficiency
- Settlement of Piles, Negative Skin Friction, Under-Reamed Piles

Unit 4: Well Foundations and Retaining Structures (8 Hours)

- Introduction to Well Foundations: Shapes, Characteristics, and Components
- Forces Acting on Well Foundations
- Sinking of Wells: Causes and Remedies for Tilts and Shifts
- Retaining Walls: Types, Support Systems, and Construction Methods
- Introduction to Sheet Piles and Their Uses

Unit 5: Soil Reinforcement Techniques (8 Hours)

- Geotechnical Properties of Reinforced Soil
- Applications of Soil Reinforcement
- Shallow Foundations on Reinforced Soil: Design Considerations
- Idealized Soil Models and Interface Behavior
- Elastic Models of Soil Behavior in Reinforced Foundations

Suggested Reading Materials:

1. Alamsingh - *Soil Mechanics & Foundation Engineering*, CBS Publishers & Distributors, Delhi
2. Taylor D.W. - *Fundamentals of Soil Mechanics*, Asia Publishing House, Mumbai
3. Das Braja M. - *Principles of Geotechnical Engineering*, Thomson Asia Pvt. Ltd.
4. Joseph E. Bowles - *Foundation Analysis and Design*, McGraw-Hill Higher Education
5. Gopal Ranjan & A.S.R. Rao - *Basic and Applied Soil Mechanics*, New Age International Pvt. Ltd.
6. Arora K.R. - *Soil Mechanics & Foundation Engineering*, Standard Publishers, Delhi
7. B.C. Punmia - *Soil Mechanics & Foundation Engineering*, Laxmi Publications Pvt. Ltd., Delhi
8. V.N.S. Murthy - *Soil Mechanics & Foundation Engineering*, Sai Kripa Technical Consultants, Bangalore
9. P. Purushothama Raj - *Soil Mechanics and Foundation Engineering*, Pearson Education
10. I.H. Khan - *Textbook of Geotechnical Engineering*
11. C. Venkataramaiah - *Geotechnical Engineering*
12. Shenbaga R Kaniraj - *Design Aids in Soil Mechanics and Foundation Engineering*
13. Gulati, S.K. - *Geotechnical Engineering*, McGraw Hill Education (India) Pvt. Ltd., Noida