

# Department of Civil Engineering

## **CVL100 Environmental Science**

2 credits (2-0-0)

Pollutant sources and control in air and water, solid waste management, noise pollution and control, cleaner production and life cycle analysis, reuse, recovery, source reduction and raw material substitution, basics of environmental impact assessment, environmental risk assessment and environmental audit, emerging technologies for sustainable environmental management, identification and evaluation of emerging environmental issues with air, water, wastewater and solid wastes.

## **CVL111 Elements of Surveying**

4 credits (3-0-2)

Introduction to Surveying, Levels, Theodolites, total station. Measurement of distances, directions and elevations. Traversing. Trigonometric levelling. Mapping and contouring. Measurement of areas, volumes. Quantity computations. Errors of measurements and their adjustments. Curve setting: simple, compound and reverse curves. Introduction to GPS, Differential GPS, Remote sensing techniques and application in land use change and mapping, aerial surveying, photogrammetry.

## **CVL121 Engineering Geology**

3 credits (3-0-0)

Engineering Geology: Introduction; Dynamic Earth; Origin, Age, Interior, Materials of Earth; Silicate Structures and Symmetry Elements; Physical properties, Formation of Rocks ;Igneous, Sedimentary and Metamorphic processes and structures, Characterisation; Weathering Processes; Geological Work of Rivers, Glaciers, Wind and Sea/Oceans, Deposits and Landforms; Formation of Soils; Geological Time Scale; Structural Features, Attitude of beds, Folds, Joints, Faults, Plate tectonics; Stress Distribution; Geophysical methods, Earthquakes. Engineering Properties of Rocks; Rock as Construction Material; Geological Site Criteria for Tunnels and Underground Structures, Foundations, Dams, Rock Slopes and Landslides.

## **CVP121 Engineering Geology Lab**

1 credit (0-0-2)

*Pre-requisites: CVL121 or concurrent with CVL121*

Geological Maps, Geological Mapping – contouring, topo sheets, outcrops, apparent and true dips, three point problems, depth and thickness problems, joints, faults; Megascopic and Microscopic identification of Minerals and Rocks, Engineering properties of rocks, refraction and resistivity methods, Guided tour through representative geological formations and structures.

## **CVL141 Civil Engineering Materials**

3 credits (3-0-0)

Mechanical properties of engineered materials, Temperature and time effects. Failure and safety. Non-mechanical properties. Durability. Nature of materials, classes of materials based on bonding, inorganic and organic solids. Variability in materials and its implication on measurement. Cement based materials, concrete production and processes; properties. Steel and other metals used in construction. Bricks and Masonry; wood and engineered wood products; glass and heat transmission properties. Polymers for construction and maintenance of infrastructure. Composites: fiber reinforced composites, particle reinforced composites. Introduction to sustainable materials.

## **CVL212 Environmental Engineering**

4 credits (3-0-2)

*Pre-requisites: CVL100*

Water and wastewater treatment overview; Unit processes: systems of water purification, processes (sedimentation, coagulation-flocculation, softening, disinfection, adsorption, ion exchange, filtration) and kinetics in unit operation of water purification-theory and design aspects; distribution of water layout systems: design aspects; Wastewater engineering: systems of sanitation, wastewater collection systems design and flows; Characteristics and microbiology of wastewater, BOD kinetics; Unit processes for wastewater treatment

(screening, sedimentation; biological aerobic and anaerobic process)-theory and design aspects; Biological processes (Nutrient and phosphorous removal); advanced wastewater treatment-theory and design aspects; Air pollution (health effects, regulatory standards, dispersion; stacks, control systems); Municipal solid waste management; Noise pollution.

## **CVL222 Soil Mechanics**

3 credits (3-0-0)

Origin and Classification of Soils; Phase Relationships; Effective Stress Principle; Effective Stress Under Hydrostatic and 1D flow; Permeability; Flow Through Soils–Laplace equation, flownets, seepage; Contaminant Transport; Compressibility; Consolidation; Terzaghi's 1D Consolidation Theory; Shear Strength; Drainage Conditions; Pore Water Pressure; Mohr's Circle; Failure Envelope and Strength Parameters; Factors Affecting Shear Strength; Critical State frame work; Behaviour of soils under cyclic loading, Liquefaction; Compaction; Engineering properties of Natural soils, Compacted Soils and modified soils; Site Investigations; Soil deposits of India.

## **CVP222 Soil Mechanics Lab**

1 credit (0-0-2)

*Pre-requisites: CVL222 or concurrent with CVL222*

Visual Soil Classification; Water Content; Atterberg Limits; Grain Size Analysis; Specific Gravity; Permeability; standard proctor compaction test, consolidation test, site investigations and introduction to triaxial testing.

## **CVL242 Structural Analysis I**

3 credits (3-0-0)

*Pre-requisites: APL108*

General Concept of Static Equilibrium of Structures, Concept of Free Body Diagram, Analysis of Statically Determinate Trusses, Energy Methods for Determination of Joint Displacements - Castigliano Theorem, Unit Load Method etc., Introduction to Analysis of Statically Indeterminate Trusses using Energy Methods, Analysis Statically Determinate Beams - Moment Area Theorem, Conjugate Beam Method, Maxwell Betti Theorem, Method of Superposition, Application of Energy Methods to Statically Determinate Beams and Rigid Frames, Solving Simple Indeterminate Beams Structures using Energy Methods, Analysis of Rolling Loads and Influence Line Diagram, Analysis of Arches and cable structures.

## **CVP242 Structural Analysis Lab**

1 credit (0-0-2)

*Pre-requisites: CVL242 or Concurrent with CVL242*

Determination of forces and displacements in statically determinate and indeterminate trusses, Influence Line Diagram for Trusses, Measurement of bending moment and shear forces in beams, Determination of Elastic Properties of Beams, Verification of the Moment Area Theorem, Maxwell Betti Theorem, Influence Line Diagram for Displacement, Support Reaction, Shear Force at an Intermediate Section and Bending Moment, Determination of Carry over Factor, Verification of Carry Over Factor, Determination of displacements in curved members, Analysis of Elastically Coupled Beams, Determination of horizontal reactions in two and three hinged arches, experiment on cable structures.

## **CVL243 Reinforced Concrete Design**

3 credits (3-0-0)

*Pre-requisites: CVL141*

Design Philosophy: Working stress and limit state design concepts; Design of and detailing of RC beam sections in flexure, shear, torsion and bond; Design for serviceability; Design of RC beams, One way and two way RC slabs, RC short and long columns, RC footings.

## **CVP243 Materials and Structures Laboratory Concrete**

1.5 credits (0-0-3)

Testing of cement, testing of aggregates, mixture design and testing, non-destructive tests, testing of reinforcement, behaviour of reinforced

concrete beams under flexure and torsion, behaviour of reinforced concrete slabs under uniform and point loads, behaviour of reinforced concrete columns under concentric and eccentric loads.

### **CVL244 Construction Practices**

2 credits (2-0-0)

*Pre-requisites: EC35*

Introduction and role of technologies, Construction technologies in RC Buildings for Reinforcement, Formwork, and concreting activities, Excavation and Concreting equipment, Formwork material and Design Concepts, Formwork system for Foundations, walls, columns, slab and beams and their design, Flying Formwork such as Table form, tunnel form. Slipform, temporary structures failure, Determining construction loads and ensuring safety of slabs during construction of high rise buildings- shoring, reshoring, preshoring and backshoring technology, Top down construction technology for high rise and underground construction, Bridge construction including segmental construction, incremental construction and push launching techniques, Prefab construction.

### **CVL245 Construction Management**

2 credits (2-0-0)

*Pre-requisites: EC35*

Introduction to construction projects, stakeholders, phases in a project, Cost estimation from clients perspective, Project selection using time value of money concept, construction contract, cost estimate – contractors perspective, Project planning and network analysis-PERT, CPM, and Precedence Network, Resource scheduling, Time Cost trade off, Time -cost monitoring and control using S-curve and earned value analysis, Construction claims and disputes, and introduction to construction quality and safety.

### **CVL261 Introduction to Transportation Engineering**

3 credits (3-0-0)

*Pre-requisites: CVL111*

Transportation systems and their classification; Role of transportation with respect to socio-economic conditions; Transportation planning process; Road user and the vehicle; Geometric design of roads: horizontal alignment, vertical alignment, cross-section elements; Relevant geometric design standards; Pavements: flexible and rigid; Characterization of pavement materials; Analysis and design of pavement systems; Pavement design specifications; Pavement construction process; Pavement performance; Traffic engineering: Traffic characteristics; Fundamental relationships; Theories of traffic flow; Intersection design; Design of traffic signs and signals; Highway capacity.

### **CVP261 Transportation Engineering Lab**

1 credit (0-0-2)

*Pre-requisites: CVL261 or Concurrent with CVL261*

Introduction to material behavior; Characterization of materials used in pavement construction: soil, aggregate, asphalt, asphalt concrete; Introduction to traffic survey methodologies; Traffic surveys: speed studies, intersection study.

### **CVL281 Hydraulics**

4 credits (3-1-0)

*Pre-requisites: APL107*

Open Channel Flow: Channel Characteristics and parameters, Uniform flow, Critical flow, Specific Energy concepts, Gradually Varied Flows, Rapidly Varied flow with special reference to hydraulic jump, Unsteady flow in open channels.

Boundary Layer Theory: Navier Stokes Equation, Boundary Layer Equation in 2-dimension, Boundary layer characteristics, Integral Momentum equation, onset of turbulence, properties of turbulent flow, skin friction, application of drag, lift and circulation to hydraulic problems.

Pipe Flow: Laminar and Turbulent flow in Smooth and Rough pipes, pipe network analysis, Losses in pipes

Fluvial Hydraulics: Settling velocity, Incipient motion, Resistance to flow and bed forms, Sediment load and transport.

### **CVP281 Hydraulics Lab**

1 credit (0-0-2)

*Pre-requisites: CVL281 or Concurrent with CVL281*

Experiments on Open Channel Flow Hydraulics, Boundary Layer Theory, Pipe flow, Sediment transport.

### **CVL282 Engineering Hydrology**

4 credits (3-0-2)

*Pre-requisites: APL107*

Hydrologic Cycle, Processes and Applied Methodologies. Rainfall; Evapotranspiration; Infiltration;

Groundwater: Occurrence, Movement, Governing equations, Well hydraulics.

Runoff: Hydrograph, Unit Hydrographs; Streamflow measurement.

Flood Routing: Hydrological routing for reservoirs and channels.

Frequency Analysis.

### **CVL284 Fundamentals of Geographic Information Systems**

3 credits (2-0-2)

*Pre-requisites: COL100*

What is GIS. Geographic concepts for GIS. Spatial relationships, topology, spatial patterns, spatial interpolation. Data storage, data structure, non-spatial database models. Populating GIS, digitizing data exchange, data conversion. Spatial data models, Raster and Vector data structures and algorithms. Digital Elevation Models (DEM) and their application. Triangulated Irregular Network (TIN) model. GIS application areas, Spatial analysis, quantifying relationships, spatial statistics, spatial search. Decision making in GIS context.

### **CVL311 Industrial Waste Management**

3 credits (3-0-0)

*Pre-requisites: CVL212*

Industrial waste types and characteristics; levels of environmental pollution due to industrial wastes; health issues due to industrial wastes; ecological and human health risk assessment due to industrial wastes; waste characterization methods; treatment methods-conventional and recent trends (for air, water, soil media); Prevention versus control of industrial pollution; hierarchy of priorities for industrial waste management; comparison of real-life industrial waste management practices (ex: superfund remedial sites, etc.); economics of industrial waste management and sustainability issues; environmental rules and regulations; clean up goals; disposal/reuse of treated wastes; Source reduction and control of industrial water and air pollution; Minimization of industrial solid and hazardous waste; Waste management case studies from various industries.

### **CVL312 Environmental Assessment Methodologies**

3 credits (3-0-0)

*Pre-requisites: CVL212*

Environmental issues related to developmental activities: Nature and characteristics of environmental impacts of urban and industrial developments.

Linkages between technology, environmental quality, economic gain, and societal goals.

Environmental indices and indicators for describing affected environment. Methodologies and environmental systems modeling tools for prediction and assessment of impacts on environmental quality (surface water, ground water, air, soil).

Monitoring and control of undesirable environmental implications. Environmental cost benefit analysis. Decision methods for evaluation of environmentally sound alternatives.

Environmental health and safety: Basic concepts of environmental risk and definitions; Hazard identification procedures; Consequence analysis and modeling (discharge models, dispersion models, fire and explosion models, effect models etc.).

Emerging tools for environmental management: Environmental Management Systems, Environmentally sound technology transfer, emission trading, international resource sharing issues, climate change, international environmental treaties and protocols. Case studies.

### **CVL313 Air and Noise Pollution**

3 credits (3-0-0)

*Pre-requisites:* CVL212

Definitions, source and types of air and noise pollution, physical and chemical properties of air pollutants, secondary pollutants formation, instrument design and industrial application, gas phase adsorption and biofiltration, carbon credit, global warming potential, case studies, data analysis, interpretation.

### **CVL321 Geotechnical Engineering**

4 credits (3-1-0)

*Pre-requisites:* CVL222

Foundations: types, selection and design considerations; Bearing capacity of shallow foundations: Terzaghi theory, factors affecting; Bearing capacity of deep foundations: single pile analysis, pile tests, pile driving formula, group capacity, introduction to laterally loaded piles; Settlement of shallow and deep foundations: stress distribution, immediate and consolidation settlements; Slope stability analysis: infinite slopes, method of slices, Swedish circle method; Earth dams: types and design aspects; Earth pressure analysis: Rankine and Coulomb methods; Earth retaining structures: types, design aspects, underground structures; Earthquake geotechnics: evaluation of liquefaction potential, seismic slope stability, seismic bearing capacity; Machine foundations: types, analysis, design procedure; Ground improvement techniques: types, deep stabilization, anchorage, grouting; Geosynthetics: types, functions, properties; reinforced soil walls; Geoenvironment: Landfills - types, liner, cover, stability; Ash ponds - stage raising, design aspects.

### **CVP321 Geotechnical Engineering Lab**

1 credit (0-0-2)

*Pre-requisites:* CVL321 or Concurrent with CVL321

Vane shear test, Direct shear test, Specimen preparation, Unconfined compression test, Unconsolidated undrained test, Consolidated drained test, Consolidated undrained test with pore water pressure measurement.

### **CVL341 Structural Analysis II**

3 credits (3-0-0)

*Pre-requisites:* CVL242

Determinacy and stability; Method of consistent deformations-Matrix formulation, Application to beams, trusses and frames; Slope-deflection method and Moment-distribution method- Beams and frames with uneven loading, support settlements, dealing with symmetry and anti-symmetry, Non-sway and sway frames; Matrix stiffness method; Matrix flexibility method; Energy methods; Approximate methods of analysis; Direct stiffness method for computer applications including computational aspects and MATLAB Assignments.

### **CVL342 Design of Steel Structures**

3 credits (3-0-0)

*Pre-requisites:* CVL242

Structural steel and properties, Design philosophy-Working stress and limit state; Connection types- Riveted, bolted and welded; Design of tension, compression and flexural members; Design of members subjected to combined loadings-Axial and bending, Torsion, Biaxial bending; Column bases, Gantry and plate girders; Roof trusses; Plastic design; Introduction to stability concepts, Design of shed-type structures.

### **CVP342 Materials and Structures Laboratory-Steel**

1 credit (0-0-2)

Basic properties of structural steel; Tensile stress-strain behaviour; Buckling of slender columns, Flexural testing of beams; Torsional behaviour of beams, Unsymmetrical bending; Lateral-torsional buckling; Flexural-torsional buckling; Connection behaviour; Tension-field action in plate girders.

### **CVL344 Construction Project Management**

3 credits (3-0-0)

*Pre-requisites:* CVL245

Additional network analysis- Ladder Network, LoB, etc., Time constrained Resource allocation and resource constrained problems, Time Cost trade off, project updating and control using EVM, Construction contracts and its types, tendering procedure, estimation and fixing of markup, bidding models, claims compensation and disputes, dispute resolution models, FIDIC contracts, Linear programming, Problems in construction, Formulation, Graphical solution, Simplex method, Dual problem, sensitivity analysis and their application to Civil engineering, Transportation Assignment problems and their applications

### **CVL361 Introduction to Railway Engineering**

3 credits (3-0-0)

*Pre-requisites:* CVL261

History: Indian railways, international perspective; Railway track gauge: factors affecting gauge choice, multi gauge; New project planning and surveys; Alignment of railway track; Structure of railway track: rails, sleepers, ballast, subgrade, track fittings; Structural design of railway track: stresses, creep; Geometric design of rail track: gradients, curves, superelevation; Locomotives and rolling stock: resistance and tractive power; Points and crossings; Railway stations and yards; Traffic control; Signalling and interlocking; Public rail transportation in metros.

### **CVL381 Design of Hydraulic Structures**

4 credits (3-0-2)

*Pre-requisites:* CVL281 and CVL282

*Input studies.*

Storage structures: Dams and reservoirs, Different types of dams and selection of suitable type and dam site, Gravity dam, Embankment dams. Diversion works: Design concepts for irrigation structures on permeable foundations, Design of Weirs and barrages. Design of energy dissipation devices. Canals: canal layout, Regime canal design, Rigid boundary canal design. Design of canal falls. Design of cross drainage works. Design of head regulator, cross regulator and canal outlet structures.

### **CVL382 Groundwater**

2 credits (2-0-0)

*Pre-requisites:* CVL282 or EC 75

Introduction, importance and occurrence of groundwater; Aquifers and groundwater scenario in India; Surface and subsurface investigation of groundwater; Construction, development and maintenance of wells; Flow through porous media, Darcy's law, regional flow; Well hydraulics; Groundwater management.

### **CVL383 Water Resources Systems**

2 credits (2-0-0)

*Pre-requisites:* CVL282

Water Resources Planning Purposes and Objectives; Multi-component, multi-user, multi-objective and multi-purpose attributes of an Integrated Water Resources System; Economic basis for selection of a Plan Alternative; Introduction to Linear Programming and applications in Water Resources Engineering; Linear, Deterministic Integrated Water Resources Management Model on River Basin Scale.

### **CVL384 Urban Hydrology**

2 credits (2-0-0)

*Pre-requisites:* CVL282 or EC 75

Distinctive characteristics of natural and urban watersheds; Urban Heat Island; Changes in rainfall, infiltration and runoff characteristics in urban watershed; IDF relationship and its adaptation for urban settings; Adjusting runoff record for urbanization; Stormwater Management and rainwater harvesting; Urban drainage: layout, structures, flooding and control, combined sewer overflows, sedimentation; Management of stormwater.

**CVL385 Frequency Analysis in Hydrology**

2 credits (2-0-0)

*Pre-requisites: CVL282*

Concepts of probability in Hydrology, Random events, Random variables; moments and expectations; Common probabilistic distributions; goodness of fit tests; Stochastic processes.

**CVL386 Fundamentals of Remote Sensing**

3 credits (2-0-2)

*Pre-requisites: EC 75*

What is Remote Sensing? Historical development of remote sensing, Remote sensing components, Data collection and transmission, Sensors and satellite imageries, Electromagnetic energy and spectrum, Wavebands, Interactions of electromagnetic energy with atmosphere and earth's surface, radiometric quantities, Photogrammetry and aerial photography, Vertical and tilted photographs, Photographic materials, Photo-processes, Stereoscopic viewing, fly view, Aerial mosaics, Various satellite systems and monitoring programs, Data Products, Satellite data, Data formats, Data acquisition for natural resources management and weather forecast, Random errors and least square adjustment, Coordinate transformation, Photographic interpretation, Image processing, Potential applications of remote sensing in diverse areas and decision making, Integrated use of remote sensing and GIS, Case studies.

**CVD411 B.Tech. Project Part-I**

4 credits (0-0-8)

**CVD412 B.Tech. Project Part-II**

6 credits (0-0-12)

**CVL421 Ground Engineering**

3 credits (3-0-0)

*Pre-requisites: CVL321*

Planning of investigation programmes, Geophysical methods. Methods of site investigations: Direct methods, semi-direct methods and indirect methods, Drilling methods. Boring in soils and rocks, Methods of stabilizing the bore holes, measurement of water table, field record. Principles of compaction, Laboratory compaction, Engineering behaviour of compacted clays, Field compaction techniques- static, vibratory, impact, Compaction control. Shallow stabilization with additives: Lime, fly ash, cement and other chemicals and bitumen; Deep Stabilization: sand column, stone column, sand drains, prefabricated drains, electroosmosis, lime column. soil-lime column, blasting. Grouting : permeation, compaction and jet. Vibro-floatation, dynamic compaction, thermal freezing. Dewatering systems. Functions and applications of geosynthetics – geotextiles, geogrids, geomembranes; soil reinforcement using strips, bars and geosynthetics; soil nailing and ground anchors, Earthmoving machines and earthwork principles, Piling and diaphragm wall construction, Tunneling methods in soils, Hydraulic barriers and containment systems for waste disposal in soil, Control and remediation of soil contamination.

**CVL422 Rock Engineering**

3 credits (3-0-0)

*Pre-requisites: CVL321*

Geological classification, rock and rock mass classification, strength and deformation behaviour of rocks, pore pressures, failure criteria, laboratory and field testing, measurement of in-situ stresses and strains, stability of rock slopes and foundations, design of underground structures, improvement of in situ properties of rock masses and support measures.

**CVL423 Soil Dynamics**

3 credits (3-0-0)

*Pre-requisites: CVL321*

Engineering problems involving soil dynamics; Role of inertia; Theory of Vibrations: Single and two-degree freedom systems; Wave propagation

in elastic media; Soil behaviour under cyclic/dynamic loading; Small and large strain dynamic properties of soils; Design criteria for machine foundations; Elastic homogeneous half space and lumped parameter solutions; Vibration isolation; Codal provisions; Causes of Earthquakes; Strong Ground Motion: Measurement, characterization and estimation; Amplification theory and ground response analysis; Liquefaction of soil and its remediation; Seismic slope stability; Seismic bearing capacity and earth pressures

**CVL424 Environmental Geotechniques & Geosynthetics**

3 credits (3-0-0)

*Pre-requisites: CVL321*

Causes and effects of subsurface contamination; Waste disposal on land; Characteristics of solid wastes; Waste Containment Principles; Types of landfills; Planning of landfills; Design of liners and covers for landfills; Environmental Monitoring around landfills; Detection, control and remediation of subsurface contamination; Geotechnical re-use of solid waste materials.

Types of geosynthetics; Manufacturing; Functions; Testing and evaluation; Designing with geotextiles, geogrids, geonets and geomembranes.

**CVL431 Design of Foundations & Retaining Structures**

3 credits (3-0-0)

*Pre-requisites: CVL321*

Shallow Foundations: Bearing Capacity, Generalized bearing capacity theory, Empirical methods, Layered soil, Foundations on or near slopes, Settlement of foundations, codal provisions.

Pile Foundations: Types and their selection, Ultimate load of individual piles in compressive, uplift, and lateral loading, Pile load tests, Downdrag, Pile groups. Caissons. Codal provisions.

Earth Retaining Structures: Types, Earth pressures, Design of rigid, flexible and reinforced soil retaining walls, braced excavations, and ground anchors for retaining walls.

Introduction to design of foundation for dynamic loads.

**CVL432 Stability of Slopes**

2 credits (2-0-0)

*Pre-requisites: CVL321*

Slope Stability: Short term and long term stabilities; Limit equilibrium methods; Infinite slopes; Finite height slopes - Swedish method, Bishop's simplified method, Stability charts; Conditions of analysis - steady state, end of construction, sudden draw down conditions; Factor of safety; Codal provisions; Earthquake effects. Seepage Analysis: Types of flow; Laplace equation; Flownet in isotropic, anisotropic and layered media; Entrance-exit conditions; Theoretical solutions; Determination of phreatic line. Earth Dams: Introduction; Factors influencing design; Design of components; Instrumentation. Reinforced Slopes: Steep slopes; Embankments on soft soils; Reinforcement design.

**CVL433 FEM in Geotechnical Engineering**

3 credits (3-0-0)

*Pre-requisites: CVL321*

Steps in FEM. Stress-deformation analysis: One dimensional, Two dimensional and Three-dimensional formulations. Discretization of a Continuum, Elements, Strains, Stresses, Constitutive, Relations, Hooke's Law, Formulation of Stiffness Matrix, Boundary Conditions, Solution Algorithms.

Settlement Analysis, 2-D elastic solutions for homogeneous, isotropic medium, Steady Seepage Analysis: Finite element solutions of Laplace's equation, Consolidation Analysis: Terzaghi consolidation problem, Choice of Soil Properties for Finite Element Analysis, Introduction to PHASE2.

**CVP434 Geotechnical Design Studio**

2 credits (0-0-4)

*Pre-requisites: CVL321*

Seepage analysis through an earth dam. Slope stability analysis of a dam. Settlement analysis of shallow and deep foundations; Analysis and design of retaining structures; Analysing the structural forces in a tunnel lining.

**CVL435 Underground Structures**

2 credits (2-0-0)

*Pre-requisites: CVL321**Overlaps with: CVL713*

Types and classification of underground structures, Functional aspects, Sizes and shapes, Support systems, Design methodology.

Stresses- deformation analysis of openings (circular, elliptical, spherical, ellipsoidal) using analytical and numerical methods

Design of underground structures using analytical methods, empirical methods and observational methods, Rock support interaction analysis, NATM Hydraulic tunnels, Shafts, Tunnel portals, Metro tunnels.

**CVL441 Structural Design**

3 credits (3-0-0)

*Pre-requisites: CVL241, CVL243, CVL342*

Design of Reinforced Cement concrete (RCC) Structures – Building frames Liquid retaining structures, Earth Retaining walls,

Design of Steel Structures – Plate girders, gantry girders and steel bridge components

**CVP441 Structural Design & Detailing**

1.5 credits (0-0-3)

*Pre-requisites: CVL243, CVL342**Part-I Concrete Structures*

Computer-aided analysis and design of real-life reinforced concrete (RC) structure. Dimensioning of concrete elements based on modular formworks available in construction industry. Detailing of concrete elements in terms of reinforcement, curtailment, lapping, splicing of reinforcements and connection with adjoining elements in the structure; member drawings. Joint detailing from ductility view point, Indian standard (IS) code recommendations and practical intricacies involved in casting and handling of the RC members, its sequence of construction and constructability.

*Part-II Steel Structures*

Computer-aided analysis and design of real-life steel structure. Steel member details as per shop/ field activities for welding/ bolting; i.e. fabrication (shop) drawings. Connection details, gusset plate design and detailing from ductility view point, Indian standard (IS) code recommendations and practical intricacies involved in fabrication and handling of the steel members, its sequence of erection and constructability.

**CVL442 Structural Analysis-III**

3 credits (3-0-0)

*Pre-requisites: CVL341*

Introduction to FEM for structural analysis with review of energy methods-2D plane stress and plane strain elements, beam element, 2D bending element, example problems, elements of structural dynamics-free and forced vibration of SDOF system, treatment of impact and arbitrary loading, frequency and time domain analysis; free vibration mode shapes and frequencies of MDOF systems; normal mode theory for forced vibration analysis of MODF system; example problems. Elements of plastic analysis; upper and lower bound theorems; methods of collapse mechanism; application to beams and multistory frames; example problems.

**CVL443 Prestressed Concrete & Industrial Structures**

3 credits (3-0-0)

*Pre-requisites: CVL241, CVL243, CVL341*

Prestressed Concrete Structures-Fundamentals of presenting, Prestressing technology, Analysis of prestressed losses, Design for Flexure, Design for shear and torsion, Design of anchorage Zones in Post-tensioned members.

Industrial Structures-Analysis and design of Cylindrical shell structures, Folded plates, Chimneys, Silos, Bunkers.

**CVL461 Logistics and Freight Transport**

3 credits (3-0-0)

*Overlaps with: SML843**Pre-requisites: CVL261 or Instructor's permission*

Evolution of freight and logistics; Interrelationships between society, environment and freight transport; Survey methodologies to understand freight movement; Cost measurement: Production, Holding, Transportation, Handling; Effect of internal and external variables on cost; Demand forecasting; Inventory planning and management; Transportation and distribution network: Design, Development, Management; Ware house operations; Pricing: Perishable, seasonal demand, uncertainty issues; Vehicle routing: One-to-one distribution, One-to-many distribution, Shortest path algorithm, Quickest time algorithm; Logistics information system; Designing and planning transportation networks; Multi-modal transportation issues.

**CVL462 Introduction to Intelligent Transportation Systems**

3 credits (3-0-0)

*Pre-requisites: CVL261*

Introduction to Intelligent Transportation Systems (ITS); ITS Organizational Issues, the fundamental concepts of Intelligent Transportation Systems (ITS) to students with interest in engineering, transportation systems, communication systems, vehicle technologies, transportation planning, transportation policy, and urban planning. ITS in transportation infrastructure and vehicles, that improve transportation safety, productivity, environment, and travel reliability. Mobile device applications of ITS such as trip planners.

**CVL481 Water Resources Management**

3 credits (3-0-0)

*Pre-requisites: CVL282 and EC 100*

Scope of water resources management, Global trends in water utilization, Crop water requirements and irrigation, Planning and desing of various irrigation methods, Soil salinity and water logging, Hydropower systems management, Strom water system management, Economic analysis of water resources projects, Flood Control studies.

**CVL482 Water Power Engineering**

3 credits (2-0-2)

*Pre-requisites: CVL281 and EC 100*

Basic principle of hydropower generation, Hydropower Project Planning, Site selection, Hydropower development schemes, Reservoir storage, Assessment of power potential, Hydrologic analysis: Flow duration and load duration curves, Dependable flow, Design flood, Reservoir operation; Hydraulic design of various components of hydropower plants: intakes, hydraulic turbines, conduits and water conveyance, penstock; Performance characteristics of turbines, Specific and unit quantities, Electrical load on hydro-turbines, Power house dimension and planning, Water hammer and surge analysis, Surge tanks, Small and micro hydro power development, tidal plants, Current scenarios in hydropower development, Project feasibility, Impact of hydropower development on water sources systems, environment, socioeconomic conditions and national economy.

**CVL483 Groundwater & Surface-water Pollution**

2 credits (2-0-0)

*Pre-requisites: CVL282 and EC 100*

Groundwater contamination; River and Lake pollution; Pollution sources, Geogenic and anthropogenic pollution; Soil Pollution;

Contaminant transport mechanisms; Pollution control, remediation technologies and role of wetlands. Environmental impact assessments, Hydrological impacts, Vulnerability, Case studies.

### **CVL484 Computational Aspects in Water Resources**

3 credits (1-0-4)

*Pre-requisites: CVL281 and EC 100*

Numerical Interpolation and Integration and application to water resources problems; Numerical solution of differential equations in Water Resources such as groundwater flow, pipe flows, open channel flows.

### **CVL485 River Mechanics**

3 credits (2-0-2)

*Pre-requisites: CVL281 and EC 100*

Introduction, river morphology, drainage patterns, stream order. Properties of mixture of sediment and water, Incipient motion and quantitative approach to incipient motion, channel degradation and armoring. Bed forms and resistance to flow, various approaches for bed load transport, suspended load profile and suspended load equations, total load transport including total load transport equations. Comparison and evaluation of sediment transport equations. Stable channel design with critical tractive force theory.

### **CVL486 Geo-informatics**

3 credits (2-0-2)

*Pre-requisites: EC 100*

Geospatial and temporal data, Data acquisition, Global positioning system, Global Navigational Satellite System, GPS survey, Aerial and laser scanning surveys, Data acquisition using remote sensing techniques, Sensors and satellite imageries, Stereoscopic 3D viewing, Fly view, Satellite data formats and specifications, Data acquisition for natural resources management and weather forecast, Image processing and interpretation, GIS concepts and Spatial data models, Introduction to microwave remote sensing & LiDAR, Geospatial analysis, DEM/DTM generation & 3D modelling, Inferential statistics, Spatial interpolation, Integrated use of geospatial technologies, Applications and case studies.

### **CVD700 Minor Project**

3 credits (0-0-6)

### **CVL700 Engineering Behaviour of Soils**

3 credits (3-0-0)

Origin, nature and distribution of soils. Description of individual particle. Clay mineralogy, clay-water-electrolytes. Soil fabric and structure. Effective stress principle. Steady state flow in soils. Effect of flow on effective stress. Determination of coefficient of permeability. Consolidation: one, two, three dimensional and radial consolidation. Various consolidation tests and determination of parameters. Stress-path. Triaxial and direct shear tests. Shear behaviour of soils under static and dynamic loads. Factors affecting shear behaviour. Determination of parameters. Shear behavior of fine grained soils. Pore-pressure parameters. UU, CU, CD tests. Total and effective stress-strength parameters. Total and effective stress-paths. Water content contours. Factors affecting strength : stress history, rate of testing, structure and temperature. Anisotropy of strength, thixotropy, creep. Determination of in-situ undrained strength. Stress-strain characteristics of soils. Determination of modulus values. Critical state model, Engineering behaviour of soils of India: Black cotton soils, alluvial silts and sands, laterites, collapsible and sensitive soils.

### **CVP700 Soil Engineering Lab**

3 credits (0-0-6)

Laboratory Tests: Preparation of samples - Sand and Clay, Consolidation test, Direct shear test, Vane shear test, Unconfined compression test, Unconsolidated undrained triaxial test, Consolidated drained triaxial test, Consolidated undrained triaxial test with pore water pressure measurement, Free swell index test, Swelling pressure test.

Field Investigations and field tests: Drilling of bore hole, standard penetration test. undisturbed and representative sampling. SCP Test, Electrical resistivity, Plate load test, Pile load test.

### **CVL701 Site Investigation and Foundation Design**

3 credits (3-0-0)

Site Investigation: Geophysical methods-Seismic, electrical; Drilling methods; Boring in soils and rocks. Field tests: In-situ tests, SPT, DCPT, SCPT, in-situ vane shear test, pressure meter test, plate load test. Sampling techniques and disturbances. Shallow Foundations: Design considerations, code provisions. Bearing capacity theories, Layered soils, Choice of shear strength parameters. Bearing capacity from field tests. Total and differential settlements. Deep foundations: Types of piles. Construction methods. Axial capacity of single piles. Axial capacity of groups. Settlement of single piles and groups. Uplift capacity (including under-reamed piles) . Negative skin friction. Pile load tests. Pile integrity tests. Code provisions. Caissons.

Laterally Loaded Piles: Analysis and Design; Foundations in Difficult soil conditions.

### **CVL702 Ground Improvement and Geosynthetics**

3 credits (3-0-0)

Principles of compaction, Engineering behaviour of compacted clays. Shallow stabilization with additives: lime, fly ash and cement. Deep stabilization: stone column, sand drains, prefabricated drains, lime column, soil-lime column, vibro-floatation, dynamic compaction, electro-osmosis. Grouting : permeation, compaction and jet; Dewatering systems. Geosynthetics: types and functions, materials and manufacturing processes, testing and evaluation; Reinforced soil structures: principles of soil reinforcement, application of geotextiles and geogrids in roads, walls, and embankments. Application of geotextiles, geonets and geocomposites as drains and filters. Multiple functions: railways and overlay design. Geosynthetics in environmental control: covers and liners for landfills – material aspects and stability considerations.

### **CVL703 Geoenvironmental Engineering**

3 credits (3-0-0)

Subsurface Contamination and Contaminant Transport; Waste disposal on Land and containment, Monitoring of subsurface contamination, Control and Remediation. Engineering Properties of waste and geotechnical reuse, erosion control, sustainability, energy geotechnics.

### **CVL704 Finite Element Method in Geotechnical Engineering**

3 credits (3-0-0)

Introduction. Steps in FEM. Variational Methods, Stress-deformation analysis: One-Two dimensional formulations; Three-dimensional formulations; Boundary conditions; Solution algorithms; Discretization; use of FEM2D Program and Commercial packages. Analysis of foundations, dams, underground structures and earth retaining structures. Analysis of flow (seepage) through dams and foundations. Consolidation Analysis, Linear and non-linear analysis. In-situ stresses. Sequence construction and excavation. Joint/interface elements. Infinite elements. Dynamic analysis. Evaluation of material parameters for linear and non-linear analysis, Recent developments.

### **CVL705 Slopes and Retaining Structures**

3 credits (3-0-0)

Slope stability: infinite slopes; finite height slopes – Swedish method, Bishop's simplified method and other limit equilibrium methods; Stability charts; conditions of analysis – steady state, end of construction and sudden draw down; earthquake effects. Seepage: flownet in isotropic, anisotropic and layered media; entrance-exit conditions; determination of phreatic line. Earth Dams: Introduction, factors influencing design, design of components, construction, instrumentation. Road and rail embankments. Reinforced slopes. Soil nailing; Gabions. Earth Pressure: Types; Rankine's theory and Coulomb's theory; Effects due to wall friction; Graphical methods; Earthquake

effects. Rigid retaining structures: Types; stability analysis. Flexible retaining structures: Types; material; cantilever sheet piles; anchored bulkheads—methods of analysis, moment reduction factors; anchorage. Reinforced soil walls: Elements and stability. Soil arching. Braced excavation: Pressure distribution in sands and clays; bottom heave. Underground structures in soils: Pipes; tunnels. Tunneling techniques.

### **CVL706 Soil Dynamics and Earthquake Geotechnical Engineering**

*3 credits (3-0-0)*

Engineering problems involving soil dynamics; Role of inertia; Theory of Vibrations: Single and two-degree of freedom systems, vibration measuring instruments, Vibration absorption and isolation techniques. Wave propagation: elastic continuum medium and semi-infinite elastic continuum medium. Measurement of small strain and large strain dynamic soil properties: Field and Laboratory tests. Selection of design values. Design criteria for machine foundations, elastic homogeneous half space solutions, lumped parameter solutions. Codal provisions; Design of Pile-supported machine foundations. Strong Ground Motion: Measurement, characterization and estimation; Amplification theory and ground response analysis. Liquefaction of soils: evaluation using simple methods and mitigation measures. Seismic slope stability analysis, Seismic bearing capacity and earth pressures. Codal provisions.

### **CVL707 Soil-Structure Interaction Analysis**

*3 credits (3-0-0)*

Basic Soil Models: Single parameter model - Winkler; Two parameter models - Bilonenko-Borodick, Pasternak; Elastic Continuum - plane strain, plane stress, Boussinesq's problem, line load strip load; Special models starting with elastic continuum - Vlazov, Reissner; Three parameter model - Kerr model; Evaluation of model parameters for different conditions. Beam on Winkler foundation: solutions for infinite and semi-infinite beams; Finite beams: method of initial parameters, method of superposition. Beams on Elastic continuum: Use of finite difference method, rigid and flexible beams, lift-off, non-homogeneous soil, non-linear soil, plastic yielding of soil. Raft of Mat foundations: thin rectangular plates, approximate theory of plates, circular plates. Pile on Winkler foundation: Vertically loaded pile - rigid pile, evaluation of spring stiffness, non-homogeneous soil, compressible pile; Laterally loaded pile - rigid pile, Elastic pile, standard solutions for different end conditions; Pile on elastic continuum - vertically loaded piles - rigid pile.

### **CVL708 Geotechnology of Waste Disposal Facilities**

*3 credits (3-0-0)*

Integrated waste management, Detailed design MSW Landfills and HW Landfills including individual components, Closure of Old landfills, Expansion of old landfills, Ashponds and Tailings Ponds, Seismic Stability; Disposal of Nuclear Waste.

### **CVL709 Offshore Geotechnical Engineering**

*3 credits (3-0-0)*

Submarine soils: Origin, nature and distribution. Terrigenous and pelagic soils. Submarine soils of India. Engineering behaviour of submarine soils: under-consolidated soils, calcareous soils, cemented soils, corals; Offshore site investigations: sampling and sampling disturbance, insitu testing, wireline technology. Offshore pile foundations for jacket type structures. Foundations of gravity structures; Foundations for jackup rigs. Anchors and breakout forces; anchor systems for floating structures. Stability of submarine slopes. Installation and stability of submarine pipelines.

### **CVD710 Minor Project (CEU)**

*3 credits (0-0-6)*

### **CVL710 Engineering Properties of Rocks and Rock Masses**

*3 credits (3-0-0)*

Introduction. Rock materials, Physical properties, Strength behaviour in uniaxial compression, tension and triaxial state. Laboratory testing methods. Stress-strain relationships. Factors influencing strength.

Failure mechanism. Anisotropy. Failure criteria, Coulomb, Mohr's, Griffiths and Modified Griffiths criteria and Empirical criteria. Brittle – ductile transition, Post failure behaviour. Strength and deformation behaviour of discontinuities. Rockmass behaviour, Shear strength of jointed rocks, roughness, peak and residual strengths. Strength criteria for rockmass. Intact and rockmass classifications, Terzaghi, RQD, RSR, RMR and Q classifications, Rating, Applications. Creep and cyclic loading. Weathered rocks. Flow through intact and fissured rocks. Dynamic properties.

### **CVP710 Rock Mechanics Laboratory 1**

*3 credits (0-0-6)*

Tests and test procedures, Rock samples, Specimen preparation, coring, cutting and lapping. Tolerance limits.

Physical Properties: Water absorption, density, specific gravity, porosity, void index, electrical resistivity and sonic wave velocity tests. Mechanical Properties: Uniaxial compression, Point load index and Brazilian strength tests, Elastic properties. Effect of L/D ratio and saturation. Strength anisotropy. Shear tests: Single, double, oblique tests, Punch shear, Triaxial compression tests, Direct shear test. Slake durability and Permeability tests. Compilation of test data. Classification. Codal provisions.

### **CVL711 Structural Geology**

*3 credits (3-0-0)*

Origin, interior and composition of the earth. Rock cycle, Igneous, Metamorphic and Sedimentary rocks. Rock structures. Plate tectonics, Continental drift and sea floor spreading. Geological time scale. Layered formations, Attitude, true and apparent dips, topographic maps, outcrops. Measurement of attitude of formations. Folds, types of folds, classification, field study of folds, mechanics of folds, causes of folding. Joints, rock mass concept, Joint description and classification. Three point problems, Depth and thickness problems. Faults, mechanics of faulting, normal, reverse and thrusts, faults. Lineations. Foliation, Schistosity. Fault problems. Stereographic projection methods, Use of DIPS software, presentation of geological data and analysis, Applications, Scan line survey of rock joints in the visit.

### **CVL712 Slopes and Foundations**

*3 credits (3-0-0)*

Introduction, Short-term and long-term stability. Influence of ground water, Seismic effects. Types of rock slope failures. Infinite slopes, Circular and non-circular slip surface analysis, Stability charts. Plane failure analysis. Wedge failure analysis analytical, Stereographic methods. Buckling and toppling failures, Rock falls, Landslides. Foundations: Bearing capacity, settlement and stress distribution in intact and layered rocks. Foundations of dams. Deep foundations. Tension foundations, Codal provisions. Foundation improvement. Use of appropriate software packages.

### **CVL713 Analysis and Design of Underground Structures**

*3 credits (3-0-0)*

Introduction. Types and classification of underground openings. Factors affecting design. Design methodology. Functional aspects. Size and shapes. Support systems. Codal provisions. Analysis: Stresses and deformations around openings, Stresses and deformations around tunnels and galleries with composite lining due to internal pressure, Closed form solutions, BEM, FEM. Design: Design based on analytical methods; Empirical methods based on RSR, RMR, Q systems; Design based on Rock support interaction analysis; Observational method-NATM, Convergence-confinement method. Design based on Wedge failure and key block analysis. Design of Shafts and hydraulic tunnels. Stability of excavation face and Tunnel portals. Use of appropriate software packages.

### **CVL714 Field Exploration and Geotechnical Processes**

*3 credits (3-0-0)*

Surface and sub surface exploration methods. Aerial and remote sensing techniques, Geophysical methods, electrical resistivity, seismic

refraction, applications. Rock drilling, Core samplers, Core boxes, Core orientations.

Logging, stratigraphic profile, scan line survey. Laboratory tests, report. Stresses in rocks. Stress anisotropy and stress ratio. Stress relief and compensation techniques, USBM, door stopper cells, flat jack, hydrofrac, strain rosette and dilatometers. Deformability, plate load, pressure tunnel and bore hole tests. Strength tests, insitu compression, tension and direct shear tests. Pull out tests. Borehole extensometers, piezometers, embedment gauges, inclinometers, Slope indicators, packer tests for insitu permeability, Codal provisions.

Ground improvement techniques. Compaction, Grouting, Types of grouts, technique, Rheological models. Viscous and viscoplastic flows. Spherical and radial flows, Shotcrete, Ground anchors, Rock bolts.

### **CVL715 Excavation Methods and Underground Space Technology**

*3 credits (3-0-0)*

Principles of rock breakage, explosive energy, energy balance, blasting mechanism. Types of explosives, initiators, delay devices, primer and booster selection. Blast hole design. Drilling methods and machines Blast hole timing. Pattern design, open pit and underground blasting, production, estimation and damage criteria of ground vibrations. TBM tunnelling. Factors influencing and evaluation, Excavation mechanics, Boom machines, transverse boom tunnelling machines and Robins mobile miner. Drag pick cutting, cutting tool materials and wear, disc cutters. Case studies.

Tunnels, energy storage caverns, nuclear waste disposal repositories, metros, underground chambers and defence installations. Geological considerations, layout, survey and alignment. Analysis and design methods. Construction methods. Ventilation, provisions, equipment. Control and monitoring system, services, operations and maintenance. Lighting, specifications, maintenance, emergency lighting. Power supply and distribution, Water supply and distribution. Safety provisions, localized hazards, fire hazards in highway tunnels, rapid transit tunnels. Surveillance and control system for highway tunnels. Tunnel finish.

### **CVL716 Environmental Rock Engineering**

*3 credits (3-0-0)*

Theory: Stress-strain behaviour of rocks and rock masses: Elastic, elasto-plastic, and brittle, Crack phenomena and mechanisms of rock fracture.

Temperature, pressure and water related, problems, Effect of temperature on rock behaviour. Fluid flow through intact and fissured rocks.

Time dependent behaviour of rocks: Creep, Viscoelasticity and Viscoplasticity

Continuum and discontinuum theories: Equivalent material, Block and Distinct element.

Application: Waste disposal, Radioactive and hazardous wastes, repositories, location and design, VLH, VDH and KBS3 concepts. Waste container, barriers, rock structure, embedment, buffers and seals. Performance assessment, quality control and monitoring. Case histories.

Hazardous Earth processes, high ground stresses, rock bursts, subsidence. Karst formations. Landslides and rock falls, slopes stabilization, mitigation, Case studies.

Earthquakes, tectonic stresses, creep, ground motions, damage, prediction. Volcanic activity and hazard. Tsunamis. Case studies.

Thermal analysis, Thermo-mechanical analysis, thermo-hydro-mechanical analysis. Rock dynamics. Physical modelling.

### **CVD720 Major thesis part1**

*6 credits (0-0-12)*

### **CVS720 Independent Study**

*3 credits (0-3-0)*

Specific to the context of the problem decided by the supervisor.

### **CVL720 Air Pollution and Control**

*3 credits (3-0-0)*

Air-pollution; Air Pollution Effect on Plants; Air Pollution effect on Human health; Air quality monitoring; Air Pollution Meteorology; Gaussian Plume model; Urban Air Pollution; Air Pollution from Industries; Air Pollution control; Air pollution indices; standards; norms; rules and regulations; Indoor Air Pollution.

### **CVD721 Major Thesis Part-II**

*12 credits (0-0-24)*

### **CVL721 Solid Waste Engineering**

*3 credits (3-0-0)*

Solid Wastes: Origin, Analysis, Composition and Characteristics. Integrated Solid Waste Management System: Collection, Storage, Segregation, Reuse and Recycling possibilities, Transportation, Treatment / Processing and Transformation Techniques, Final Disposal. Management of: Municipal, Biomedical, Nuclear, Electronic and Industrial Solid Wastes and the rules and regulations.

### **CVL722 Water Engineering**

*3 credits (3-0-0)*

Water quality parameters-conventional contaminants and emerging contaminants; Sedimentation; Coagulation and flocculation; Filtration-mechanisms and interpretations; Ion exchange and adsorption; Disinfection; Reverse osmosis, electrodialysis, desalination.

Water treatment : Source selection process, selection of treatment chain, plant siting, Treatability studies. Design of physico-chemical unit operations.

### **CVL723 Wastewater Engineering**

*3 credits (3-0-0)*

Wastewater quality parameters, Biological processes; Microbial growth kinetics; Modeling of suspended growth systems; concepts and principles of carbon oxidation, nitrification, denitrification, methanogenesis. Biological nutrient removal; Anaerobic treatment; Attached growth reactors; decentralised wastewater treatment systems; constructed wetlands; Design of pretreatment, secondary treatment, and tertiary disposal systems. Sludge stabilization, treatment, sludge thickening, sludge drying, aerobic and anaerobic digestion of sludges; reliability and cost effectiveness of wastewater systems; Emerging contaminants in wastewater-treatment issues.

### **CVL724 Environmental Systems Analysis**

*3 credits (3-0-0)*

Introduction to natural and man-made systems. Systems modeling as applied to environmental systems. Nature of environmental systems, the model building process addressing to specific environmental problems. Strategies for analyzing and using environmental systems models. Fate and transport models for contaminants in air, water, and soil. Optimization methods (search techniques, linear programming, non-linear programming, dynamic programming) to evaluate alternatives for solid-waste management and water and air pollution control. Optimization over time. Integrated environmental management strategies addressing multi-objective and multi-stakeholder planning.

### **CVL725 Environmental Chemistry and Microbiology**

*3 credits (1-0-4)*

Chemical equilibria and kinetics fundamentals; Acids and bases; Titrations; Acidity; Alkalinity; Buffers and buffer intensity; Chemical equilibrium calculations; pC-pH diagram; Langelier index; Solubility diagram; Oxidation and reduction reactions; Cell structure; Types of microorganisms in environment; metabolic classification of organisms; laboratory procedure for determining chemical and microbial parameters, Introduction to advanced instruments.

### **CVD726 Minor Project**

*3 credits (0-0-6)*



**CVL727 Environmental Risk Assessment**

3 credits (3-0-0)

Basic concepts of environmental risk and definitions; Human health risk and ecological risk assessment framework; Hazard identification procedures and hazard prioritization; Environmental risk zonation; Consequence analysis and modelling (discharge models, dispersion models, fire and explosion models, effect models etc). Estimation of incident frequencies from historical data, frequency modelling techniques e.g., Fault tree analysis (FTA) and Event tree analysis (ETA), Reliability block diagram. Human factors in risk analysis; Risk management & communication. Rules, regulations and conventions.

**CVL728 Environmental Quality Modeling**

3 credits (3-0-0)

Plume Rise Models; Introduction to Air Quality Modelling; Turbulence fundamentals; Basic diffusion equation; Fick's law; deterministic; numerical and statistical modeling approach; Fundamentals of Receptor modelling; Dispersion and receptor models; Fundamentals of Indoor air quality modelling techniques; Fundamentals of Water quality modeling: surface water and ground water models; Fate and transport of Conservative and non-conservative pollutants. Modelling as a tool for strategising pollution prevention and control.

**CVL729 Environmental Statistics and Experimental Design**

3 credits (2-0-2)

Introduction on environmental data, environmental statistics estimation (concentration, frequency of detection, minimum detection limit, sample size), frequency and probability distributions, inferences concerning mean and variance, confidence Interval estimation, hypotheses test, ANOVA, regression, goodness of fit, factorial experimentation, exceedance factor, intervention model, Case studies.

**CVL730 Hydrologic Processes and Modeling**

3 credits (3-0-0)

Hydrologic Cycle and its individual component processes. River Basin as a Linear Hydrologic System. Linear Theory of Hydrologic Systems. Lumped Integral and Distributed Differential modelling approaches. Transform methods of Linear Systems Analysis. Morphological attributes of watersheds and its role in runoff dynamics. Flood Routing by Lumped Hydrologic and Distributed Hydraulic approaches. Unsaturated zone Hydrology and physics of the Soil-Plant-Atmosphere Continuum. Calibration and Validation of Rainfall-Runoff models.

**CVP730 Simulation Laboratory-I**

1.5 credits (0-0-3)

Basic of Fortran 90, Fortran 95 and computing, Numerical solution of different types of partial differential equations: parabolic equation, elliptical equation, hyperbolic equation, Backwater curve analysis; Groundwater flow problems, Pipe network analysis, Unsteady channel flow.

**CVS730 Minor Project (CEW)**

3 credits (0-0-6)

**CVL731 Optimization Techniques in Water Resources**

3 credits (3-0-0)

Optimization techniques commonly used in water resources planning & management, water infrastructures, and irrigation and hydropower projects; Linear programming and duality, Network flow algorithms, Dynamic programming, Nonlinear programming, Geometric and Goal programming, Introduction to modern heuristic methods like genetic algorithm and simulated annealing, Multiobjective optimization, Applications and case studies in water resources, agriculture, environment and other areas of science & engineering.

**CVP731 Simulation Laboratory-II**

1.5 credits (0-0-3)

Simulate hydraulic, hydrologic, pipe flow, water hammer using various softwares such as Visual Mod Flow, SWAT, HYDRUS, Hytran, MIKE, Bentley Software, Fluent, HMS, SAMS.

**CVL732 Groundwater Hydrology**

3 credits (3-0-0)

Occurrence and movement of groundwater including subsurface investigations of groundwater. Flow through saturated and unsaturated media. Well Hydraulics and aquifer parameters. Pumping wells and their design, construction, monitoring and rehabilitation of wells. Recharge of groundwater by various means. Salt water intrusion and coastal aquifer hydraulics. Analog and numerical models and application of Finite Difference method to groundwater, case studies.

**CVL733 Stochastic Hydrology**

3 credits (2-0-2)

Concepts of probability and Random variables; moments and expectations; Common probabilistic distributions and estimation of parameters; goodness of fit tests; Modelling of Hydrologic High and Low Extremes, Regional Frequency Analysis, Stochastic processes and modelling of stochastic time series; Markov Chains and Probabilistic Theory of Reservoir Storages.

**CVL734 Advanced Hydraulics**

3 credits (3-0-0)

Energy and Momentum principles in open channel, Curvilinear Flows, Backwater computations, Controls, Rapidly varied flows, Spatially varied flows, Unsteady flow, Surges, Flood wave passage, Roll waves, Sediments transport, Incipient motion criteria, Resistance to flow and bed forms, Bed load theory, Stratified flows, Fluvial Systems, Industrial Hydraulics.

**CVL735 Finite Element in Water Resources**

3 credits (3-0-0)

Introduction to finite element method, Mathematical concepts and weighted residual techniques, Spatial discretization, Shape functions, Isoparametric elements, Explicit and implicit time marching schemes, Equation assembly and solution techniques, Application: Navier-Stokes equations, dispersion of pollutants into ground and surface water, Flow through earthen dams, seepage beneath a hydraulic structure, Groundwater flow in confined and unconfined aquifers.

**CVL736 Soft Computing Techniques in Water Resources**

3 credits (2-0-2)

Artificial Intelligence; Expert Systems; Artificial Neural Networks; Introduction, Training, Applications in Hydrology; Genetic Algorithms; Fuzzy Logic Systems, Fuzzy Set Theory, Predictive and Descriptive Data Mining; Classification Methods: Decision trees, NN, Bayesian, ANN, SVM, Applications; Association Analysis; Cluster Analysis - K-means, Fuzzy, Self-Organising maps; Anomaly detection; Applications in Water Resources - Forecasting, Regionalization.

**CVL737 Environmental Dynamics and Management**

3 credits (3-0-0)

Environmental property and processes, Environmental simulation models, Elements of environmental impact analysis, Impact assessment methodologies, Framework of environmental assessment, Environmental impact of water resources projects, Assessment of hydrological hazards, Environmental management, Case studies.

**CVL738 Economic Aspects of Water Resources Development**

3 credits (3-0-0)

Economics of water and development, Basic economic concepts, Financial analysis of a project, Pricing concepts, Benefit-cost-sensitivity analysis, Capital budgeting and cost allocation, Economics of natural resources management, Hydro economic model, Hydro-economic risk assessment, Economics of river restoration, Economics of trans-boundary water resources management.

**CVL740 Pavement Materials and Design of Pavements**

4 credits (3-0-2)

Components of pavement structure and its requirements; Materials used in pavement construction: aggregate, Portland cement, asphalt, Portland cement concrete, asphalt concrete; Aggregates: production,

properties, testing procedures, gradation and blending; Portland cement based materials: mixture design, production, properties, testing, construction; Asphalt binder: refining process, properties, testing procedures, grading systems; Asphalt concrete mixture design: fundamentals of mix design procedure, mixture volumetrics, current mix design procedures; Production and construction practices; Stresses and strains in pavement system: traffic, environment considerations; Design of pavements: new, overlay; Pavement performance; Drainage consideration.

### **CVL741 Urban and Regional Transportation Planning**

4 credits (3-0-2)

Fundamentals of transportation planning. Components of transportation system and their interaction. Historical development and current status of techniques used in travel demand forecasting; Economic Theory of travel demand forecasting; trip generation, trip distribution, mode choice, traffic assignment models. Integration of landuse transport models. Comparison and evaluation of various models. Simultaneous travel demand models: Parameter Estimation and Validation. Travel Data collection and use of surveys. The role of transportation planning in the overall regional system. Methodology and models for regional transportation system, planning, implementation framework and case studies. Applications to passenger and freight movement in urban area. Implications for policy formulations and analysis.

### **CVL742 Traffic Engineering**

4 credits (3-0-2)

Introductory concepts of traffic engineering, road user and vehicle characteristics, Road way geometric characteristics, traffic stream characteristics, and traffic flow theory basics. Statistical applications in traffic engineering. Traffic data collection methods - speed, volume, travel time and delay studies. Parking studies. Highway safety and statistics. Capacity analysis of freeway and multilane highways - fundamental concepts, freeway segment analysis, two-way highways. Intersections concepts of intersection control, intersection layout, signalization basics, signal timing. Analysis of signals and coordination under undersaturated and oversaturated conditions.

### **CVL743 Airport Planning and Design**

3 credits (3-0-0)

Overview of air transport; Forecasting demand-passenger, freight; Aircraft characteristics; Airport planning-requirements site selection, layout plan; Geometric design of runway, taxiway and aprons; Airport capacity-airside, landside; Passenger terminal-functions, passenger and baggage flow; Airport pavement design and drainage; Parking and apron design; Air cargo facilities; Air traffic control lighting and signing; Airport safety; Environmental impact of airports; Airport financing and economic analysis.

### **CVL744 Transportation Infrastructure Design**

3 credits (2-0-2)

Transportation infrastructure: components, structural and functional requirements, capacity, level of service; Highway infrastructure: grade intersections, rotaries, interchanges; Railway infrastructure: trackbed design, grade-crossing design, embankment, retaining walls; Drainage infrastructure: culverts, bridges; Pedestrian infrastructure: pedestrian sidewalks, foot bridges; Miscellaneous: bus and truck terminals, parking facilities, guard rails, tunnels, underpasses;.

### **CVL745 Modeling of Pavement Materials**

3 credits (2-0-2)

Role of constitutive modeling; Laboratory testing in relation to constitutive modeling: elastic modulus, resilient modulus, complex modulus, creep, rheological tests; Introduction to continuum mechanics: strain tensor, stress tensor, isotropy, anisotropy, constitutive relationships; Factors affecting material behavior: temperature, rate, time, confining pressure; Unbound materials: soil, aggregate; Bound materials: binding using asphalt, water, lime, polymer, fly ash, cement; Constitutive models: unbound materials, bound materials; Field performance of pavement materials: fatigue, rutting, temperature issues, moisture damage, permeability; Transfer functions to relate laboratory performance with field performance.

### **CVL746 Public Transportation Systems**

3 credits (3-0-0)

This course discusses the role of urban public transportation modes, focusing on bus and rail systems. Operational and Technological characteristics are described, along with their impacts on capacity, service quality, and cost. Current practice and methods for data collection and analysis, performance evaluation, route and network design, frequency determination, and vehicle and crew scheduling are covered. Main topics include: Transit System; Estimation of Transit Demand; Route planning techniques; Bus Scheduling; Transit Corridor identification and planning; Mass Transport Management Measures; Integration of Public Transportation Modes. Public transport Infrastructure; Case Studies. Multimodal Transportation Systems.

### **CVL747 Transportation Safety and Environment**

3 credits (3-0-0)

Scientific management techniques in planning, implementing, and evaluating highway safety programs, strategies to integrate and amplify safety in transportation planning processes., multidisciplinary relationships necessary to support effective traffic safety initiatives. Traffic Safety as public health problem, Injury indices and costing , emergency care, pollution inventory in urban areas, environment and safety standards.

### **CVL750 Intelligent Transportation Systems**

3 credits (3-0-0)

Introduction to Intelligent Transportation Systems (ITS); ITS Organizational Issues, the fundamental concepts of Intelligent Transportation Systems (ITS) to students with interest in engineering, transportation systems, communication systems, vehicle technologies, transportation planning, transportation policy, and urban planning. ITS in transportation infrastructure and vehicles, that improve transportation safety, productivity, environment, and travel reliability. Mobile device applications of ITS such as trip planners, ETA s of public transit vehicles.

### **CVD753 Minor Project in Transportation Engineering**

3 credits (0-0-6)

### **CVS754 Independent Study**

3 credits (0-0-6)

### **CVD756 Minor Project in Structural Engineering**

3 credits (0-0-6)

The course content will be decided by the concerned faculty member (supervisor) who will be assigning the research project to the students registered for this course.

### **CVL756 Advanced Structural Analysis**

3 credits (3-0-0)

Matrix methods for 3-D skeletal structures: force and displacement methods including analysis using substructures, static condensation. Computational aspects including in plane rigidity of slab, non-prismatic members, and shear deformation effects. Non-linear analysis: second order and elastoplastic analysis. Energy approaches. Analysis of plates and singly curved shells.

### **CVP756 Structural Engineering Laboratory**

3 credits (0-0-6)

Concrete: Concrete mix-design Evaluation of stress-strain response of plain, self-compacting and high-performance concrete; Behaviour of RC members under axial, flexure, shear torsion, and interaction; Behavior of slabs, Non-destructing testing. Response of structures and its elements against extreme loading events. Model testing: Models of plates, shells, and frames; Free and forced vibrations; Evaluation of dynamic modulus; Beam vibrations; Vibration isolation; Shear wall building model; Time and frequency-domain study. Smart materials; Photogrammetry for Displacement Measurement; Vibration Characteristics of RC Beams using Piezoelectric Sensors etc.

**CVS756 Independent Study (CES)**

3 credits (0-0-6)

Course content will be decided by the concerned faculty member of structural engineering.

**CVD757 Major Project Part-I (CES)**

9 credits (0-0-18)

**CVL757 Finite Element Methods in Structural Engineering**

3 credits (2-0-2)

Review of principles of virtual work and minimum potential energy. Elements of theory of elasticity. Finite element (FE) techniques for linear and static problems. Developing various types of finite elements: 1-D, 2-D, and 3-D. Formulating displacement and shape functions. Variational and weighted residual techniques. Higher order/isoparametric formulation for truss, beam, frame, plate, and shell elements. Numerical solution procedures and computational aspects. Applications to structures such as dams, frames, shear walls, grid floors, rafts etc. Algorithms for FE problem solving and commercial software modeling issues. Application of FE methods to solve thermal problems.

**CVD758 Major Project Part-II (CES)**

9 credits (0-0-18)

**CVL758 Solid Mechanics in Structural Engineering**

3 credits (3-0-0)

Introduction; Historical developments; Theory of stress; Kinematics; Isotropic/ anisotropic linear elastic solids; Axioms of constitutive equations; Finite isotropic elasticity; Hypo/ hyperelasticity; Hardening plasticity; Viscoelasticity; Boundary Value Problems (BVPs); Plane elasticity; Polar coordinates; Torsion and bending of prismatic bars with general section; Elastic wave propagation; Current trends.

**CVL759 Structural Dynamics**

3 credits (3-0-0)

Theory of structural dynamics and vibration analysis. Free and forced vibration of single degree of freedom (SDOF) systems, load regimes and response to harmonic, periodic, impulsive, and general dynamic loading. Response of SDOF to earthquake and response spectrum concept. Damping in structures and its evaluation. Free and forced vibration of lumped multi degree of freedom (MDOF) structures. Methods for obtaining natural frequencies and mode shapes. Normal mode theory; mode combination rules; dynamic response evaluation. Force excited and base excited dynamical systems. Time domain analysis using numerical integration scheme. Free and forced vibration of continuous systems. Frequency domain analysis of dynamical systems. Introduction to advanced topics in structural dynamics.

**CVL760 Theory of Concrete Structures**

3 credits (3-0-0)

Introduction: Historical developments, Material properties; Cracked concrete members under flexural moment and axial force; Deformations and collapse; M-P interaction. Beams without stirrups under flexural and torsional shear: Morsch and Regan theories; Skew-bending theory. Beams with stirrups under flexural and torsional shear: Plane and space truss analogies, Modified compression field theory, Unified theory, P-M-V-T interaction; Strut and tie model; Cracking: Bond slip, Development length, Tension stiffening, Durability detailing; Serviceability: Elastic, creep and shrinkage deformations; Elastic analysis: Redistribution of moments; Plastic analysis: Inelastic and hysteretic behaviour, Limit design, Confined concrete: Ductility detailing requirements; Buckling of columns; Concrete slabs: Yield line theory, Strip Theory; Reliability and safety: Limit state design method, Target reliability; Current trends: Constitutive modelling, Capacity design, Finite element analysis.

**CVL761 Theory of Steel Structures**

3 credits (3-0-0)

Structural steel: Classifications, Grades, Behavioural characteristics,

Plasticity and hardening; Material models: Simple, Rigid, Power function, Smooth hysteretic; Design methodology: Allowable, Limit state, Ultimate; Methods of analysis including second-order effects; Plastic design: Plate instabilities, Local buckling, Section classifications; Structural stability: Global buckling, Member and frames under axial and combined loading; Sway and non-sway frames; Design of members under combined bending, shear and torsion; Connections: Simple, Semi-rigid, Rigid; Plates girders: Simple post-critical theory, Tension-field theory, Section design, Stiffener requirements; Gantry girder; Grillage foundation; Earthquake-resistant design and detailing; Fire-resistant design; Fatigue-resistant design.

**CVL762 Earthquake Analysis and Design**

3 credits (3-0-0)

Seismology Seismic Risk and Hazard; Soil Dynamics and Seismic Inputs to Structures; Response Spectrum Analysis (RSA); Special Analysis; Nonlinear and Push-Over Analysis; Dynamic Soil-Structure Interaction (SSI); Earthquake Resistant Design Philosophy; Performance Based Earthquake Engineering; Code Provisions for Seismic Design of Structures; Retrofitting and Strengthening of Structures; Concept of Base Isolation Design and Structural Vibration Control; Advanced Topics in Earthquake Engineering.

**CVL763 Analytical and Numerical Methods for Structural Engineering**

3 credits (3-0-0)

Introduction: Mathematical foundations of structural theory. Linear algebra: vector spaces and linear transformations. Linear differential equations and function spaces. Partial differential equations; Elliptic, parabolic and hyperbolic PDEs. Nonlinear differential equations. Gaussian Elimination; Factorization Techniques - LU, Cholesky; Iterative Methods of Solution of Linear Simultaneous Equations. Properties of Eigenvalues and Eigenvectors; Similarity Transforms; Diagonalization and Numerical Techniques to Compute Eigenvalues - Vector Iteration, QR algorithm, Jacobi Method. Time Marching Schemes (Step by Step Solutions); Euler's Method; Runge Kutta Method; Newmark Beta Method. Numerical Solution of Boundary Value Problems - Finite Difference Method, Explicit and Implicit Approaches; Method of Weighted Residuals, Galerkin's Method. Numerical Integration: Gauss-Legendre Method, Newton-Cotes Method. Regression Analysis and Curve Fitting. Applications of mathematical and numerical methods to static, dynamic and stability analysis of elastic structures and cables.

**CVL764 Blast Resistant Design of Structures**

3 credits (2-0-2)

Blast Engineering: Explosion Phenomena, Shock Front, Fragmentation, Waves, Ground Shock, and Interaction with Structures; Structural Analysis for Impulsive Loading; Pressure-Impulse (PI) Diagrams; Material Behaviour under High Strain-Rate of Loadings; Blast Resistant Design of Structures; Performance-Based Blast Design; Progressive Collapse; Anti-Terrorism Planning and Design of Facilities; Blast Retrofitting; Indian/ International Standards and Codes of Practice; Numerical Analysis Tools for Blast Analysis using Finite Element (FE) Software and Hydrocodes.

**CVL765 Concrete Mechanics**

3 credits (3-0-0)

Introduction; Rheological modelling of fresh concrete; Flowing concrete; Mechanics of hardened concrete: Failure criteria; Constitutive equations; Elasto-plasticity, visco-elasticity, fatigue, damage mechanics and fracture; Mechanics of hydrating concretes, Durability Mechanics, Transport processes; Drying shrinkage; Micromechanics, Numerical and analytical homogenisation, poromechanics, Crystalline growths and internal microstresses.

**CVL766 Design of Bridge Structures**

3 credits (3-0-0)

Introduction, historical/ magnificent bridges; Site Selection, Planning, and Type of Bridges, Loads and Forces; Code Provisions for Design of Steel and Concrete Bridges; Analysis Methods, Grillage Analogy; Theories of Lateral Load Distribution and Design of Superstructure: Slab Type, Beam-Slab, and Box Type; Distribution of Externally

Applied and Self-Induced Horizontal Forces among Bridge Supports in Straight, Curved, and Skewed Decks; Continuous Type and Balanced Cantilever Type Superstructure; Temperature Stresses in Concrete Bridge Deck; Different Types of Foundations: Open, Pile, and Well Foundations; Choice of Foundation for Abutments and Piers; Design of Abutments, Piers, Pile/ Pier Caps; Effect of Differential Settlement of Supports; Bridge Bearings; Expansion Joints for Bridge Decks; Vibration of Bridge Decks; Parapet and Railings for Highway Bridges; Construction Methods; Segmental Construction of Bridges; Inspection and Maintenance of Bridges; Health Monitoring and Evaluation of Existing Bridges; Bridge Failure: Case Studies.

### **CVL767 Design of Fiber Reinforced Composite Structures** 3 credits (3-0-0)

Introduction; Types of structural fibers: matrix, fiber and interface; Fiber reinforced concrete (FRC); High-performance concrete; Stress transfer, Bond, Pull-out, Toughening mechanism; Fracture mechanics; Modeling of tensile and flexural behaviours; Behaviour under compression; Shear failure theory; Behaviour under seismic loading; Composite structural design: Design spirals, Selection Criteria configurations; Laminate design; Mathematical analysis of laminates; Design of single skin panels, Design of composite stiffeners.

### **CVL768 Design of Masonry Structures** 3 credits (3-0-0)

Introduction and Historical Perspective; Masonry Materials; Masonry Design Approaches; Overview of Load Conditions; Compression Behavior of Masonry; Masonry Wall Configurations; Distribution of Lateral Forces; Flexural Strength of Reinforced Masonry Members: In-plane and Out-of-plane Loading, Interactions; Structural Wall; Columns and Pilasters; Retaining Wall; Pier and Foundation; Shear Strength and Ductility of Reinforced Masonry Members; Prestressed Masonry; Stability of Walls; Coupling of Masonry Walls, Openings, Columns, Beams; Elastic and inelastic analysis; Modelling Techniques; Static Push-Over Analysis and use of Capacity Design Spectra.

### **CVL769 Design of Tall Buildings** 3 credits (3-0-0)

Structural systems and general concepts of tall buildings; Various methods of structural analysis; Gravity systems for steel, concrete, and composite buildings; Lateral systems for steel, concrete, and composite buildings; Interaction of frames and shear walls; Simultaneous and sequential loading; Differential shortening of columns; P- $\Delta$  effects; Effect of openings; Foundations and foundation-superstructure interaction; Wind/ earthquake effects and design for ductility; Damping systems; Asymmetric structures and twisting of frames.

### **CVL770 Prestressed and Composite Structures** 3 credits (2-0-2)

Introduction; Need, Advantages, and Disadvantages; High Strength Materials; Pretensioning and Post-Tensioning Methods; Prestressing Methods; Prestressing Systems and Devices; Camber, Deflections, and Cable Profiles/ Layouts; Load-Balancing; Codes and Standards; Prestressed Concrete Members - Flexure, Shear, Torsion Behaviors; Design Methods and Code Provisions; Strain Compatibility Method; Pressure/ Thrust Line; Pre-Tensioning; Grouted/ Bonded and Ungouted/ Unbonded Post-Tensioning; Partial Prestressing; Bursting Stresses; Anchorage Zone (End Block Design); Transmission and Transfer Length; De-Bonding and Draping of Prestressing Tendons; Camber, Deflection, and Ductility; External Prestressing; De-Compression; Losses in Prestress; Bearing and Bond Stresses; Case Studies of Prestressed Concrete Bridge Design and Practices.

Need of Composite Construction; Analysis of Indeterminate and Composite Structures; Design Methods for Composite Beams, Slabs, Columns, Box-girders, Shear Studs etc.

### **CVC771 Seminar in Construction Technology and Management-I** 0 credits (0-0-2)/Compulsory Audit

### **CVD771 Minor Project (CEC)** 3 credits (0-0-6)

### **CVL771 Advanced Concrete Technology** 3 credits (3-0-0)

Hydration of cements and microstructural development, Mineral additives, Chemical admixtures, Rheology of concrete, Creep and relaxation, Shrinkage, cracking and volume stability, deterioration processes, special concretes, Advanced characterisation techniques, sustainability issues in concreting, Modelling properties of concrete.

### **CVP771 Construction Technology Laboratory** 1.5 credits (0-0-3)

Tests related to quality control at site, in-situ tests, tests related to damage and deterioration assessment, performance monitoring of structures.

### **CVS771 Independent Study (CEC)** 3 credits (0-0-6)

### **CVC772 Seminar in Construction Technology and Management-II** 0 credits (0-0-2)/Compulsory Audit

### **CVD772 Major Project Part-I (CEC)** 9 credits (0-0-18)

### **CVL772 Construction Project Management** 3 credits (3-0-0)

Introduction to construction project management - CPM, PERT, PDM, LOB. Scope management, WBS, PDRI. Time and cost management, material related management - purchase & inventory control, time-cost-resource optimization, quality, safety - planning & control. Labor productivity variations, productivity improvement - work study. Measuring project progress & performance - EVA & ES. Identification of risks and impact. Management Information systems.

### **CVP772 Computational Laboratory for Construction Management** 1.5 credits (0-0-3)

Introduction to construction project models - analytical and numerical. Application software for project planning, scheduling & control. Programming exercises for estimation, network planning and control, LP in construction.

MATLAB Programming in linear and non-linear programming.

### **CVD773 Major Project Part-II (CEC)** 12 credits (0-0-24)

### **CVL773 Quantitative Methods in Construction Management** 3 credits (3-0-0)

Introduction and concepts of probability and statistics, Linear programming, Transportation and assignment problems. Dynamic programming, Queuing theory, Decision theory, Games theory. Simulations applied to construction, Modifications and improvement on CPM/PERT techniques.

### **CVL774 Construction Contract Management** 3 credits (3-0-0)

Professional Ethics, Duties and Responsibilities of Parties. Owner's and contractor's estimate, Bidding Models and Bidding Strategies, Qualification of Bidders. Tendering and Contractual procedures, Indian Contract Act 1872, Definition of Contract and its Applicability, Types of Contracts, Clauses in Domestic and International Contracts - CPWD, MES, FIDIC, AIA, NEC, JCT, etc. Contract Administration, Delay Protocol, Change Orders Analysis, Claim Management and Compensation, Disputes and Resolution Techniques, Arbitration and Conciliation Act 1996, Arbitration Case Studies.

### **CVL775 Construction Economics and Finance** 3 credits (3-0-0)

Engineering economics, Time value of money, discounted cash flow,

NPV, ROR, PI. Basis of comparison, Incremental rate of return, Benefit-cost analysis, Replacement analysis, Break even analysis. Depreciation and amortization. Taxation and inflation, Evaluation of profit before and after tax. Risks and uncertainties and management decision in capital budgeting. Working capital management, financial plan and multiple source of finance. Budgeting and budgetary control, Performance budgeting. Profit & Loss, Balance Sheet, Income statement, Ratio analysis, Appraisal through financial statements, International finance, forward, futures and swap. Practical problems and case studies.

### **CVD776 Minor Project (CET)**

3 credits (0-0-6)

### **CVL776 Construction Practices and Equipment**

3 credits (3-0-0)

Form work design and scaffolding, slipform and other moving forms, Shoring, Reshoring, and Backshoring in multistoreyed Building construction. Prestressing, Steel and composites construction methods: Fabrication and erection of structures including heavy structures, Prefab construction, Industrialized construction, Modular coordination. Special construction methods: High rise construction, Bridge construction including segmental construction, incremental construction and push launching techniques.

Factors affecting selection of equipment - technical and economic, Analysis of production outputs and costs, Characteristics and performances of equipment for major civil engineering activities such as Earth moving, erection, material transport, pile driving, Dewatering, and Concreting.

### **CVS776 Independent Study (CET)**

3 credits (0-0-6)

### **CVD777 Major Project Part-I (CET)**

9 credits (0-0-18)

### **CVL777 Building Science**

3 credits (3-0-0)

Introduction to environmental features relevant to functional design. Their measures description and quantification. Periodic nature of variation of environmental descriptors. Heat exchange of building with environment under diurnal periodic variation temperature and modelling. Estimation of hourly internal temperature through CIBS method. Thermal Design philosophy and optimization for decision variables such as shape, orientation, envelope properties etc. Purpose of ventilation, wind and stack effect as driving force. Design for desired flow and indoor velocity. Fundamentals of acoustics, Sound ion free field and enclosure. External and Internal air borne noise control. Protection against structure borne noise. Lighting principles and daylighting. Day light factor, and design for desired illumination and glare free lighting.

### **CVD778 Major Project Part-II (CET)**

12 credits (0-0-24)

### **CVL778 Building Services and Maintenance Management**

3 credits (3-0-0)

Concepts of functional design of building for fire protection, design of lift systems for optimum service. Building service system design. Control and intelligent buildings, HVAC, hot and cold water services, waste water handling system, electrical services, building maintenance management.

### **CVL779 Formwork for Concrete Structures**

3 credits (3-0-0)

Requirements and selection for Formwork, Formwork Materials, such as Timber, Plywood, Steel, Aluminum Form, Plastic Forms, and Accessories, Horizontal and Vertical Formwork Supports; Formwork Design Concepts, Illustration of Formwork system for Foundations, walls, columns, slab and beams and their design, Formwork for Shells, Domes, Folded Plates, Overhead Water Tanks, Natural Draft Cooling Tower. Formwork for Bridge Structures, Flying Formwork such as Table form, Tunnel form. Slipform, Formwork for Precast Concrete, Formwork Management Issues pre award and post award, Formwork

failures-causes and Case Studies in Formwork Failure, Formwork issues in multi-story building construction.

### **CVD800 Major Project Part-I**

6 credits (0-0-12)

### **CVL800 Emerging Topics in Geotechnical Engineering**

3 credits (3-0-0)

A course which will vary from year to year to study new and exciting developments in the broad spectrum of Geotechnical and Geoenvironmental Engineering. The course will also focus on new offshoots of Geotechnical and Geoenvironmental Engineering.

### **CVP800 Geoenvironmental and Geotechnical Engg. Lab**

3 credits (0-0-6)

Engineering properties and compaction characteristics of waste - coal ash, mine tailings. Permeability of clays and bentonite amended soils.

Physical, Mechanical and Hydraulic Testing of Geosynthetics

Landfill liner and cover: Evaluation of shear strength parameters of various Interfaces and design.

Project based laboratory for evaluation of engineering properties of soils for design of embankments.

### **CVS800 Independent Study**

3 credits (0-0-6)

### **CVD801 Major Project Part-II**

12 credits (0-0-24)

### **CVL801 Constitutive Modelling in Geotechnics**

3 credits (3-0-0)

Introduction: fundamental relations, models and soil mechanics. Elasticity: Isotropic, anisotropic, soil elasticity. Plasticity and yielding: yielding of clays, yielding of sands, slip line fields, introduction to upper and lower bounds, selected boundary value problems. Elastic-plastic model for soils: elastic volumetric strains, plastic volumetric strains, plastic hardening, plastic shear strains, plastic potentials, flow rule. Cam clay model: critical state line, shear strength, stress-dilatancy, index properties, prediction of conventional soil tests. Applications.

### **CVD810 Major Project Part-I (CEU)**

6 credits (0-0-12)

### **CVL810 Emerging Topics in Rock Engineering and Underground Structures**

3 credits (3-0-0)

Advanced and state-of-the-art rock engineering topics.

### **CVP810 Rock Mechanics Laboratory-II**

3 credits (0-0-6)

*Pre-requisites: Rock Mechanics Lab-I CVP710*

Project planning, Schedule and cost assessment, DPR and GD for Major projects, Field visit, Sample collection, Scanline survey and seismic survey, Rock characterization, Determination of physical and mechanical properties of rocks, Analysis of slopes using GEOSLOPE and Analysis of tunnels using Phase2, both using the material properties determined through laboratory tests. Design of slopes and tunnels.

### **CVS810 Independent Study (CEU)**

3 credits (0-0-6)

### **CVD811 Major Project Part-II (CEU)**

12 credits (0-0-24)

### **CVL811 Numerical and Computer Methods in Geomechanics**

3 credits (2-0-2)

*Pre-requisites: CVL704 or Equivalent*

Introduction to Numerical Methods, ODEs, PDEs, Equation solution

techniques, Root finding techniques, Fourier Series, Types of geotechnical boundary value problems, Numerical modeling, Numerical solution schemes, pros and cons, Programming tools- FORTRAN, MATLAB, MATHCAD, Development of programming flowchart.

Simplified and advanced constitutive models and their calibration: Elastic Models, Elasto-plastic Models, Formulation of Elasto-Plastic Stiffness Matrix, Governing equations of elastoplasticity, Rock and Soil constitutive models.

Integration of stress-strain equations, Concepts of verification and validation, Selection of model input parameters, Integration of load-displacement relations, Integration of seepage, consolidation and heat conduction equations, Sturm–Liouville problem, Solution of seepage, consolidation, heat conduction and Sturm-Liouville equations using finite difference and finite element programming methods, Comparison with commercially available software results.

### **CVL817 Structural Safety and Reliability (PG)**

*3 credits (3-0-0)*

Fundamentals of set theory and probability, probability distribution, regression analysis, hypothesis testing. Stochastic process and its moments and distributions, concepts of safety factors, Safety, reliability and risk analysis, first order and second order reliability methods, simulation based methods, confidence limits and bayesian revision of reliability, reliability based design, examples of reliability analysis of structures.

### **CVL818 Design of Plates and Shells (PG)**

*3 credits (2-1-0)*

Prismatic folded plate systems. Shell equations. Approximate solutions. Analysis and design of cylindrical shells. Approximate design methods for doubly curved shells.

### **CVL819 Concrete Mechanics (PG)**

*3 credits (3-0-0)*

Introduction; Rheological modelling of fresh concrete; Constitutive equations; Nonlinear elasticity, plasticity, visco-elasticity and fracture mechanics of hardened concrete; Confinement and ductility; Moisture diffusion; Drying shrinkage; Solid and structural mechanics of reinforced concrete, Skew bending, modified compression field and unified theories of R.C. beams under bending, shear and torsion; Bond-slip and phenomenon of cracking in reinforced concrete; Static and dynamical analysis of R.C. Structures; Trends.

### **CVL820 Environmental impact assessment**

*3 credits (3-0-0)*

Planning and Management of Environmental Impact Studies. Impact indentation methodologies: base line studies, screening, scoping, checklist, networks, overlays. Prediction and assessment of impacts on the socio-economic environment. Environmental cost benefit analysis. Decision methods for evaluation of alternatives. Case Studies. Environmental impact assessment at project level, regional level, sectoral level, and policy level. Sustainable development; Environmental policy in planned, mixed and market economies. Preventive environmental management.

### **CVP820 Advanced Air Pollution Laboratory**

*3 credits (1-0-4)*

Monitoring of TSP using HVS, Monitoring of PM<sub>2.5</sub> using cyclone based sampler, Size segregated particle collection and data analysis using histogram, inversion program, Personal exposure assessment, determination of count and geometric mean diameter, determination of chemical species in air samples, Determination of emission factors of particle and gases for combustion sources, Determination of TVOC; Determination of indoor air quality parameters, determination of Bioaerosol; Monitoring and analysis of meteorological parameters.

### **CVL821 Industrial Waste Management and Audit**

*3 credits (3-0-0)*

Industrial Wastes: Nature and characteristics, Prevention and Control, Tools for clean processes: reuse, recycle, recovery, source reduction,

raw material substitution, process modification, Flow sheet analysis, Energy and resources audit, Waste audit, emission inventory and waste management hierarchy for process industries, Zero discharge, Environmental indicators, Industrial ecology and ecoparks, rules and regulations, Case studies: Dairy, Fertilizer, Distillery, Pulp and Paper, Iron and steel, Metal plating, Refineries, Thermal power plants, etc.

### **CVP821 Advanced Water and Wastewater Laboratory**

*3 credits (1-0-4)*

Principles of instrumentation and application for water quality parameters measurements, Operation of batch scale models for various processes: Activated sludge process, Disinfection, Settlers, Coagulation, Filtration, Anaerobic digestion, Adsorption. Design and operation of treatability studies and microbial growth kinetics, microbial toxicity and bioaccumulation studies. Micropollutants detection; Package programmes for water and wastewater conveyance, treatment and disposal.

### **CVL822 Emerging Technologies for Environmental Management**

*3 credits (3-0-0)*

Contemporary micro and macro environmental issues of importance, global environmental and resource sharing issues, international treaties and protocols. Emerging contaminants and emerging technologies for waste management, Case studies of environmental pollution and innovative management strategies. Environmental technology transfer, Non-conventional Energy, Emission trading, Adaptation to climate change.

### **CVL823 Thermal Techniques for Waste Management**

*3 credits (3-0-0)*

Fundamentals of Thermodynamics, Heat Transfer and Combustion as applied to Waste Incineration. Introduction to fuels, reactor design, fluidization engineering and furnace technology. Combustion of gaseous, liquid and solid fuels. Wastes as fuels. Low, medium and high temperature thermal treatment techniques, Energy recovery, pollution control techniques for thermal facilities, Design of thermal treatment facilities with pollution control devices.

### **CVL824 Life Cycle Analysis and Design for Environment**

*3 credits (3-0-0)*

Engineering products and processes : Environmental health and safety, Product life cycle stages, Material toxicity, pollution, and degradation, Environmentally conscious design and manufacturing approaches, Sustainable development and industrial ecology. System life-cycles from cradle to reincarnation, Product life-extension, Organizational issues. Pollution prevention practices, Manufacturing process selection and trade-offs. Design for Environment : Motivation, concerns, definitions, examples, guidelines, methods, and tools. Recyclability assessments, Design for recycling practices. Re- manufacturability assessments, Design for Remanufacture / Reuse practices. Industrial ecology and Eco-industrial parks. Eco-Labels and Life-Cycle analysis (LCA): LCA methodology, steps, tools and problems, Life-Cycle Accounting and Costing. ISO 14000 Environmental Management Standards. New business paradigms and associated design practices.

### **CVL825 Fundamental of Aerosol: Health and Climate Change**

*3 credits (3-0-0)*

This course will introduce the students with fundamentals of aerosols, Difference in gas and particle motion in the air, physio-chemical and optical properties of individual and mixed particles, behaviour of non-spherical particles, thermodynamic properties of aerosol, particle formation, application of aerosol fundamentals and properties in research and industries, impact of aerosol properties on indoor/ outdoor air quality, health and climate.

### **CVL826 Quantitative microbial risk assessment**

*1 credit (1-0-0)*

Pathogens, Occurrence and fate in environment, Human exposure pathways, Microbial exposure dose estimation, Infection and dose-response modeling, Risk of infection estimation, Uncertainty estimation.

**CVL827 Environmental Implications of Engineered Nanomaterials**

2 credits (2-0-0)

Engineered nanomaterials, Occurrence of nanomaterials in environment, Fate of nanomaterials in environment, Exposure pathways-model development and parameter estimation, Dose-response effects of nanomaterials to humans and aquatic species; dose-response modeling and risk estimation of nanomaterials exposures; Risk management of nanomaterials pollution; Prioritization of nanomaterials for monitoring; Regulatory guidelines for implications assessment and pollution regulations; Emerging challenges for long-term management of nanomaterials exposure.

**CVL828 Water Distribution and Sewerage Network Design**

3 credits (3-0-0)

Planning for water supply sources and demand assessment. Water demand forecasting. Types of water distribution systems. Intermittent and continuous water supply systems. Design and analysis of Water mains. Design and analysis of water distribution system. Analysis of water deficient systems. Optimal design of water distribution systems. On-line monitoring of water quality parameters. Retrofitting of the existing water supply systems.

Planning for wastewater conveyance system in urban areas. Combined and separate systems for storm and sewage. Design and analysis of wastewater conveyance system. Optimal design of wastewater conveyance systems. Operation and maintenance issues. Retrofitting of the sewerage system.

**CVL830 Groundwater Flow and Pollution Modeling**

3 credits (3-0-0)

Subsurface processes and concepts for groundwater resources evaluation, Unsaturated zone properties: Soil moisture levels, Retention curves, Flow through unsaturated porous media, Multiphase flows, infiltration and Wetting front, Groundwater contamination, Sources and causes of groundwater pollution, Pollution dynamics, Hydrodynamics dispersion, Adsorption, Biodegradation, Radioactive decay, Reactive processes, Multiphase contamination, NAPLs, VOCs, Site specific groundwater quality problems in Indian context, Numerical models, Finite difference methods, Numerical modeling of steady and transient flows in saturated and unsaturated domain, Contaminant transport modeling, Application of FEM and BIEM in groundwater modeling, Regional aquifer simulation, Contaminated groundwater systems and their rehabilitation, Development and optimization based management of aquifer systems, Stochastic models, Random field concepts in groundwater models; Application of emerging techniques to groundwater management.

**CVS830 Independent Study (CEW)**

3 credits (0-3-0)

**CVD831 Major Project Part-I**

6 credits (0-0-12)

**CVL831 Surface Water Quality Modeling and Control**

3 credits (3-0-0)

River hydrology and derivation of Stream Equation, Derivation of Estuary equation, Distribution of water quality in rivers and estuaries. Physical and Chemical characteristics of Lakes, Finite Difference steady state river, estuary and Lake models, Dissolved Oxygen models in rivers, estuaries and Lakes, Fate of Indicator Bacteria and pathogens in water bodies. Basic Mechanism of Eutrophication, Lake phytoplankton models, eutrophication in rivers and estuaries. Elements of Toxic substance analysis.

**CVD832 Major Project Part-II**

12 credits (0-0-24)

**CVL832 Hydroelectric Engineering**

3 credits (3-0-0)

Hydropower development schemes and their various configurations, Planning for firm Capacities, Peak Load and Base Load configurations,

Role of and Regulation of Hydropower development in a mixed hydro-steam system, Governing of Hydropower systems; study of hydraulic transients in Penstocks. Surge analysis and dynamics of Surge tanks. Micro hydro power developments.

**CVL833 Water Resources Systems**

3 credits (3-0-0)

Water Resources Planning Purposes and Objectives, Multi-component, multi-user, multi-objective and multi-purpose attributes of an Integrated Water Resources System, Economic basis for selection of a Plan Alternative.

Introduction to Linear Programming and applications in Water Resources Engineering.

Irrigation Planning and Operation Models, Linear, Deterministic Integrated Water Resources Management Model on River Basin Scale, River Basin Scale Integrated Stochastic Water Resources Planning and Management Models.

**CVL834 Urban Water Infrastructure**

3 credits (3-0-0)

Urban water cycle, Urban water infrastructures - water supply, storm water drainage, sanitation, sewerage and wastewater conveyance infrastructures, Water supply and sewerage network hydraulics, SCADA systems, Sustainable urban designs, Methodologies for assessing sustainability of urban water infrastructures, Emerging sustainable materials and design procedures for water supply and sewerage pipelines, Hydraulic performance and structural strength, chemical resistance and resilience characteristics of emerging materials based water and sewer pipelines, Rehabilitation and augmentation technologies for water supply and sewerage networks, Analytic hierarchy process and optimization techniques for arriving at the best appropriate rehabilitation/augmentation technology, Urban water management, Rain water harvesting, Managed aquifer recharge, Constructed/engineered wetlands, Sprinkler and drip irrigation, Water use efficiencies, Effect of water management practices on urban water infrastructure, hydrology and groundwater regime, Surface and subsurface mapping of water supply and sewerage networks, Structural safety and mitigating plans against natural and human caused threats.

**CVL835 Eco-hydraulics and Hydrology**

3 credits (3-0-0)

Classification of Hydro environmental systems, governing equations for open surface flow domains, pollutant transport equations in hydro-environmental flow systems, computational methods and solution techniques. Study of ecological descriptors, numerical ecology, multi-objective definitions of environmental flows, Hydrologic indices for e-flows and river health assessment. Riverine habitat characterization and habitat simulation models. Anthropogenic triggers for changes in riverine habitat.

**CVL836 Advanced Hydrologic Land Surface Processes**

3 credits (3-0-0)

Introduction: Eco-hydro-climatology; Climate System; Climate, weather and Climate Change; Water, Energy and Carbon Cycle; Overview of Earth's Atmosphere: Heat-Balance of Earth Atmosphere System; Temporal Variation of Air temperature; Introduction to Atmospheric Thermodynamics: First and second law of thermodynamics, Adiabatic process and adiabatic lapse rate, Entropy, Clausius-Clapeyron Theory, Introduction to cloud microphysics and cloud droplet formation process, Cloud liquid water content, entrainment, warm and cold cloud. Hydrologic Cycle: Global water balance; Precipitation and Weather, Forms of Precipitation; Atmospheric Stability; Monsoon; Global Wind Circulation; Indian Summer Monsoon Rainfall. Climate Variability: Floods, Droughts, Climate Extremes. Climate Change: Introduction; Causes and Modeling of Climate Change, Climate Models, Downscaling; IPCC Scenarios; Commonly used Statistical Methods in Hydro-climatology: Trend Analysis; EOF, PCA; Canonical Correlation; Statistical Downscaling; Ecological Climatology: Leaf energy fluxes and leaf photosynthesis; Ecosystem and vegetation dynamics; Coupled climate vegetation dynamics, Carbon cycle climate feedbacks.

**CVL837 Mechanics of Sediment Transport***3 credits (2-0-2)*

Introduction; Equations of Particle Motion particle in a moving fluid, collision with the bed, diffusion of turbulence; Macroscopic View of Sediment Transport – bedload, suspended load; Threshold Condition for Sediment Motion – Critical stress for flow over a granular bed, Shields diagram; Mechanics of Bedload Transport: Bagnold hypothesis of bedload transport, bedload transport relations; Mechanics of Suspended Sediment Transport; Total load transport; Descriptive Analysis of Bedforms – introduction of bedform mechanics, dunes, antidunes, ripples, bars; Stability Analysis of Bedforms; Mechanism of transportation of materials by fluid flow through pipeline; Rheology and classification of complex mixtures; Fundamentals of two-phase flow; Phase separation and settling behaviour; Flow of non-Newtonian fluids through pipes: Turbulent flows of Complex mixtures, Slurry pipeline transportation, Design methods.

**CVL838 Geographic Information Systems***3 credits (2-0-2)*

What is GIS. Geographic concepts for GIS. Spatial relationships, topology, spatial patterns, spatial interpolation. Data storage, data structure, non-spatial database models. Populating GIS, digitizing, data conversion. Spatial data models, Raster and Vector data structures and algorithms. Digital Elevation Models (DEM) and their application. Georeferencing and projection systems, GIS application areas, Spatial analysis, quantifying relationships, spatial statistics, spatial search.

**CVL839 Hydrologic Applications of Remote Sensing***3 credits (2-0-2)*

Principles of remote sensing, Remote sensing platforms and data acquisition systems, Wavebands, Radiometric quantities, Spectral reflectance and spectral signature, Interaction of electromagnetic radiation with land surface features, hydrosphere and atmosphere, Data capture for simulation of land surface processes, Photographic and image interpretation, Satellite image processing, Earth surface features inventory, Geomorphology, Landuse classification, Landuse planning and landcover mapping, Flood plain mapping and flood plain zoning, Remote sensing applications in water resources, agriculture, geology and environmental monitoring, Applications in snow and glacier studies, Snow line, Ice cover, Snow-pack properties, Integrated use of remote sensing and GIS, Database preparation and Decision support analysis, Estimation of damages due to hydrologic extremes and preparation of contingency plans, Case studies.

**CVL840 Planning and Design of Sustainable Transport Systems***3 credits (3-0-0)*

Sustainable Transportation Planning and Design including: Consideration of bicycles, pedestrian, mass transit modes, and private vehicles like cars and two wheelers as well as how these modes interrelate. Applicability at varying scales, from a downtown street to a neighborhood to a regional network Case studies are discussed from different parts of the world. Various indicators for measuring sustainability index of transport system including public health, resource consumption, local and global pollution and equity considerations are discussed.

**CVL841 Advanced Transportation Modelling***3 credits (2-0-2)*

Systems Approach to Travel demand models, Trip generation Models Using Different Statistical techniques, Trip distribution, Discrete Choice Logit, Nested Logit and other Models, Network Assignment, Traffic Assignment Using User Equilibrium and Systems Optimization Techniques, Revealed preference and Stated Preference surveys, Analysis of Ranked and Rated data, Demand models for Nonmotorised transport and Public Transport systems.

**CVL842 Geometric Design of Roads***3 credits (2-0-2)*

Introduction to basic road geometric design elements and methodology - design philosophy and design techniques; Design

controls - human, vehicle and speed related factors. Road vehicle performance - road vehicle dynamics - tractive and resisting forces. Braking forces. Theoretical and practical stopping distances. Elements of geometric design - cross section elements; Horizontal Alignment - tangents, curves, transitions, superelevation; Vertical Alignment - grades and curves; Coordination of Horizontal and Vertical Alignment. Design of Intersections at-grade- design principles, channelization, roundabouts, Interchanges- types, warrants, lane balancing; Road side safety- hazards and clear zone concept, traffic safety barriers, impact attenuation.

**CVL844 Transportation Infrastructure Management***3 credits (3-0-0)*

Transportation infrastructure components; Deterioration phenomena; Effect of external factors like environment, traffic loading, material properties on deterioration mechanisms; Evaluation techniques to evaluate damage: destructive, nondestructive; Performance models: development, calibration; Infrastructure management systems; Serviceability of condition and safety; Decision making and optimization techniques applied to infrastructure management; Life cycle cost analysis techniques.

**CVL845 Viscoelastic Behavior of Bituminous Materials***3 credits (3-0-0)*

Overview of material behavior-elastic, plastic, viscoelastic, Viscoplastic response; Aging; Issues in representative volume element; Mechanical analogs for viscoelastic response; Fundamental viscoelastic response-creep compliance, relaxation, complex modulus; Interconversion techniques to obtain fundamental viscoelastic responses; Time-temperature superposition; linear viscoelastic constitutive equations; Elastic-viscoelastic correspondence principle; Predicting material behavior-undamaged, damaged state conditions, Introduction to nonlinear viscoelasticity, Viscoelastoplastic behavior, fracture mechanics.

**CVL846 Transportation System Management***3 credits (3-0-0)*

Transportation systems - resource management, approaches to funding. Asset and demand management - Integrated network design, changing travel behaviour, optimising asset management, role of technology; Optimizing the investment outcomes - movement of freight and passenger, traffic. Land use planning and urban growth management - land use and its effect on infrastructure and efficient network operations. Congestion, systemic congestion improvement and system-wide efficiency, Transit oriented development, safety considerations; evaluation of strategies; case studies.

**CVL847 Transportation Economics***3 credits (3-0-0)*

Overview of Transportation Economics; Transportation Investments and economic Development. Basics of Engineering economics, marginal analysis, opportunity cost, shadow price, money value of time, discounted cash flow, NPV, ROR, benefit-cost analysis. Road User Costs; Public transportation economics; Social Cost of Transportation; Cost of congestion, pollution, traffic accidents. Taxation, regulations, financing Transport Systems; Legal framework for transportation sector, case studies.

**CVL849 Traffic Flow Modelling***3 credits (3-0-0)*

Descriptors of traffic flow: Macroscopic and Microscopic, time, space and generalized measurement regions. Cumulative plots. Traffic Flow models - General classification and typology. Macroscopic Flow Models - continuity equation, LWR model, higher order models, numerical schema, Mesoscopic Flow Models - gas kinetic theory, Microscopic and Submicroscopic Flow Models - car following and lane changing; Pipes and forbes models; General motors-Gazis-Herman-Rothery (GHR) models, Stability analysis, macro-micro bridge. Modelling at Junctions/Intersections; Un-signalized and Signalized; Roundabouts; Pedestrian Modelling - normal and panic movements; variations across infrastructure; Simulation - simple and complex traffic conditions.



**CVL850 Transportation Logistics***3 credits (3-0-0)*

Evolution of freight and logistics; Interrelationships between society, environment and freight transport; Survey methodologies to understand freight movement; Cost measurement: Production, Holding, Transportation, Handling; Effect of internal and external variables on cost; Demand forecasting; Inventory planning and management; Transportation and distribution network: Design, Reverse Logistics. Development, Management; Ware house operations; Pricing: Perishable, seasonal demand, uncertainty issues; Vehicle routing: One-to-one distribution, One-to-many distribution, Shortest path algorithm, Quickest time algorithm; Logistics information system; Designing and planning transportation networks; City logistics.

**CVL851 Special Topics in Transportation Engineering***3 credits (3-0-0)*

Course details shall be announced by the instructor at the time of offering of the course. The lectures will be supplemented by reading materials. The assessment will be based on a combination of assignments, quizzes, and term papers and tests.

**CVS852 Advanced Topics in Transportation Engineering***3 credits (0-0-6)*

This is an advanced course for M.Tech. Transportation engineering program where students will study a specialized topic within transportation engineering (including but not limited to transportation planning, traffic engineering and pavement engineering). The topic shall be announced by instructor at the beginning. The performance of student in this course will be evaluated through presentation(s) and report(s) made by student during the registered term.

**CVD853 Major Project Part-I***9 credits (0-0-18)***CVD854 Major Project Part-II***12 credits (0-0-24)***CVL856 Strengthening and Retrofitting of Structures***3 credits (3-0-0)*

Structural assessment, damage under accidental and cyclic loads, cracking in structures, evaluation of damage, analysis of existing structures, compression, flexural and shear strengthening, strengthening using laminates, strengthening using prestressing, bracing and stiffening of structures, maintenance of retrofitting, design codes for retrofitting of structures, retrofitting of steel structures, retrofitting of masonry structures.

**CVL857 Structural Safety and Reliability***3 credits (3-0-0)*

Fundamentals of Set Theory and Probability; Probability Distribution, Regression Analysis, Hypothesis Testing. Stochastic Process and Its Moments; Probability Distributions; Concepts of Safety Factors, Safety, Reliability and Risk Analysis; First Order and Second Order Reliability Methods; Simulation Based Methods; Confidence Limits and Bayesian Revision of Reliability; Reliability Based Design; System Reliability; Examples of Reliability Analysis of Structures.

**CVL858 Theory of Plates and Shells***3 credits (3-0-0)*

Thin and thick plate theories. Bending of long rectangular plate to a cylindrical surface. Prismatic folded plate systems. Pure and symmetric bending of plates. Small and large deflections of plates. Special and approximate methods in theory of plates. General theory of cylindrical shells. Shell equations. Approximate solutions of plates and shells equations. Analysis and design of cylindrical shells. Approximate design methods for doubly curved shells. Stress analysis methods in spherical shells. Spherical shell of constant thickness. Symmetrical bending of shallow spherical shells. Conical shells.

**CVL859 Theory of Structural Stability***3 credits (3-0-0)*

Introduction: Buckling of steel and concrete structures; Conservative and non-conservative loads. Elastic buckling of columns and beam-columns: Static, dynamical and energy-based approaches. Viscoelastic and elastoplastic buckling. Torsional buckling. Flexural-torsional and lateral buckling. Plate and frame buckling. Imperfection sensitivity; Post-buckling theory. Snap-through. Dynamic stability: Divergence, flutter and parametric resonance. Nonlinear dynamical systems theory; Bifurcations. Recent trends.

**CVL860 Advanced Finite Element Method and Programming***3 credits (3-0-0)*

Finite element method (FEM) to solve complex structural engineering problems. Various types of finite elements (FE) considering nonlinear material models; constitutive laws; hybrid elements. Strong and weak form representation and solutions. FEM for dynamic problems: consistent mass matrix, vibration of bars, beams, and plate elements. FEM for buckling problems: geometric matrix, buckling of struts, and plate elements. FE modeling and analysis of complex structures: 3-D frames, shear walls, bridges, cooling towers, continua etc. Computational aspects: meshing, convergence, singularity, etc. Interpretation of results. Comparison with other methods.

**CVL861 Analysis and Design of Machine Foundations***3 credits (2-0-2)*

General design requirements, general dynamics of machine foundations for rotating and reciprocating machines, determination of soil properties, modelling, analysis and design of block/frame type foundations, specific details for machines applying impulsive loads, compressors and turbo-generators, detailed dynamic analysis and modes of vibration for frame type foundations, techniques for vibration isolation, practical case studies, code requirements, construction aspects of machine foundations.

Laboratory : Instrumentation aspects in terms of sensors and data acquisition systems, measurement of dynamic soil parameters, measurement of vibration related parameters, vibration isolation, computational aspects related to frame type foundations including dynamic analysis.

**CVL862 Design of Offshore Structures***3 credits (3-0-0)*

Rudiments of offshore engineering; sea spectra; wave theories; wave-structure interaction. Design of offshore platforms: introduction, fixed and floating platforms. Buoyed structures/ articulated towers; tension-leg platform (TLP); Marine risers; compliant and non-compliant structures; offshore pipelines and risers; Steel, concrete, and hybrid platforms. Buoys and mooring system design; Design criteria and code provisions. Environmental loading. Wind, wave, and current loads. Loads and stability during handling and towing. Introduction to stochastic dynamics of ocean structures considering different sea spectra. Soil-structure interaction (SSI): beam on Winkler foundation (p-y curve approach). Dynamic analysis of SPAR platforms. Fatigue analysis of fixed and floating offshore structure: stress concentration, S-N curves. Foundations: site investigations, gravity, jacket platforms, hybrid platforms. Piled foundation and behavior under dynamic loading. Static and dynamic analysis of platforms and components. Dynamic analysis using software: response of fixed type offshore structures, articulated towers, single leg and multi-legged towers.

**CVL863 General Continuum Mechanics***3 credits (3-0-0)*

Introduction: Field and particle theories in physics. Historical development of continuum mechanics-A basic engineering science. Classical theories: Stress and kinematics. Elasticity, Viscoelasticity and Elastoplasticity; Newtonian fluids.

Continuum thermomechanics; Clausius-Duhem Inequality; Thermodynamics with internal variables. Constitutive equations;

Axioms for simple materials; Frame indifference; Finite elasticity; Hyper/hypoelasticity; Non-Newtonian fluids.

Polar and nonlocal materials; Materials of differential/gradient type; Configurational mechanics; Biomechanics; Nanomechanics. Theories of conduction and diffusion; Electromagnetism. Coupled fields: Thermoelasticity and electromagnetoelasticity; MHD; Chemomechanics. Intermediate problems; Statistical continuum theories; Relativistic continuum mechanics; Materials models for luminiferous Aether.

Rational methodology and realism; Current trends.

### **CVL864 Structural Health Monitoring**

*3 credits (3-0-0)*

Concept of structural health monitoring, sensor systems and hardware requirements, global and local techniques, computational aspects of global dynamic techniques, experimental mode shapes, damage localization and quantification, piezo-electric materials and other smart materials, electro-mechanical impedance (EMI) technique, adaptations of EMI technique.

Laboratory: Sensor installation and diagnostics, mode shape extraction, location and quantification of damage using global dynamic techniques, damage detection using electro – mechanical impedance technique, remote monitoring.

### **CVL865 Structural Vibration Control**

*3 credits (3-0-0)*

Introduction; Types and classifications; Control theories; Optimal stiffness distributions for building type structures; Role of damping in controlling motion; Active and semi-active systems; Tuned mass dampers - single/ multiple; Quasi-static active control; Passive control: viscous, visco-elastic, friction, hysteretic dampers, base isolation; Nonlinear modeling; Dynamic feedback control; Neural network based control systems; Design for buildings, bridges, power plants, and other structures; Current trends and performance-based design.

### **CVL866 Wind Resistant Design of Structures**

*3 credits (3-0-0)*

Causes and types of wind. Atmospheric boundary layer and turbulence. Wind velocity measurements and distribution. Bluffbody aerodynamics, random vibrations, and spectral analysis. Along wind and across wind response considering vortex shedding of tall buildings, towers, and slender structures. Vortex induced vibrations of slender structures. Wind-Induced lock-in excitation of tall structures. Buffeting response prediction subjected to random load. Aeroelastic phenomena. Turbulence modeling. Gust buffeting and fluttering effect on structures. Vibration of cable supported bridges and power lines due to wind effects. Wind pressure on cooling towers. Design of cladding and wind damping devices. Wind tunnel simulations and tornado effects.

### **CVL871 Durability and Repair of Concrete Structures**

*3 credits (3-0-0)*

Chemical composition of concrete, permeability and transport processes, corrosion of reinforcement and prestressing steel in concrete, carbonation, chloride attack, alkali-silica reaction, freeze-thaw attack, sulphate attack, acid attack, effect of fire and high temperatures and seawater attack, cracking, weathering, biological processes, non-destructive testing, repairs, protection and retrofitting, durability based design of structures.

### **CVL872 Infrastructure Development and Management**

*3 credits (3-0-0)*

Introduction to Indian Infrastructure. Govt. initiatives through various five year plans.

Overview of various sectors of infrastructure and SEZ.

Infrastructure procurement through Public-Private-Partnership. Sector-wise differences in policies, Concession agreement, Selection procedure of concessionaires, Issues in financial closure, Stakeholder management.

Financial Models, Risk management, Environmental Impact Assessment, Case studies.

### **CVL873 Fire Engineering and Design**

*3 credits (3-0-0)*

(A) Fire engineering: fundamentals of fire science, fire dynamics, hazard mitigation, and safety; codes, standards, rules and fire safety regulations; thermodynamics, thermofluids, heat and mass transfer; human behavior in fire and urban planning; fire testing methods for materials; large-scale fire testing. "Fire protection" - current methods in fire safety engineering; mechanics of repair; mitigation of fire damage by due design, and construction; industrial fire safety. Passive fire protection: analyzing the thermal effects of fires on buildings and designing structural members. Introduction to active fire protection.

(B) Structural fire engineering: fire behavior and scenarios, heat transfer to the structure, structural response and stability under thermo-mechanical loads; fire safety design; mechanical properties of structural materials at elevated temperatures; fire response of steel, concrete, fiber reinforced polymers, high-performance materials etc.; computational procedures to predict structural behavior under fire conditions; structural fire resistance based on theoretical/ empirical relationships; performance-based fire engineering; strengthening/ repair of structures.

### **CVL874 Quality and Safety in Construction**

*3 credits (3-0-0)*

Introduction to safety. Types of injuries, Factors affecting safety, Strategic Planning for safety provisions. Personal & Structural safety - Safety consideration during construction, demolition and during use of equipment. Recording injuries and accident indices. Method statement, SOPs, PPE, Inspections, Investigations. Site safety programmes - JSA, JHA, Root cause analysis, meetings, safety policy, manuals, training & orientation. Safety legislation regard to violation.

Introduction to quality, assurance, control and audit. Regulatory agent - owner, designer, contractor. Strategic Planning and control of quality during design and construction, Quality tools in construction projects, Customer satisfaction and QFD, Quantitative techniques in quality control, Quality assurance during construction, Inspection of materials and machinery. Assessing quality. Teachings/findings of Gurus - Concept and philosophy of TQM, 6Sigma, ISO Certification.

IS codes and standards regard to quality & safety.

### **CVL875 Sustainable Materials and Green Buildings**

*3 credits (3-0-0)*

Introduction and definition of Sustainability. Carbon cycle and role of construction material such as concrete and steel, etc. CO<sub>2</sub> contribution from cement and other construction materials. Construction materials and indoor air quality. No/Low cement concrete. Recycled and manufactured aggregate. Role of QC and durability. Life cycle and sustainability. Components of embodied energy, calculation of embodied energy for construction materials. Exergy concept and primary energy. Embodied energy via-a-vis operational energy in conditioned building. Life Cycle energy use. Control of energy use in building, ECBC code, codes in neighboring tropical countries, OTTV concepts and calculations, features of LEED and TERI Griha ratings. Role of insulation and thermal properties of construction materials, influence of moisture content and modeling. Performance ratings of green buildings. Zero energy building.

### **CVD895 MS Research Project**

*36 credits (0-0-72)*