# Syllabus for exam to candidates seeking admission to Direct Ph. D. program

## General Guidelines:

All the candidates shortlisted for the selection to the Direct Ph. D. program should take an online exam on the date of the interview. The exam would be of 90 minutes duration. There are two parts to each exam. Part A would contain questions in mathematics and general aptitude. Part B would be technical on a subject area in civil engineering. Depending on your interest you can chose one of the seven subject areas listed in part B.

A candidate can take the at most two online exams. But the subject area in the two exams have to be different.

Candidates would be further shortlisted based on the score obtained in the online exam. These shortlisted candidates would only be interviewed in the subject area in which they have written the exam and scored the minimum marks required. The final list of candidates recommended by the department for possible admission into the Direct Ph. D. program in a subject area would be from the pool who were interviewed.

The syllabi for part A and part B is given below.

## PART A

### Mathematics

**Linear Algebra**: Matrix algebra; Systems of linear equations; Eigen values and Eigen vectors.

**Calculus**: Functions of single variable; Limit, continuity and differentiability; Mean value theorems, local maxima and minima, Taylor and Maclaurin series; Evaluation of definite and indefinite integrals, application of definite integral to obtain area and volume; Partial derivatives; Total derivative; Gradient, Divergence and Curl, Vector identities, Directional derivatives, Line, Surface and Volume integrals, Stokes, Gauss and Green's theorems.

**Ordinary Differential Equation (ODE)**: First order (linear and non-linear) equations; higher order linear equations with constant coefficients; Euler-Cauchy equations; Laplace transform and its application in solving linear ODEs; initial and boundary value problems.

**Partial Differential Equation (PDE)**: Fourier series; separation of variables; solutions of one-dimensional diffusion equation; first and second order 1D wave equation and 2D Laplace equation.

**Probability and Statistics**: Definitions of probability and sampling theorems; Conditional probability; Discrete Random variables: Poisson and Binomial distributions; Continuous random variables: normal and exponential distributions; Descriptive statistics -Mean, median, mode and standard deviation; Hypothesis testing.

**Numerical Methods**: Accuracy and precision; error analysis. Numerical solutions of linear and non-linear algebraic equations; Least square approximation, Newton's and Lagrange polynomials, numerical differentiation, Integration by trapezoidal and Simpson's rule, single and multi-step methods for first order differential equations.

### Aptitude

**Verbal**: Word completion, sentence completion, verbal analogies, word groups, instructions and verbal deduction, verbal reasoning, reading comprehension

**Non-verbal**: Critical reasoning, numerical computation, numerical estimation, non-verbal reasoning and data interpretation.

## PART B

## 1. Construction materials:

**Mechanics of Materials:** Tension, compression, shear; Axially loaded members; Torsion; Shear forces and Bending moments; Stresses in beams; Analysis of stress and strain; Stress and strain in two dimensions, principal stresses, stress transformation, Mohr's circle; Deflection of beams; Columns; Centroid and Moment of Inertia; Toughness

**Construction Materials:** Production of cement and concrete materials; Chemistry and hydration of cement and mineral admixtures; Chemical admixtures; Concrete Technology – fresh and hardened properties of various types of concretes (such as fiber reinforced concrete, self-compacting concrete, light-weight concrete, heavy-weight concrete); Basics of concrete mix design; Aggregates; Masonry systems; Basic properties of bituminous materials, wood and wood products, steel and other metallic materials used in construction; Basics of the mechanisms of deterioration of construction materials and systems

## 2. Construction Management:

Construction management; Construction planning and scheduling; Quantity take-off and costing; Productivity measurement; Risk management; Engineering Economics, Time Value of Money, Alternative Comparison, Cost Benefit Analysis

## 3. Environmental Engineering:

**Water Treatment and Supply**: Water quality standards, basic unit processes and operations for water treatment. Water characteristics, water requirements, basic unit operations and unit processes for surface water treatment. Water supply systems and analysis of water supply pipe networks.

**Wastewater Collection and Treatment**: Sewage and sewerage system, quantity and characteristics of wastewater. Primary and secondary treatment of wastewater, sludge disposal, effluent discharge standards. Unit operations and unit processes of domestic wastewater (design and process details).

**Air Pollution**: Types of pollutants, their sources and impacts, air pollution control, air quality standards, Air quality Index and limits, greenhouse gases

**Municipal Solid Wastes**: Characteristics, generation, collection and transportation of solid wastes, engineered systems for solid waste management (reuse/ recycle, energy recovery, treatment and disposal.

## 4. Hydraulics and water resources engineering:

**Fluid Mechanics:** Properties of fluids; fluid statics; Continuity, momentum, energy and corresponding equations, applications of continuity, momentum and energy equations; Laminar and turbulent flow; Potential flow; Flow in pipes and pipe networks; Concept of boundary layer and its growth.

**Hydraulics:** Forces on immersed bodies; Flow measurement in channels and pipes; Dimensional analysis and hydraulic similitude; Kinematics of flow, velocity triangles, Basics of hydraulic machines, specific speed of pumps and turbines; Open channel Hydraulics: Energy-depth relationships, specific energy, critical flow, slope profile, hydraulic jump, uniform flow and gradually varied flow.

**Hydrology:** Hydrologic cycle, precipitation, evaporation, evapotranspiration, watershed, infiltration;unit hydrographs, hydrograph analysis, flood estimation and routing; reservoir capacity, reservoir and channel routing; surface run-off models; ground water hydrology: steady state well hydraulics and aquifers, application of Darcy's law.

**Irrigation:** Duty, delta, estimation of evapotranspiration, Crop water requirements; Design of lined and unlined canals; head works; gravity dams and spillways; Design of weirs on permeable foundation; Types of irrigation systems, irrigation methods, Water logging and drainage, Canal regulatory works, cross-drainage structures, outlets and escapes.

## 5. Geotechnical Engineering:

**Soil Mechanics:** Origin of soils, soil structure and fabric; Three-phase system and phase relationships, index properties; Unified and Indian standard soil classification system; Permeability, one-dimensional flow, Darcy's law; Seepage through soils -two-dimensional flow, flow nets, uplift pressure, piping; Principle of effective stress, capillarity, seepage force and quicksand condition; Compaction in laboratory and field conditions; One-dimensional consolidation, time rate of consolidation; Mohr's circle, stress paths, effective and total shear strength parameters, strength characteristics of clays and sand.

**Foundation Engineering:** Subsurface investigations -scope, drilling bore holes, sampling, plate load test, standard penetration and cone penetration tests; Earth pressure theories-Rankine and Coulomb; Stability of slopes -finite and infinite slopes, method of slices and Bishop's method; Stress distribution in soils-Boussinesq's and Westergaard's theories, pressure bulbs; Shallow foundations -Terzaghi's and Meyerhoff's bearing capacity theories, effect of water table; Combined footing and raft foundation; Contact pressure; Settlement analysis in sands and clays; Deep foundations -types of piles, dynamic and static formulae, load capacity of piles in sands and clays, pile load test, negative skin friction.

## 6. Structural Engineering:

**Engineering Mechanics:** System of forces, free-body diagrams, equilibrium equations; Internal forces in structures; Friction and its applications; Kinematics of point mass and rigid body; Centre of mass; Euler's equations of motion; Impulse-momentum; Energy methods; Principles of virtual work

**Solid Mechanics:** Bending moment and shear force in statically determinate beams; Simple stress and strain relationships; Theories of failures; Simple bending theory, flexural and shear stresses, shear center; Uniform torsion, buckling of column, combined and direct bending stresses.

**Structural Analysis:** Statically determinate and indeterminate structures by force/ energy methods; Method of superposition; Analysis of trusses, arches, beams, cables and frames; Displacement methods: Slope deflection and moment distribution methods; Influence lines; Stiffness and flexibility methods of structural analysis

**Concrete Structures:** Working stress, Limit state and Ultimate load design concepts; Design of beams, slabs, columns; Bond and development length; Prestressed concrete; Analysis of beam sections at transfer and service loads

**Steel Structures:** Working stress and Limit state design concepts; Design of tension and compression members, beams and beam-columns, column bases; Connections-simple and eccentric, beam-column connections, plate girders and trusses; Plastic analysis of beams and frames.

## 7. Transportation Engineering:

**Transportation Infrastructure**: Highway alignment and engineering surveys; Geometric design of highways - cross-sectional elements, sight distances, horizontal and vertical alignments; Geometric design of railway track; Airport runway length, taxiway and exit taxiway design.

**Highway Payments:** Highway materials -desirable properties and quality control tests; Design of bituminous paving mixes; Design factors for flexible and rigid pavements; Design of flexible pavement using IRC: 37-2012; Design of rigid pavements using IRC: 58-2011; Distresses in concrete pavements

**Traffic Engineering:** Traffic studies on flow, speed, travel time -delay and O-D study, PCU, peak hour factor, parking study, accident study and analysis, statistical analysis of traffic data; Microscopic and macroscopic parameters of traffic flow, fundamental relationships; Control devices, signal design by Webster's method; Types of intersections and channelization; Highway capacity and level of service of rural highways and urban roads