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

General Guidelines:

All the candidates shortlisted for the selection to the 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 nine subject areas listed in part B.

A candidate can take only one online exam.

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 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. Building Sciences:

Climatology, Heat transfer and Thermal comfort, Lighting and daylighting, Energy and sustainability, Ventilation, air quality, Sensors and measurements of indoor environment quality

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. 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

4. Environmental Engineering for candidates with Engineering background:

Water Treatment: Quality standards, basic unit processes and operations for watertreatment. Drinking water characteristics, water requirements, basic unit operations and unit processesfor surface water treatment. Advanced water treatment methods including desalination, membrane filtration, ion-exchange, adsorption and electrodialysis. Water softening, arsenic removal, fluoridation and defluoridation.

Wastewater Collection and Treatment: Sewage and sewerage system, quantity and characteristics of wastewater. Primary and secondary treatment of wastewater, sludge disposal, biological nutrient removal (both nitrogen and phosphorous), effluent discharge standards. Unit operations and unit processes of domestic wastewater (design and process details), wastewater reuse and sludge disposal. Advanced wastewater treatment technologies including Up-flow anaerobic sludge blanket reactors (UASB), sequential batch reactors (SBR), and Membrane bioreactors (MBR).

Environmental Chemistry and Microbiology: Types of chemical reactions,Chemical equilibria, acid-base equilibria, oxidation-reduction equilibria, solubility equilibria. chemical thermodynamics, stability diagrams.

Identification and classification of bacteria, bacterial metabolism, growth kinetics, Monod equation, substrate and food mass balance, microbiology of domestic wastewater treatment.

Air Pollution: Air Pollution, Sources, Environmental and Health Impacts, Emission Inventory and Source Apportionment, air pollution meteorology, air pollution control, air quality standards and limits. Design of air pollution control equipment's (both particulate and gaseous) and Biological air pollution control technologies. Climate change, greenhouse gases,Impacts of noise, permissible limits of noise pollution, measurement and control of noise pollution.

Municipal Solid Waste: Characteristics, generation, collection and transportation of solid wastes, engineered systems (aerobic, anaerobic and hybrid) for solid waste management (reuse/ recycle, energy recovery, treatment and disposal).

5. Environmental Engineering for candidates with Science background:

Environmental Chemistry: Chemical equations; Types of chemical reactions; Chemical equilibria; Chemical thermodynamics; Acid-base equilibria; Solubility equilibria; Oxidation-reduction equilibria; Water stabilization; Chemical precipitation, Ion-exchange; Application of redox chemistry; Ideal gas equation of state, equation of motion, Greenhouse effect.

Environmental-Microbiology:Characterization, classification and identification of microorganisms, morphology and fine structure of bacteria, Reproduction and growth; Pure cultures and cultural characteristics; Enzymes and their regulations; Microbial metabolism, energy production, utilization of energy and biosynthesis.

Air Pollution: Different types of air pollutants, sources, and effects; Measurement and monitoring and statistics of Air Pollutants; PM sampling and trace gas measurement techniques; Thermochemical and Photochemical reactions in Atmosphere, Aerosols radiative and microphysical properties, Atmospheric stability; Inversion and mixing height; Elements of regulatory control. Transport of air pollutants; dispersion modelling; Carrying capacity analysis; Urban air quality management.

Atmospheric Meteorology and Climatology: Thermal structure and chemical composition of the atmosphere; atmospheric boundary layer and Earth's radiative budget, Basics understanding of energy, water and biogeochemical cycles of Earth climate, cloud physics, cloud formation and precipitation processes; Rayleigh and Mie scattering and multiple scattering; latitudinal and seasonal variation of wind belts; Indian monsoon system and basic knowledge about operational Numerical weather prediction. Concept and foundation of Remote Sensing; Concepts of satellite platform and sensors, types of sensors, their characteristics and application;

Environmental Management and Sustainability: Ecology and various ecosystems, Environmental Management Systems; Environmental Law and Policy; Energy and Environment; Sustainable Development Goals and concept of circularity; Environmental impact assessment, life cycle assessment.

6. Hydraulics and water resources engineering:

Hydraulics: Properties of fluids; Fluid statics; Control volume approach: Conservation laws for mass, momentum and energy, Potential flow; Differential equations for fluid flow analysis: Governing equations, initial and boundary conditions; Fully developed laminar and turbulent flows; Concept of boundary layer and its growth; Pipe flow: Friction factor and head loss, pump pipeline system, water distribution network analysis and design, transients in pipelines, transient control using surge tanks; Open channel flow: Critical flow and uniform flow concepts, Design of erodible and lined channels for clear and sedimentladen flows, flow transitions; Gradually varied flow: Classification of profiles, computation of profiles by standard step, direct step methods; Compound channels, channel networks; Spatially varied flow; Rapidly varied flow: Hydraulic jump, surge analysis, design of spillways, energy dissipaters.

Surface Water Hydrology - Hydrologic cycle, space and time scales, classification of hydrologic models; Precipitation: mechanisms, types, spatial and temporal variation, use of IDF and DAD curves, design storm, probable maximum precipitation; Infiltration: process description, measurement, modelling - Richard's equation, Green Ampt model, SCS model; Evaporation: process description, modified Penman equation, evaporation control; Evapotranspiration: process description, measurement, irrigation scheduling; Overland flow: Hortonian and Saturation overland flow mechanisms; Drainage basin characteristics, stream network laws; Streamflow: Factors affecting base flow, Hydrograph analysis, UH theory, IUH and GIUH; Watershed modelling: discrete and continuous simulation models; Design flood estimation: PMF estimation, regional flood frequency analysis; Flood Routing: reservoir routing, channel routing Muskingum-Cunge method, Diffusion wave routing; Droughts: indicators, classification, forecasting and management; Hydrologic Design: uncertainty concepts, first order reliability method (FORM), risk based design of culverts, storm sewers, reservoirs; Basics of stochastic modelling of hydrologic processes.

Ground Water Engineering - Introduction: role of groundwater in the hydrologic cycle, problems and perspectives; Occurrence and movement of groundwater: origin, age, distribution, hydrogeology of aquifers, Darcy's law, flow characteristics, general flow equations, unsaturated flow; Groundwater and Well Hydraulics: steady and unsteady radial flows in aquifers (confined, unconfined and leaky), multiple well systems, partially penetrating wells, characteristic well losses, specific capacity; Surface and Subsurface investigations of Groundwater: Geologic methods, remote sensing, geophysical exploration, electrical resistivity and seismic refraction, gravity and magnetic methods, Test drilling - various logging techniques including geophysical and resistivity methods; Water wells: methods of construction, completion and development, yield tests, protection and rehabilitation of wells; Quality of groundwater: measures of quality, groundwater samples, physical, chemical and biological analyses, water quality criteria, and salinity; Pollution of groundwater: sources and causes, distribution, attenuation, evaluation and monitoring, remediation; Management of Groundwater: concepts of basin management, groundwater basin investigations, conjunctive use, mathematical modelling, examples; Artificial recharge of groundwater: concepts, recharge methods, recharge mounds, induced recharge; Saline water intrusion in aquifers: occurrence, shape and structure of the interface, upcoming, control of saline water intrusion.

River Engineering – Introduction, River Morphology: Bars, Bends and Meanders, Thalweg, Braiding, Bifurcations and Confluences, Flood Plains, River Channel Migration, River system evolution; Urban rivers and streams Sediment Transport Mechanics: Sediment properties, Bed forms, Bed Load transport, Transport of suspended sediment, Critical Shear stress, Flocculation, Settling, Consolidation, Sediment Transport Equations,

Aggradation and Degradation, Local Scour at Bridge Piers and other Hydraulic Structures; Measurements: Stage measurements, Channel geometry, Discharge, Stage-Discharge Relationship, Sediment samplers and suspended load measurement, Bed load measurement; River Models: Physical Models - Basic Scaling Laws, fixed and movable bed models, Sectional Models, Distorted Models; Mathematical models: 1D and 2D models for aggradations and degradation, 3D Models for turbulence and local scour; River Protection and Training Works: Design of Revetments, Dikes, Gabions, Spurs, Bank Protective measures and Bed control structures, Design of river training and flood protection structures, material specifications, Diversion and Cofferdams, River regulations systems; Dredging and Disposal, River restoration.

GIS and Remote Sensing – Projections, Datum and Coordinate system, Digital Elevation model, watershed delineation, Remote sensing fundamentals.

7. 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; Laplace equation, Seepage through soils, two-dimensional flow, flow nets, numerical analysis of seepage, 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, 3D effects, numerical analysis of consolidation; Stress-strain relations, 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, empirical correlations; Earth pressure theories-Rankine and Coulomb; Stability of slopes -finite and infinite slopes, method of slices and Bishop's method, Morgenstern-Price 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; IS code procedure, 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, Drilled shafts; Well foundations; Sheet pile walls; Braced-cuts; Deep excavations and Diaphragm walls.

8. 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,

Linear finite element method: Numerical integration; Truss element; beam element; isoparametric elements,

Structural Dynamics: Single degree of freedom and multiple degree of freedom systems.

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.

9. Transportation Engineering:

Traffic Engineering and Management

Traffic characteristics: Road user characteristics - visual acuity, legibility distance, reading time of signs, visual field, peripheral vision, hearing, reaction time, walking speed, driver eye height. Vehicle characteristics – static and dynamic characteristics.

Traffic studies: Volume, speed, travel time and delay, O-D, Accident and parking studies – use, variations in the data, presentation of data.

Capacity and level of service: Importance, passenger car units, LOS concept, factors affecting capacity and LOS, capacity of different types of facilities – HCM approach.

Traffic control: Signs, markings, islands and signals; At-grade and grade separated Intersections; Rotaries; Basic principles of intersection signalization; Signal Design – HCM approach; Analysis of signalized intersection, signal coordination.

Urban Transportation Planning

Concepts: Urban transportation planning process - systems approach to planning process, problem definition, solution generation, solution analysis, evaluation and choice.

Trip generation analysis: Trip generation - trip production, causal variables, modeling trip production, category analysis, trip attraction, influencing factors, modeling trip attraction.

Trip distribution analysis: Production-Attraction (PA) and Origin-Destination (OD) matrices, factors governing trip distribution, growth-factor methods of distribution, gravity models.

Mode-choice analysis: Factors influencing mode choice, aggregate and disaggregate choice models, logit model of mode choice, and log likelihood method of calibration.

Route assignment: Road network description for route assignment, minimum-path tree, all-or-nothing, multi path, and capacity restrained assignment techniques.

Transportation surveys: Transportation surveys – definition of study area, zoning, home-interview survey, cordon-line and screen line surveys, traffic surveys, inventory of transport facilities, inventory of land-use and economic activities.

Geometric Design

Design controls and criteria: Vehicle, driver and traffic characteristics and their influence on geometric design of highways; Access control.

Cross section elements: Considerations with regard to cross section elements such as, carriageway width, right-of-way, camber, shoulders, kerbs, footpaths, drainage elements, traffic barriers and medians; Frontage roads; Pedestrian crossings; Bicycle facilities; Bus bays.

Sight distances and applications: Stopping, decision, overtaking and intermediate sight distances; Sight distances on horizontal curves and at intersections; Applications of sight distances for various situations

Highway alignment: Horizontal: Theoretical, general and design considerations; Super elevation; Simple, compound, reverse and transition curves; Guidelines for design; Vertical: Terrain; Grades; Climbing lanes; General considerations in vertical curves; Crest and sag vertical curves; Coordination of horizontal and vertical curves; Guidelines for design.

Pavement Materials and Design

Highway Materials: Materials used in highway construction - Soils - Stone aggregates- Bituminous binders - Bituminous paving mixtures - Cement concrete for highway construction.

Design of Bituminous Pavements: Bituminous pavements - components and their functions; Factors affecting design and performance of bituminous pavements - Stresses in bituminous pavements - Various design methods - IRC37 method of design of bituminous pavements.

Design of Concrete Pavements: Concrete pavements - components and their functions; Factors affecting design and performance of concrete pavements - Stresses in concrete pavements - Various design methods - IRC58 method of design of rigid pavements

Pavement Construction Technology

Subgrade: Earthwork grading, compaction and construction of embankments and cuts for roads, problems in embankment construction on weak and compressible foundation, quality control tests

Flexible Pavements: Specifications of materials, construction methods and field control checks for various types of flexible pavement materials in sub-base, base, binder and surface course layers and their choice.

Cement Concrete Pavement Layers: Specifications and method of cement concrete pavement construction; Construction of interlocking block pavements, Quality control tests; Construction of various types of joints.

Soil Stabilized Pavement Layers: Principles of gradation/proportioning of soil-aggregate mixes and compaction; Design factors, mix design, construction control and quality control checks for mechanical, soil-cement, soil-bitumen and soil-lime stabilization methods. Use of additives, Numerical problems on mix design and applications

Drainage: Design and construction of surface and sub-surface drainage system for highways and airports. Drainage materials, design procedures and IRC Guidelines for Drainage of Urban Roads

Special problems in high rainfall areas and wet /water logging condition, maintenance of drainage system.

Recycling Techniques in Bituminous Pavements: Need for recycling, methods of recycling, construction controls and economics.

Use of Geosynthetics in Highway Construction: Functions and applications of Geosynthetics in highway embankment, slopes, new pavements and overlays

Utilization of waste materials in road construction:C&D waste**,** products like flyash, slag, marginal materials. in road construction.

Pavement Asset Management

Pavement management process: Concepts, different levels of pavement management and functions, applications of Pavement Management System as a planning and technology improvement tool.

Data Requirements: Overview of pavement management data needs, inventory data, characterizing pavement performance, evaluation of pavement structural capacity, evaluation of pavement surface distress condition, evaluation of pavement safety, combined measures of pavement quality, data base management, communicating the present status of pavement networks

Determining Present and Future Needs and Priority Programming of Rehabilitation and Maintenance: Establishing criteria, prediction models for pavement deterioration, determining needs, rehabilitation and maintenance alternatives, priority programming of rehabilitation and maintenance, developing combined programs of maintenance and rehabilitation

Rehabilitation Design and Economic Analysis: Generating alternate strategies of design and rehabilitation; Materials, construction and maintenance policy alternatives, consideration of preservation in pavement design and analysis procedures, economic evaluation of alternate pavement design strategies and selection of optimal strategies, Application of Highway Development and Management Tools in pavement management.

Implementation of Pavement Management System: Role of construction quality on performance, pavement preservation on maintenance needs; emerging trends in road asset management; Urban Pavement Management System.