Civil & Environmental Engineering Department
PhD Comprehensive Exams

General Exam Rules:

1. Students must bring their university identification card to the exam hall.
2. Cheating, attempting to cheat, or violating exam instructions will result in disciplinary action in accordance with university regulations.
3. Unauthorized materials, including mobile phones and programmable devices, are strictly prohibited in the exam hall.
4. Students must bring necessary items (e.g., calculators, pens, pencils) as sharing these items is not allowed.
5. Students must cooperate with instructors and proctors and follow all provided instructions.
6. **Exam Format**: Most exams will be closed-book. For open-book exams, only hard copies of reference materials, including design tables and charts, are permitted. Electronic devices for referencing are strictly prohibited.
7. **Duration**: Exam durations vary depending on the subject area, ranging from 1.5 to 3 hours.
8. **Question Types**: Some exams will include short descriptive questions. Be brief, specific, and concise when answering descriptive questions. For numerical problems, if any required information is missing, assume suitable data and mention it in your solution.
9. In certain areas, all questions will be compulsory, while others may provide optional questions.
10. **Fundamental vs. Advanced Questions**: For exams in some areas, fundamental questions are mandatory, while the advanced sections may include optional questions.
11. **Use of Software**: For some areas, Mathematica and other commercial software may be allowed as required for problem-solving. However, access to the Internet or other files on a computer is strictly prohibited.
12. **Area Selection**: PhD students appearing for comprehensive exams are allowed to select three areas from their specific track and one area from any of the other three tracks.

Track 1: Materials and Structures

Area 1: Concrete Materials

Description:

Properties of concrete constituents; cement hydration; role of mineral and chemical admixtures; concrete mix design; fresh and hardened properties of concrete; factors affecting mechanical properties of concrete, shrinkage and durability of concrete; concrete sustainability perspective.

Area 2A: Concrete Design, Part A: Reinforced Concrete

Description:

Design loads; reinforcing steel and concrete; shrinkage and creep in concrete; serviceability issues; crack; deflection; flexural analysis of beams; strength analysis; design of beams and slab; design of T-beams and doubly reinforced beams; bond; development lengths; splices; shear and diagonal tension; short and slender columns; moment-curvature relation; column interaction diagram; sway and non-sway frames; two-way slabs; direct design method; equivalent frame method; flat slab flooring systems; footings; continuous reinforced concrete structures; yield line analysis for beams and slabs; design of reinforcement at joints; analysis and design of buildings for lateral loads; walls; shear walls; retaining wall; design for torsion; strut-and-tie models; design considerations for seismic loading; reinforced concrete design applications

Area 2B: Concrete Design, Part B: Prestressed Concrete

Description:

Prestressing systems; materials and properties; hardware; loading stages; behavior of prestressed concrete beams; criteria for analysis and design; loss of prestress; analysis of stresses; cracked and uncracked sections; cracking load; flexural design; allowable stresses; design criteria; tendon profile; load balancing; ultimate strength; shear strength; shear design; torsional design; diagonal cracking; web reinforcement; continuity in prestressing; indeterminate prestressed concrete structures; end blocks; bond; anchorage; deflection and camber; crack control; composite members and design; continuous beams; secondary moments from prestress; linear transformation; prestress columns; partial prestress; anchor zone; axially loaded members; prestressed compression and tension members; floors and roof slabs; two-way prestressed slabs; introduction to segmental construction; connections; prestressed concrete design applications.

Area 3: Mechanics

Description:

Fundamentals (statics and basic mechanics); beams on elastic foundation; stress & strain tensors and their transformations; stress vector and boundary conditions; constitutive equations; linear elasticity; plate analysis; mechanics of composite materials; failure theories.

Area 4: Structural Analysis

Description:

Basic concepts and principles of structural analysis, shear force and bending moment diagrams, influence lines for beams and trusses, fundamental methods of analysis (Castigliano's theorem, moment-area method, slope-deflection method, moment distribution method), virtual work, structural indeterminacies, flexibility and stiffness methods, structural vibrations, applications of any commercial structural analysis software.

Area 5: Dynamics and Earthquake Engineering

Description:

Kinematics of rectilinear and curvilinear motion of particles, dynamics of particles and systems of particles, kinematics of rotation and plane motion of rigid bodies, work and energy relations, impulse and momentum principles, and dynamics of rigid bodies in plane motion. It also covers the equations of motion, free and forced vibrations of single degree of freedom systems, multi degree of freedom systems (MDOF), free vibration analysis of MDOF structures, forced vibrations by harmonic analysis, generalized impulsive loadings, numerical solutions, basic principles of earthquake engineering, earthquake analysis of linear systems, base isolations, and structural dynamics considerations in building codes. Additionally, it includes the damping and response spectra, static lateral force procedure for buildings, multistory structures, load combinations, lateral force resisting system, torsion, and rigidity, seismically isolated buildings, dynamic lateral force procedure for buildings, application of modal analysis to buildings, seismic design of reinforced concrete structures, special moment resisting frames, shear walls, seismic design of steel structures, braced frames, seismic design of masonry structures.

Track 2: Geotechnical Engineering

Area 1: Foundation Engineering

Description:

Geotechnical field inspection methods, bearing capacity and settlement analysis, and drained and undrained response of foundation. Further, foundation type is of particular interest like shallow, deep and mat foundation depending on the structural loads and site conditions.

Area 2: Geotechnical Earthquake Engineering

Description:

Earthquake reconnaissance; Ground motion characterization; seismic site response; seismic zonation; Analysis of earthquake-induced ground failures (soil liquefaction, cyclic softening of clays, surface fault rupture, and seismic slope stability); Wave propagation through soils; Dynamic properties of geomaterials; Strength and deformation characteristics of cyclically loaded soils; Experimental analysis (cyclic tests, shake table, centrifuge testing); Dynamic soil-structure interaction; seismic code provision; Analysis and design of foundations under seismic load; Seismic analysis and stability of slopes; Computer applications.

Area 3: Soil Behavior

Description:

Soil formation, composition, crystallography, and mineralogy; soil-water-electrolyte system; physio-chemical nature of soil; soil fabric and structure; relationship between soil composition and mechanical behavior; time-deformation processes; compressibility and volume change in clay soils; conduction phenomena.

Area 4: Advanced Soil Mechanics

Description:

Basic concepts of soil mechanics, Stresses and strains in soil media, Lateral earth pressure, Shear strength, stress paths, constitutive models, failure criteria, Critical state soil mechanics, Consolidation theory, Unsaturated soils, Elasticity, viscoelasticity, and plasticity theories, Constitutive, numerical, and experimental modeling

Track 3: Transportation Engineering

Area 1: Urban Transportation Planning and Modeling

Description:

Transportation planning processes, transportation land use interaction, travel evaluation and demand estimation, traffic generation theories and assignment models, and transit analysis. Advanced theories and applications for analysis and forecasting of user behavior and demand. Formulation and estimation of discrete choice models; their application in the characterization of choice behavior, advanced choice models, and Bayesian methods.

Area 2: Traffic Flow Theory

Description:

Macroscopic and microscopic characteristics of flow, speed and density; statistical distribution of traffic characteristics; time-space diagram; shock wave analysis; queuing theory; bottleneck analysis; application of theory of traffic flow to design and control of traffic; traffic simulations; fundamentals and applications of existing tools and software.

Area 3: Transportation Data Analysis

Description:

Methods and statistics of model estimation; linear and non-linear regression analysis; error propagation and parameters sensitivity analysis, analysis of variance with their applications; hypothesis testing; questionnaire design; sampling; advanced data analysis techniques.

Area 4: Traffic Control and Operation

Description:

Traffic control at road segments and intersections, traffic signal theory, signal actuation and coordination, multimodal signal operation, freeway control (ramp metering), roundabouts control; capacity analysis; urban traffic management, relevant ITS technologies in vehicle detection and advanced control systems.

Area 5: Transportation Safety Analysis

Description:

Traffic safety challenges and influencing factors; Safety impact studies and design of potential countermeasures; Safety in cross-section and roadside design; Safety auditing; Traffic conflict analysis and other surrogate techniques; safety indices; Crash prediction methods; Implications of ITS concepts for traffic safety.

Area 6: Pavement Structural Design

Description:

Pavement-vehicle interaction; mechanics of pavement response; stress analysis in flexible and rigid pavements; Non-linear analysis; fatigue and permanent deformation; back calculation of layer moduli; mechanistic empirical design methods; theories of pavement behaviour. Design of flexible and rigid pavements for highways and airports; modern design techniques and their applications; performance evaluation; reliability aspects in design and construction; pavement evaluation and cost analysis.

Area 7: Pavement Materials Analysis and Design

Description:

The nature, engineering characteristics, and selection of materials for highway and airport pavements; mix design procedures for hot and cold asphalt mixes, including Marshall and SuperPave; composition, physical behaviour, production, construction and performance of bituminous materials and mixtures; concrete mixes for rigid pavements; durability of concrete and asphalt mixes; polymer materials and additives. Pavement material characterization procedures; simulation of in-service conditions. experimental program for fatigue cracking modeling and plastic deformation modeling under repetitive loading; development of constitutive laws; advancement in accelerated environmental conditioning and loading simulation, durability testing, and material performance-based evaluation.

Area 8: Pavement Management and Maintenance

Description:

Transportation asset management; Techniques of network and project level pavement management; introduction to mapping/facility management system; field evaluation methods and equipment. performance modeling; maintenance and rehabilitation strategies; non-destructive testing techniques for structural evaluation of pavements; rehabilitation design; recycling and overlay design; priority ranking procedures; quality control/assurance; performance-based maintenance specifications.

Track 4: Water Resources & Environmental Engineering

Area 1: Subsurface Flow & Transport

Description:

Storage mechanisms, moisture distribution, Darcy's law, recharge and infiltration, well hydraulics, mechanisms of contaminant transport

Area 2: Hydraulics Structure & Dam Design

Description:

Open channel design, water distribution network design, culvert hydraulic design, gravity and earth dam design.

Area 3: Engineering Hydrology

Description:

Hydrological Cycle, Unit Hydrograph, Rainfall-Runoff Relationships, Hydrological Models, Frequency Analysis.

Area 4: Waste Management

Description:

Waste management including waste characteristics, handling, collection, transportation, & disposal. Design of landfills, leachate production, & gas production. Conversion of waste into energy and recycling of waste materials.

Area 5: Environmental Chemistry

Description:

Water chemistry, chemical thermodynamics, chemical equilibrium & precipitation, chemical kinetics & modeling, acid-base systems, and redox chemistry.

Area 6: Physicochemical Environmental Processes

Description:

Theory, modeling, and applications of physical and chemical processes including coagulation, flocculation, sedimentation, softening, membrane filtration, adsorption, absorption, fluoridation, gas transfer, disinfection, and advanced oxidation.

Area 7: Biological Environmental Processes

Description:

Microbial growth kinetics and bioenergetics, theory, modeling, and applications of biological processes employed in water treatment, wastewater treatment and reuse, compost facilities, and hazardous waste treatment systems as well as subsurface bioremediation.

Area 8: Quantitative Sustainability Assessment

Description:

Theory, modeling, and applications of quantitative sustainability assessment methods in civil and environmental engineering. Focus on life cycle assessment (LCA), life cycle costing (LCC), and other

quantitative tools to evaluate trade-offs across environmental, economic, and social dimensions. Application of these methods to the analysis, planning, and optimization of sustainable infrastructure systems. Development of strategies to address challenges in sustainability through a data-driven and systems-oriented approach.