Department of Civil Engineering

Mackenzie Bldg. 277

The Department

Chair of the Department:
J.L. Humar

Departmental Supervisor of Graduate Studies:
S.J. Kennedy

The Department of Civil Engineering offers programs of study and research leading to the Master of Engineering and Ph.D. degrees in Civil Engineering. These degrees are offered through the Ottawa-Carleton Institute for Civil Engineering which is jointly administered by the Department of Civil Engineering at Carleton University, and the Department of Civil Engineering at the University of Ottawa. For further information,
including admission and program requirements, see page 107.

The department conducts research and has developed graduate programs in the following areas:

- Geotechnical Engineering

The graduate program in geotechnical engineering places an emphasis on both theoretical and applied problems related to soil and rock mechanics and foundation engineering. These generally include the study of mechanical properties of soil and rock materials, stability of natural slopes and earth embankments, soil-foundation-structure interaction, and problems in foundation design and geomechanics. Broader programs in geotechnical engineering may be arranged by making use of courses offered in the Department of Geography at Carleton University and in the Department of Civil Engineering at the University of Ottawa.

Graduate research in geotechnical engineering is primarily directed towards the following areas:

Soil-Foundation Interaction
Elastic and consolidation effects of soil-foundation interaction; soil-frame interaction; contact stress measurement; performance of rigid and flexible foundations; buried pipelines.

Earth Retaining Structures
Experimental and analytical studies of anchored and braced excavations, flexible and rigid retaining walls, soil reinforcement, tunnels and conduits, field behavior.

Bearing Capacity and Settlement
Problems related to design of bridge abutments and footings located on sloped granular fill, experimental and field studies.

In-Situ Testing of Soils
The use of devices such as the pressure meter, the screw plate test, the borehole shear device, and borehole dilatometer in the assessment of geotechnical properties of soils.

Mechanical Behavior
Development of constitutive relations for soils and rock masses with yield and creep characteristics; applications to foundation engineering.

Mechanics of Geological Structures
Large strain phenomena; buckling of strata; applications to underground storage structures; hydraulic fracture of oil- and gas-bearing geological media.

Performance of Anchors
Theoretical and experimental analysis of deep and shallow anchors in soil, rock and concrete; group action; creep effects; prestress loss.

Nuclear Waste Disposal
Theoretical modeling of rockmass-buffer-canister interaction during moisture migration; non-homogeneous swelling of buffer materials; swelling pressures in buffer systems; coupled heat and moisture flow in materials.

- Structural Engineering

The graduate program in structural engineering embodies a broad spectrum of topics involving material behavior, structural mechanics and analysis, and the behavior and design of buildings and bridges. These topics are in the following fields: computer applications in structural analysis; structural dynamics, seismic analysis, earthquake engineering; finite element analysis; structural systems and design optimization;
behavior and design of steel, concrete, composite, timber and masonry structures; integrated treatment of structural, mechanical and electrical building requirements; construction economics; project planning; and bridge engineering. Graduate research in structural engineering is primarily directed towards the following areas:

Computer Applications in Structural Design
Development of knowledge-based systems for the analysis, design, detailing, fabrication and erection of buildings and bridges. Includes graphic interfaces, pre- and post-processing of frame analysis, load determination and finite element analysis packages.

Seismic Analysis and Design
Seismic response of set-back and other irregular buildings; computer analyses of linear and non-lin-

ear structural response; design of buildings for seismic forces; seismic behavior of liquid storage tanks; fluid structure interaction problems.

Continuum Mechanics
Linear and non-linear problems in elasticity; analysis of contact problems in elasticity, plasticity, and viscoelasticity; mechanics of composite materials; fracture processes in geological materials; finite deformations of rubber-like materials; poro-elasticity and micromechanics.

Numerical Modeling of Buildings and Bridges
Advanced analytical modeling of reinforced and prestressed concrete, steel, and composite concrete-steel buildings and bridges. Material and geometric non-linearities, bond-slip, the advent and propagation of cracks, tension-stiffening and shear-connectors behavior are modeled to predict the full response of structures up to failure.

Behavior and Design of Steel, Concrete and Composite Structures
Analytical and experimental studies of structural members, substructures and connections for buildings, bridges and offshore structures. Development of the corresponding limit states design format design rules.

Masonry Behavior and Design
Study of strength and serviceability issues by means of theoretical approaches, testing and field work.

Timber Structures
Analysis, design and performance evaluation of wood-structured systems and components; structural reliability.

- Transportation Planning and Technology

The graduate program in transportation planning and technology deals with problems of policy, planning, economics, design, and operations in all modes of transportation. In the area of transportation planning, the focus is on the design of transport systems, including terminals, modeling and simulation, urban and regional studies, traffic engineering, and geometric design. In the transportation technology area, programs deal with technology of vehicles and facilities, acoustics and noise, materials and pavement design. Graduate research in transportation is currently focused on the following areas:

Transport Policy
Assessment and impact analysis of national, regional, and urban transportation policies.

Planning and Design Methodology
Development and application of models for optimization of transport supply, transportation system management.

Travel and Traffic Analysis
Behavioral theories of passenger travel, goods movement, empirical traffic studies.

Transportation Terminals
Airport planning, air terminal design; bus, rail, subway terminal design, layout methods, pedestrian traffic.

Transportation Technology Development and Assessment
Modernization of passenger and freight rail services; soil properties; pavement design, multi-layered systems, low temperature cracking of pavements, thermo-mechanical modeling of fracture processes in pavements, highway design, energy.

Departmental Facilities

The structures laboratory facility includes an 11 m x 27 m strong floor with a clear height of 11 m; a strong pit, measuring 3 m x 3.7 m x 6.6 m for geotechnical and highway material testing; a 400,000 lb. universal testing machine with auxiliary equipment for load and displacement control; numerous hydraulic actuators; test frames; specialized equipment for torsion and impact studies; and a wide selection of measurment devices (strain gauges, LVDT's, pressure transducers, load cells, thermocouples) and several data acquisition systems for testing structural materials and components. The concrete laboratory has facilities for the casting, curing, and testing of reinforced concrete members. Laboratory facilities in geotechnical engineering include both large scale and conventional tri-axial testing, consolidation testing, pore water pressure measurements, and model studies of contact stress measurements. The soil dynamics and highway materials laboratories provide facilities for studies of the physical properties of soil, stabilized soil, aggregate and bituminous mixtures.

Computer-related equipment with the department comprises an HP9000, several Apollo and SUN workstations, a network of microcomputers and related peripherals. The computing centre of the university provides access to a Honeywell Level 66 computer and SUN4 workstation. A library of computer programs in structural, geotechnical and transportation engineering provides a significant resource for advanced study and research.

Graduate Courses

All courses listed are one term courses and may be offered in either fall or winter with the exception of projects and theses. Please consult the cur-

rent course listing at the beginning of the fall and winter terms.

- Engineering 82.511 (CVG7120)
Introductory Elasticity
Stresses and strains in a continuum; transformations, invariants; equations of motion; constitutive relations, generalized Hooke's Law, bounds for elastic constants: strain energy, superposition, uniqueness; formulation of plane stress and plane strain problems in rectangular Cartesian and curvilinear coordinates, Airy-Mitchell stress functions and Fourier solutions, application of classical solutions to problems of engineering interest.

- Engineering 82.512 (CVG7121)
Advanced Elasticity
Continuation of topics introduced in Engineering 82.511. Complex variable solutions: torsional and thermal stresses; axially symmetric three-dimensional problems, Love's strain potential, Boussinesq-Galerkin stress functions; problems related to infinite and semi-infinite domains. Introduction to numerical methods of stress analysis, comparison of solutions.
Prerequisite: Engineering 82.511 or permission of the department.

- Engineering 82.513 (CVG7122)
Finite Element Methods in Stress Analysis
Stress-strain and strain-displacement relationships from elasticity. Plane stress and plane strain finite elements. Lagrange interpolation and Lagrange based element families. Introduction to the theory of thin plates; overview at plate bending elements. General formulation of the finite element method.

- Engineering 82.514 (CVG7123)
Earthquake Engineering and Analysis
Advanced topics in earthquake engineering: description of earthquake motions, seismological background; analysis of earthquake response, response spectrum approach, multiple input excitation, extended Ritz coordinates, complex eigenproblem analysis; response analysis via frequency domain; design considerations and code requirements, earthquake forces in building codes; dynamic soil-structure interaction, direct method, substructure method, fundamentals of wave propagation, half-space modeling of soil;dynamic fluid-structure interaction, incompressible and compressible fluid elements, substructure method with liquid continuum; special topics of current interests.
Prerequisite: Engineering 82.516 or permission of the department.

- Engineering 82.515 (CVG7124)
Advanced Finite Element Analysis in Structural Mechanics
Fundamentals of calculus of variations; variational and Galerkin formulations: assumed displacement, assumed stress and hybrid elements; isoparametric elements and numerical integration; plate bending: convergence, completeness and conformity, patch test, Kirchhoff and Mindlin plate theories, nonlinear elasticity and plasticity; cracking and non-linearities in reinforced concrete structures; incremental and iterative schemes, geometric non-linearity: small strain–large displacement, large strain–large displacement, Eulerian and Lagrangian formulations; finite elements in dynamics; finite element programing.
Prerequisite: Engineering 82.513 or permission of the department.

- Engineering 82.516 (CVG7137)
Dynamics of Structures
Structural dynamics, single and multi-degree-of-freedom systems, formulation of equations of motion, methods of analytical mechanics, free and forced vibrations, normal mode analysis, numerical methods for the response analyses of single and multiple-degree-of-freedom systems.

- Engineering 82.520 (CVG7138)
Engineered Masonry Behavior and Design
Properties of masonry materials and assem-blages. Behavior and design of walls, columns and lintels. Treatment of specialized design and construction topics. Design of lowrise and highrise structures. Discussion of masonry problems. Emphasis throughout the course is placed on a practice-oriented approach.

- Engineering 82.522 (CVG7139)
Behavior and Design of Steel Structures
Brittle fracture and fatigue; behavior of plate girders; composite beams, girders and columns; stub girders; plastic design principles; frame behavior; structural stability; bracing of members and frames.
Prerequisite: Engineering 82.524 or permission of the department.

- Engineering 82.523 (CVG7125)
Theory of Structural Stability
Elastic and inelastic behavior of beam-columns; elastic and inelastic buckling of frames; application of energy methods to buckling problems; lateral-torsional buckling of columns and beams; buckling of plates; local buckling of columns and beams.
Prerequisite: Engineering 82.525 or equivalent.

- Engineering 82.524 (CVG7126)
Behavior and Design of Structural Steel Members
Limit states design philosophy; material behavior; tension members; plate buckling; torsion; lateral torsional buckling; beams, axially loaded columns and beam-column behavior; bolted and welded connections; applications in design.

- Engineering 82.525 (CVG7127)
Analysis of Elastic Structures
Application of matrices to structural analysis; force and displacement method of analysis for framed elastic planar and space structures; symmetric and anti-symmetric structures.

- Engineering 82.526 (CVG7128)
Prestressed Concrete
Prestressed concrete materials; working stress design for flexure; ultimate strength design for flexure, shear, and torsion; prestress losses; deflection and camber; slabs; indeterminate beams and frames; introduction to prestressed bridges and circular tanks.

- Engineering 82.527 (CVG7129)
Advanced Structural Design
A number of topics, such as the evolution of a structure, structural form, aesthetics, progressive collapse, and design in various structural materials, are treated by members of the department and outside experts.

- Engineering 82.528 (CVG7130)
Advanced Reinforced Concrete
The research background, development, and limitations in current building code provisions for reinforced concrete; yield line theory of slabs; safety and limit state design; computer design of concrete structures.

- Engineering 82.529 (CVG7100)
Case Studies in Geotechnical Engineering
The critical study of case histories relating to current procedures of design and construction in geotechnical engineering. The importance of instrumentation and monitoring field behavior will be stressed. In-situ testing.

- Engineering 82.530 (CVG7101)
Advanced Soil Mechanics I
Effective stress, pore pressure parameters, saturated and partially saturated soils; seepage; permeability tensor, solutions of the Laplace equation; elastic equilibrium; anisotropy, non-homogeneity, consolidation theories; shear strength of cohesive and cohesionless soils.

- Engineering 82.531 (CVG7102)
Advanced Soil Mechanics II
Plasticity in soil mechanics; failure and yield criteria, plastic equilibrium, upper and lower bound solutions, uniqueness theorems; statically and kinematically admissible states; stability analysis of cohesive and cohesionless soils.

- Engineering 82.533 (CVG7160)
Pavements and Materials
An analysis of the interaction of materials, traffic, and climate in the planning, design construction, evaluation, maintenance, and rehabilitation of highway and airport pavements.

- Engineering 82.534 (CVG7150)
Intercity Transportation, Planning and Management
Current modal and intermodal issues, including energy. Framework and process of intercity transport planning and management. Recent trends and system development. Passenger and freight demand and service characteristics.
Future prospects and possibilities.

- Engineering 82.535 (CVG7151)
Traffic Engineering
Introduction to principles of traffic engineering. Basic characteristics of drivers, vehicles, and traffic. Volume, speed, and delay studies.
Traffic stream characteristics and queuing theory. Capacity analysis of roads and intersections. Safety.

- Engineering 82.536 (CVG7152)
Highway Materials
Materials characterization and strength evaluation of soils, stabilized soils, aggregates, and asphalt concrete. Effects of low temperatures and frost on materials behavior.

- Engineering 82.537 (CVG7153)
Urban Transportation Planning and Management
Urban transportation systems planning and management. Urban development models – an introduction. Urban transportation policy.

- Engineering 82.538 (CVG7154)
Geometric Design
Basic highway geometric design concepts. Vertical and horizontal alignment. Cross-sections. Interchange forms and design. Adaptability and spacing of interchanges. Design of operational flexibility; operational uniformity, and route continuity on freeways.

- Engineering 82.539 (CVG7155)
Transportation Supply
Advanced treatment of transportation planning and management concepts and techniques: transport supply issues, capacity and costs, evaluation of system improvements and extensions, transportation and development, policy impact analysis.

- Engineering 82.541 (CVG7156)
Transportation Economics and Policy
Transportation, economic analysis framework. Transport industry output. Carrier operations. Issue of resource utilization, measurement, economics, supply of infrastructure, pricing; subsidies, externalities. Transport policy in Canada.

- Engineering 82.542 (CVG7159)
Transportation Terminals
Framework for passenger terminal planning and design. Theory: the transfer function and network modeling; pedestrian flow characteristics; capacity of corridors, stairs, escalators, and elevators; layout planning. Practical applications: air, rail, metro, bus, ferry, and multi-modal terminals.

- Engineering 82.543 (CVG7158)
Airport Planning
Framework for airport planning and design. Aircraft characteristics; demand forecasting; airport site selection; noise, airside capacity; geometric design; the passenger terminal complex; cargo area; general aviation; ground transportation; land use planning.

- Engineering 82.550 (CVG7104)
Earth Retaining Structures
Approaches to the theoretical and semi-empirical analysis of earth retaining structures. Review of the earth pressure theories. Analysis and design methods for rigid and flexible retaining walls, braced excavations, and tunnels. Instrumentation and performance studies.

- Engineering 82.551 (CVG7105)
Foundation Engineering
Review of methods of estimating compression and shear strength of soils. Bearing capacity of shallow and deep foundations. Foundations in slopes. Pile groups. Use of in-situ testing for design purposes.

- Engineering 82.552 (CVG7106)
In-Situ Methods in Geomechanics
Scope of a subsurface exploration program. Techniques of soil and rock sampling. Geo-physical methods. Mechanical and hydraulic properties of soil and rock. In-situ determination of strength, deformability and permeability of soils and rocks. Critical evaluation of vane, pressuremeter, screw plate, flat dilatometer, borehole shear and plate load tests. Pumping, recharge and packer tests. Permeability of jointed rocks. Rock testing techniques, borehole dilatometer, flat jack, cable jacking tests. Properties of rock joints. In-situ stress measurements.

- Engineering 82.553 (CVG7107)
Numerical Methods in Geomechanics
Critical review of advanced theories of soil and rock behavior. Linear elasticity, non-homogeneity and anisotropy. Plasticity models. Generalized Mohr-Coulomb and Rucker-Prager failure criteria. Critical state and cap models. Dilatancy effects. Associative and non-associative flow rules. Hardening rules, hypo-elasticity. Soil consolidation, visco-elasticity and creep behavior of rock masses. Rock joints. Finite element formulation of nonlinear problems. Iterative schemes; tangent stiffness, initial stress and initial strain techniques, mixed methods. Time marching schemes. Solution of typical boundary value problems in geomechanics with the aid of existing research class finite element codes.
Prerequisite: Engineering 82.511, 82.513, or permission of the department.

- Engineering 82.554 (CVG7108)
Seepage and Waterflow through Soils
Surface-subsurface water relations. Steady flow. Flownet techniques. Numerical techniques. Seepage analogy models. Anisotropic and layered soils. Water retaining structures. Safety against erosion and piping. Filter design. Steady and non-steady flow towards wells. Multiple well systems. Subsidence due to ground water pumping.

- Engineering 82.560 (CVG7131)
Project Management
Introduction to managing the development, design, and construction of buildings. Examination of project management for the total development process, including interrelationships among owners, developers, financing sources, designers, contractors, and users; role and tasks of the project manager; setting of project objectives; feasibility analyses; budgets and financing; government regulations; environmental and social constraints, control of cost, time, and content quality and process; human factors.

- Engineering 82.561 (CVG7140)
Statistics, Probabilities and Decision-Making Applications in Civil Engineering
Review of basic concepts in statistics and the Theory of Probabilities. Bayes' Theorem. Probability distributions. Moments. Parameter Estimation. Goodness-of-fit. Regression and correlation. OC curves. Monte Carlo simulation. Probability-based design criteria. Systems reliability. Limit States Design. Selected applications in transportation,

geomechanics and structures. Emphasis will be given to problem solving. Use of existing computer software.

- Engineering 82.562 (CVG7141)

Advanced Methods in Computer-Aided Design
Representation and processing of design constraints (such as building codes and other design rules); decision tables; constraint satisfaction. Automatic integrity and consistency maintenance of design databases; integrated CAD systems. Introduction to geometric modeling. Introduction to artificial intelligence.

- Engineering 82.563 (CVG7132)

Computer-Aided Design of Building Structures
Relevant aspects of computer systems, information handling, auxiliary storage; design methods, computerized design systems, computer graphics; application of structural theory; examination of a selected series of structural engineering programs and programming systems.

- Engineering 82.564 (CVG7142)

Engineering Management
Engineering management principles, including program and project organization, personnel management, major management systems, project management, legal aspects of management, communication problems, politics and management, management of the engineering competition and union-management problems.

- Engineering 82.565 (CVG7143)

Design of Steel Bridges
Basic features of steel bridges, design of slab-on-girder, box girder and truss bridges. Composite and non-composite design. Introduction to long span suspension and cable-stayed bridges. Discussion of relevant codes and specifications.

- Engineering 82.566 (CVG7144)

Design of Concrete Bridges
Concrete and reinforcing steel properties, basic features of concrete bridges, design of superstructure in reinforced concrete slab, slab-on-girder and box girder bridges, an introduction to prestressed concrete bridges, design of bridge piers and abutments. In all cases the relevant provisions of Canadian bridge codes are discussed.

- Engineering 82.575-82.579 (CVG7300-7304)

Special Topics in Structural Engineering
Courses in special topics related to building design and construction, not covered by other graduate courses; details will be available some months prior to registration.

- Engineering 82.580-82.584 (CVG7305-7309)

Special Topics in Geotechnical Engineering
Courses in special topics in geotechnical engineering, not covered by other graduate courses; details will be available some months prior to registration.

- Engineering 82.580 (CVG7305)

Analysis of Embankments and Slopes
Stability of embankments of soft clays; stress-strain analysis; anisotropy; strain rate effect; short and long-term settlement; methods of slope stability analysis; progressive failure; use of stability charts; slope analysis for residual and unsaturated soils.

- Engineering 82.585-82.589 (CVG7310-7314)

Special Topics in Transportation Planning and Technology
Courses in special topics in transportation engineering, not covered by other graduate courses; details will be available some months prior to registration.

- Engineering 82.590

Civil Engineering Project
Students enrolled in the M.Eng. program by course work will conduct an engineering study, analysis, or design project under the general supervision of a member of the department.

- Engineering 82.596 and 82.597

Directed Studies

- Engineering 82.599

M.Eng. Thesis

- Engineering 82.699

Ph.D. Thesis

Other Courses of Particular Interest

Mechanical and Aerospace Engineering
88.514 Ground Transportation Systems and Vehicles
88.517 Experimental Stress Analysis
88.521 Methods of Energy Conversion
88.550 Advanced Vibration Analysis
88.561 Creative Problem Solving and Design
88.562 Failure Prevention
88.568 Advanced Engineering Materials

Systems and Computer Engineering
94.501 Simulation and Modeling

Geography
45.415E Slope Development: Forms, Processes and Stability

45.417 Glacial Geomorphology
45.532 Soil Thermal and Hydrologic Properties
45.533 Periglacial Geomorphology
45.534 Aspects of Clay Mineralogy and Soil Chemistry
45.579 Research and Development in Outdoor Recreational Geography

Public Administration

50.510 Management Accounting
50.511 Financial Management