

# CIVIL ENGINEERING (CVG)

The following courses are offered by the Faculty of Engineering.

## **CVG 1107 Civil Engineering Graphics and Seminars (3 units)**

Fundamentals of graphical communications. Sketching, orthographic projections, sectional views, basic dimensioning, axonometric drawings, auxiliary views, relationships between lines and planes in space, intersections and developments, fasteners, AutoCAD. Drawing of points, lines, curves, splines, 2D views (with dimensions) and 3D views on AutoCAD. Use of Layers. A project using AutoCAD. Seminars in Civil Engineering practice including ethics, environmental obligations and workplace health and safety.

**Course Component:** Laboratory, Lecture

## **CVG 1507 Dessin industriel et séminaires en génie civil (3 crédits)**

Notions fondamentales en communication graphique. Exécution de croquis, projections orthographiques, sections, représentations axonométriques, vues auxiliaires, relations entre lignes et surfaces dans l'espace, lignes d'intersections et développement, éléments d'attache. AutoCAD. Dessin des points, lignes, courbes, splines, vues en 2D (avec cotations) et des vues en 3D. Utilisation des niveaux. Un projet utilisant AutoCAD. Séminaires consacrés à divers sujets dans la pratique de génie civil incluant l'éthique professionnelle, les obligations en matières d'environnement et les aspects de santé et sécurité au travail.

**Volet :** Laboratoire, Cours magistral

## **CVG 2107 Geotechnical Materials and Processes (3 units)**

Nature and behaviour of materials forming earth's crust: their formation and alteration due to action of ice, water, and wind; glaciation; land heave; permafrost; residual soils. Basic physical properties of soils: structure; index properties; grain size and visual identification; consistency limits; organic content; classification; compaction; capillarity; shrinkage and swelling; water in soil.

**Course Component:** Laboratory, Lecture

## **CVG 2116 Introduction to Fluid Mechanics (3 units)**

Fluid statics, atmospheric stability, properties of fluids. Kinematics of fluids, analysis by continuity, energy and momentum equations. Applications of one-dimensional method to flow in pipelines, flow measurement, dynamic forces and turbo machines. Laminar and turbulent pipe flow; energy losses in pipe flow and open channel flow. Viscous and form drag in fluid flow; role of boundary layer in drag. Similitude and dimensional analysis with application to hydraulic models.

**Course Component:** Laboratory, Lecture, Tutorial

Prerequisites: GNG 1105, MAT 1322, PHY 1122.

## **CVG 2132 Fundamentals of Environmental Engineering (3 units)**

An introductory study of environmental resources and their use. Relations and cycles within ecosystems. The causes, monitoring and correction of pollution of environmental systems. Water quality. Examination of water and wastewater for physical, chemical and biological characteristics.

**Course Component:** Laboratory, Lecture, Tutorial

Prerequisite: CHM 1311.

## **CVG 2140 Mechanics of Materials I (3 units)**

Stress and strain, mechanical properties of materials, bending moment and shear force diagrams; stresses and deformations in members subjected to tension, compression, shear and torsion; flexural and shearing stresses in beams; deflection of beams; combined stresses.

**Course Component:** Lecture, Tutorial

Prerequisite: GNG 1105.

## **CVG 2141 Civil Engineering Materials (3 units)**

Chemical, physical and mechanical properties of steels. Concrete materials and mix design. Properties of fresh and hardened concrete. Structure, properties and utilization of timber.

**Course Component:** Laboratory, Lecture

Prerequisite: CHM 1311.

## **CVG 2149 Civil Engineering Mechanics (3 units)**

Basic concepts of engineering mechanics applicable to civil engineering. Analysis of statically determinate beams, trusses and cables. Conservation of energy, principle of impulse and momentum, angular momentum, and impact for particles and systems of particles. Kinematics of particles, system of particles and rigid bodies. D'Alembert's principle.

**Course Component:** Lecture, Tutorial

Prerequisites: GNG 1105, MAT 1322, PHY 1122.

## **CVG 2170 Measurements I (4 units)**

Principles and analysis of civil engineering measurements. Probability and normal distribution; systematic and random errors; probabilistic principles of errors; statistical treatment of experimental data. Basic theory of mechanical and electrical strain measurement systems. Measurements in water resources and geotechnical engineering.

**Course Component:** Research, Discussion Group, Laboratory, Lecture, Seminar, Work Term, Theory and Laboratory, Tutorial

Prerequisites: MAT 1320, MAT 1322, MAT 1341.

## **CVG 2171 Surveying and Measurements (3 units)**

Theory and technique of linear and angular measurements in plane surveying. Surveying instruments: Level, Theodolite, EDM and Total Station. Topographic surveys and mapping. Astronomical observations: solar and star (Polaris) observations. Route surveying: horizontal and vertical curves. Measurements of volumes. Principles of photogrammetry. Includes field work on practical applications of measurement theories using surveying equipment

**Course Component:** Lecture, Tutorial

## **CVG 2181 Numerical Modelling in Civil Engineering (3 units)**

Development of computer programs in environmental geotechnical, structural and water resources engineering fields. Formulation of ordinary and partial differential equations with particular emphasis on civil engineering problems. Use of both microcomputers and mainframe facilities will be emphasized.

**Course Component:** Laboratory, Lecture

Prerequisites: (GNG 1106 or ITI 1120), MAT 2322, MAT 2384.

## **CVG 2507 Matériaux et processus géotechniques (3 crédits)**

Nature et comportement des matériaux formant la croûte terrestre : leur formation et altération par l'action de la glace, de l'eau, du vent; glaciation; soulèvement terrestre; pergélisols; sols résiduels; structure; propriétés physiques fondamentales des sols; indices de propriétés; granulométrie et identification visuelle; limites de consistance; composition organique; classification; compactage; capillarité; retrait et gonflement; l'eau dans le sol.

**Volet :** Laboratoire, Cours magistral

### **CVG 2516 Mécanique élémentaire des fluides (3 crédits)**

Hydrostatique, stabilité de l'atmosphère, les caractéristiques des fluides; cinématique des fluides, analyse par les méthodes de continuité d'énergie et d'impulsion. Applications de la méthode unidimensionnelle au débit en tuyaux, mesure des débits, forces dynamiques et machines hydrauliques; débit tranquille et turbulent (en tuyaux); pertes d'énergie pour les débits en tuyaux et aux canaux à ciel ouvert; résistance aux fluides due à la viscosité et à la forme. Rôle de la couche superficielle en résistance; similitude et analyse dimensionnelle avec applications aux modèles hydrauliques.

**Volet :** Laboratoire, Cours magistral, Tutoriel

Préalables : GNG 1505, MAT 1722, PHY 1522.

### **CVG 2532 Principes fondamentaux du génie de l'environnement (3 crédits)**

Une étude introductive des ressources environnementales et de leur utilisation. Relation et cycles dans les écosystèmes. Bilan de matière et de l'énergie pour expliquer les phénomènes environnementaux. Les causes, la surveillance, la prévention et les mesures correctives de la pollution des systèmes environnementaux. Qualité de l'eau. Analyse de l'eau et des eaux usées en termes des caractéristiques physiques, chimiques et biologiques. Météorologie et dispersion des polluants dans l'atmosphère.

**Volet :** Laboratoire, Cours magistral, Tutoriel

Préalable : CHM 1711.

### **CVG 2540 Mécanique des matériaux I (3 crédits)**

Contrainte et déformation, propriétés mécaniques des matériaux, moment de flexion et effort tranchant; contraintes et déformations dues aux forces axiales, de flexion et de torsion; contraintes de flexion et de cisaillement dans les poutres; déflexions; contraintes combinées.

**Volet :** Cours magistral, Tutoriel

Préalable : GNG 1505.

### **CVG 2541 Matériaux du génie civil (3 crédits)**

Propriétés chimiques, physiques et mécaniques des aciers. Matériaux constitutifs et formulation des bétons. Propriétés du béton frais et durci. Structure, propriétés et utilisation de bois de construction.

**Volet :** Laboratoire, Cours magistral

Préalable : CHM 1711.

### **CVG 2549 Mécanique de génie civil (3 crédits)**

Concepts de base de génie mécanique appliqués au génie civil. Étude des poutres statiquement déterminées, des treillis et des câbles. Conservation de l'énergie. Principe de l'impulsion et de la quantité de mouvement. Moment angulaire et impact des particules et des systèmes de particules. Cinématique des particules, de système de particules et des corps rigides. Le principe de D'Alembert.

**Volet :** Cours magistral, Tutoriel

Préalables : GNG 1505, MAT 1722, PHY 1522.

### **CVG 2571 Mesures et arpentage (3 crédits)**

Théorie et technique des mesures linéaires et angulaires. Instruments d'arpentage: niveau, théodolite, EDM et station total. Topographie et cartographie. Observations astronomiques solaires et astrales (Étoiles du Nord). Arpentage des routes: courbes horizontales et verticales. Mesures des volumes. Principes de la photogrammétrie. Travail pratique sur le terrain portant sur des mesures d'arpentage.

**Volet :** Cours magistral, Tutoriel

### **CVG 2581 Méthodes numériques en génie civil (3 crédits)**

Le développement de logiciels spécialisés dans les domaines de l'environnement, de la géotechnique, des structures et des ressources hydriques. La formulation d'équations différentielles ordinaires et aux dérivées partielles avec un emphase sur la résolution de problèmes typiques en génie civil. Une attention particulière sera accordée à l'application de ces outils au moyen de micro-ordinateurs ainsi que d'ordinateurs centraux.

**Volet :** Laboratoire, Cours magistral

Préalables : (GNG 1506 ou ITI 1520), MAT 2722, MAT 2784.

### **CVG 3106 Soil Mechanics II (3 units)**

Review of soil properties; site investigation methods; bearing capacity of shallow foundations; allowable bearing capacity and settlement analysis; lateral earth pressures; retaining wall design; sheet pile walls and braced cuts; slope stability analysis.

**Course Component:** Lecture, Tutorial

Prerequisite: CVG 3109.

### **CVG 3109 Soil Mechanics I (3 units)**

Fundamental characteristics of soils; total and effective stresses; permeability and seepage; stress and strain, shear strength; stress distribution; consolidation and settlements.

**Course Component:** Laboratory, Lecture, Tutorial

Prerequisites: CVG 2107, CVG 2140.

### **CVG 3116 Hydraulics (3 units)**

Review of fundamentals; flow in complex pipe systems; theory and operations of centrifugal pumps; gradually-varied open channel flows; backwater computations; flow measurements; unsteady flows; hydraulic models; sediment transport theory; introduction to wave theory.

**Course Component:** Laboratory, Lecture, Tutorial

Prerequisite: CVG 2116.

### **CVG 3120 Hydrology (3 units)**

Hydrologic cycle; evaporation and transpiration; snow and snowmelt; infiltration; subsurface water; well hydraulics; stream flow; unit hydrograph and S-curve analysis of flood flows; river and reservoir routing techniques; statistics of extreme values.

**Course Component:** Lecture, Tutorial

Prerequisite: MAT 2377.

### **CVG 3132 Physical/Chemical Unit Operation of Water and Wastewater Treatment (3 units)**

Water and wastewater treatment objectives. Theory and design of the fundamental physical/chemical unit operations for water and wastewater treatment. Flow regimes in reactors and mass balances. Unit operations: sedimentation, mixers, flocculation, mass transfer/aeration, filtration, softening and disinfection.

**Course Component:** Laboratory, Lecture, Tutorial

Prerequisites: CVG 2116, CVG 2132.

### **CVG 3140 Theory of Structures I (3 units)**

Analysis of statically determinate beams and frames. Deflections; moment-area method, conjugate-beam method, virtual work and energy methods. Analysis of statically indeterminate beams, frames and trusses; force method, flexibility method, slope-deflection method, moment distribution. Influence lines for beams, frames and trusses. Analysis of statically determinate cables and arches. Introduction to loads on structures.

**Course Component:** Lecture, Tutorial

Prerequisites: CVG 2140, CVG 2149.

**CVG 3141 Mechanics of Materials II (3 units)**

Combined stresses; buckling; unsymmetric bending, composite beams, inelastic bending, plastic collapse of beams, shear flow, shear centre; vibrations; Castigliano's theorem; torsion of thin-walled closed and open sections, inelastic torsion.

**Course Component:** Laboratory, Lecture

Prerequisites: CVG 2140, CVG 2149, MAT 2384.

**CVG 3147 Structural Steel Design I (3 units)**

Design of statically determinate steel structures. Limit States Design. Properties of structural steel. Loads from building codes. Tributary area. Live-load-reduction factors. Tension members: Effective area, shear lags. Compression members: strength and stability. Beams: Plastic flexure, local and lateral torsional buckling, shear strength, deflection control, bearing resistance. Structural bolts in shear, tension, and in combination; prying action.

**Course Component:** Lecture, Tutorial

Prerequisites: CVG 2141, CVG 3140. MAT 2377 is corequisite to CVG 3147.

**CVG 3148 Reinforced Concrete Design I (3 units)**

Behaviour and design of reinforced concrete members subjected to bending, shear and axial force. Analysis of reinforced concrete sections. Design of beams, one-way slabs, columns, bearing walls and retaining walls using the ultimate strength theory and the principles of limit states design. Introduction to prestressed concrete. Design of simple prestressed concrete beams.

**Course Component:** Laboratory, Lecture

Prerequisites: CVG 2141, CVG 3140.

**CVG 3509 Mécanique des sols I (3 crédits)**

Caractéristiques fondamentales des sols ; contraintes totales et effectives ; perméabilité et infiltration ; contraintes et déformations relatives, résistance au cisaillement ; répartition des contraintes ; consolidation et tassement.

**Volet :** Laboratoire, Cours magistral, Tutoriel

Préalables : CVG 2507, CVG 2540.

**CVG 3516 Hydraulique (3 crédits)**

Révision des principes fondamentaux ; écoulement dans les systèmes complexes de conduites ; théorie et opération de pompes centrifuges ; écoulements à surface libre graduellement variés ; calcul de courbes de remous ; mesure de débit ; écoulements non stationnaires ; modèles hydrauliques ; théorie de transport de sédiments ; introduction à la théorie des vagues.

**Volet :** Laboratoire, Cours magistral, Tutoriel

Préalable : CVG 2516.

**CVG 3520 Hydrologie (3 crédits)**

Cycle hydrologique; évaporation et transpiration; neige et fonte des neiges; infiltration; eaux souterraines; hydraulique des puits; débit; analyse par hydrogramme unitaire et hydrogramme en S des débits d'inondation; techniques de routage en rivière et en réservoir; statistiques des valeurs extrêmes.

**Volet :** Cours magistral, Tutoriel

Préalable : MAT 2777.

**CVG 3540 Théorie des structures I (3 crédits)**

Analyse de poutres et cadres isostatiques. Calcul des flèches ; méthode des moments d'aire, méthode de poutre conjuguée, travail virtuel et méthodes d'énergie. Analyse de poutres, cadres et treillis hyperstatiques ; méthodes des forces, de flexibilité, des rotations, de distribution de moments. Lignes d'influence pour poutres, cadres et treillis. Analyse de câbles et arcs isostatiques. Introduction aux surcharges sur les structures.

**Volet :** Cours magistral, Tutoriel

Préalables : CVG 2540, CVG 2549.

**CVG 3547 Conception des structures en acier I (3 crédits)**

Calculs et conception de structures isostatiques en acier. Calculs aux états limites. Propriétés de l'acier. Charges selon les normes de bâtiments. Aires tributaires. Facteurs de réduction des surcharges d'exploitation. Pièces en traction: section effective, décalage. Pièces en compression : résistance et comportement en stabilité. Poutres: moment plastique, voilement des sections à parois minces, déversement, résistance à l'effort tranchant, contrôle de déformations, résistance aux charges concentrées. Résistance des boulons en cisaillement, en traction et en cisaillement et traction combinés, effet de levier.

**Volet :** Cours magistral, Tutoriel

Préalables : CVG 2541, CVG 3140. MAT 2777 est concomitant à CVG 3547

**CVG 4001 Introduction à la conception en génie civil / Introduction to Civil Engineering Project (3 crédits / 3 units)**

Introduction à la méthode de conception. Identification des critères et contraintes d'un projet. Génération des options de conception et sélection du meilleur concept. Compétences en gestion de projet telles que production d'un échéancier et allocation des ressources. / Introduction to the design method. Identification of project criteria and constraints. Generation of design options and selection of preferred design. Project management skills, such as cost prediction, timeline evaluation and resource allocation.

**Volet / Course Component:** Cours magistral / Lecture, Tutoriel / Tutorial

Préalables : CVG 3106, CVG 3116, CVG 3132, CVG 3147, CVG 3148.

**CVG 4107 Rock Mechanics (3 units)**

Rock exploration, laboratory and in-situ testing; rock mass classification; deformation and strength; failure criteria; stresses in rock; foundations on rock.

**Course Component:** Lecture

Prerequisites: CVG 3109, CVG 3106.

**CVG 4108 Geotechnical Design (3 units)**

Applications of soil mechanics theory to bearing capacity, settlement, and stability evaluation; design of foundations, retaining structures, embankments, and excavations; geotechnical exploration, reporting and spatial variability considerations; introduction to ground improvement.

**Course Component:** Lecture

Prerequisites: CVG 3109, CVG 3106.

**CVG 4110 Hydraulics of Open Channels (3 units)**

Equations of open channel flow. Rapidly varied flow. Gradually varied flow in regular and natural channels. Unsteady flow. Application to flood waves and tides in natural channels. Turbulence and related diffusion phenomena. Sediment transport, bed and suspended load. Scour.

**Course Component:** Lecture

Prerequisites: CVG 3116, CVG 3120.

**CVG 4113 Hydraulics of Water Supply and Sewer Systems (3 units)**

Population forecasting techniques. Design of network distribution systems for flow and pressure requirements, hydraulics of sewer junctions and transitions, measuring devices in urban water and sewer networks, pumps, and pumping stations, valves, hydrants. Environmental considerations. Fieldwork.

**Course Component:** Lecture

Prerequisite: CVG 3116.

**CVG 4122 Groundwater and Seepage (3 units)**

Types and physical properties of aquifers. Darcy's Law; hydraulic conductivity of isotropic, anisotropic, and multilayered soils; uniform flow, unidirectional and radial flow – steady and unsteady flow nets; methods of images, partially penetrating wells; leaky aquifers; application of mapping techniques to seepage problems.

**Course Component:** Lecture

Prerequisites: CVG 2116, CVG 3109.

**CVG 4130 Advanced Environmental Engineering (3 units)**

Water quality objectives; cell microbiology; bacterial energetics; biological treatment kinetics; design of conventional wastewater treatment systems (lagoons, activated sludge); design of advanced wastewater treatment systems (membrane bioreactors, and moving bed bioreactors).

**Course Component:** Lecture, Tutorial

Prerequisite: CVG 2132.

**CVG 4133 Solid Waste Management (3 units)**

Quantities and characteristics of municipal solid waste. Collection and transportation systems. Resource recovery. Solid waste separation processes. Energy recovery from municipal solid waste. Disposal methods. Environmental impacts of landfilling of solid waste. Environmental legislation and risk assessment.

**Course Component:** Lecture

Prerequisite: CVG 2132.

**CVG 4135 Water Treatment in Northern Communities (3 units)**

Specific context of water and wastewater treatment in northern communities: type of water and wastewater treatment units, type of distribution systems, major challenges related to water and wastewater services and water strategies implemented.

**Course Component:** Lecture

Prerequisites: CVG 3116, CVG 3120.

**CVG 4142 Structural Dynamics (3 units)**

Dynamic problems in civil engineering; single-degree-of-freedom system; free and forced vibrations; transient phenomena and Duhamel's integral; distributed mass system; seismic response of structures; multi-storey buildings; random vibration and wind-induced response of structures.

**Course Component:** Lecture

Prerequisites: CVG 3140.

**CVG 4143 Structural Steel Design II (3 units)**

Design of fully and partially composite beams. Beam-Columns design including local buckling, strength and stability interaction equations, biaxial bending, and bending and tension members. Plate girders design including ultimate shear strength, tension-field action, design of bearing and intermediate stiffeners, local buckling considerations, and flexural resistance. Second-order analysis techniques.

**Course Component:** Lecture

Prerequisites: CVG 3147, CVG 3148.

**CVG 4145 Reinforced Concrete Design II (3 units)**

Extension of course CVG 3148. Behaviour and design of reinforced concrete members, subjected to biaxial bending, torsion, lateral loads and two-way action. Two-way slab systems. Strip method, direct design approach and equivalent frame analysis of two-way slabs. Yieldline theory of slabs. Inelastic response of reinforced concrete structures and moment re-distribution. Earthquake resistant design.

**Course Component:** Lecture, Tutorial

Prerequisites: CVG 3148.

**CVG 4146 Structural Design in Timber (3 units)**

Timber engineering; species groups, stresses, load factors. Mechanical fasteners and adhesives. Preservative treatments; fire safety, design and analysis of timber structures.

**Course Component:** Lecture, Tutorial

Prerequisite: CVG 3140.

**CVG 4147 Sustainable Building Design (3 units)**

Basic principles of heat transfer in buildings; energy-efficient envelope design; bioclimatic design; energy use in buildings; building energy codes and standards; indoor environmental quality.

**Course Component:** Lecture, Tutorial

Prerequisites: CVG 3147, CVG 3148.

**CVG 4148 Theory of Structures II (3 units)**

Topics in structural analysis related to statistically indeterminate structures. Introduction to stiffness and flexibility coefficients; matrix formulation and computer programming to solve indeterminate structures such as trusses, continuous beams and tall building frames.

**Course Component:** Laboratory, Lecture

Prerequisites: CVG 2181, CVG 3140.

**CVG 4150 Highway and Transportation Engineering (3 units)**

Importance of highways and transportation; urban transportation planning; driver, vehicle, and general traffic characteristics; traffic engineering and studies; highway capacity and level of service; highway location and geometric design; earthwork operations; highway drainage and subgrade structure; structural analysis and design of rigid and flexible pavements; economic analysis and evaluation of transportation systems.

**Course Component:** Lecture, Tutorial

Prerequisites: CVG 2171, CVG 2107, CVG 2141.

**CVG 4161 Mechanics of Unsaturated Soils (3 units)**

Stress state variables for unsaturated soils interpretation; measurement of suction, permeability, shear strength, volume change behavior of unsaturated soils; application of the mechanics of unsaturated soils for geotechnical engineering problems.

**Course Component:** Lecture

Prerequisites: CVG 3109, CVG 3106.

**CVG 4172 Advanced Concrete Technology (3 units)**

Cement: types, hydration, physical properties; aggregate: classification, grading, properties; fresh concrete: influence of basis constituents and admixtures on workability, mixing, placing; strength of hardened concrete; nature of strength, influence of constituents, curing methods; durability; chemical attack, frost action, thermal effects; elasticity, shrinkage and creep; special concrete; lightweight, high density; mix design; approaches, weigh batching, volume proportioning, special mixes; field and laboratory test methods.

**Course Component:** Lecture

Prerequisite: CVG 2141.

**CVG 4173 Construction Management (3 units)**

Planning and operation of construction project by the civil engineer, coordination and control of personnel, materials and machines, scheduling, estimation, purchasing cost control and other topics. Influence of construction procedures on civil engineering design processes. Common and civil law as applied to engineering contracts and specifications.

**Course Component:** Lecture

Prerequisites: CVG 3106, CVG 3147, CVG 3148.

**CVG 4175 Field Investigations and Environmental Impact Assessment of Civil Engineering Projects (3 units)**

Field investigations in geotechnical, water resources and environmental engineering. Experimental design, data acquisition, data analysis and site visits. Principles of environmental impact assessment of civil engineering projects.

**Course Component:** Laboratory, Lecture

Prerequisites: CVG 2132, CVG 3116, CVG 3106.

**CVG 4180 Special Directed Studies (3 units)**

Selected topics of special interest in civil engineering.

**Course Component:** Research

Prerequisite: Permission of the Department.

**CVG 4181 Special Topics in Structural Engineering (3 units)**

Specialized course on a selected topic in structural engineering

**Course Component:** Lecture

Prerequisites: CVG 3147, CVG 3148.

**CVG 4184 Special Topics in Geotechnical Engineering (3 units)**

Specialized course on a selected topic in geotechnical engineering.

**Course Component:** Lecture

Prerequisite: CVG 3106.

**CVG 4186 Special Topics in Water Resources Engineering (3 units)**

Specialized course on a selected topic in water resources engineering.

**Course Component:** Lecture

Prerequisites: CVG 3116, CVG 3120.

**CVG 4188 Special Topics in Environmental Engineering (3 units)**

Specialized course on a selected topic in environmental engineering.

**Course Component:** Lecture

Prerequisites: CVG 3116, CVG 3120.

**CVG 4260 Thesis (6 units)**

Thesis on an approved research or design topic in Civil Engineering which will emphasize independent work. The thesis will be done under the direction of a faculty adviser and the student must obtain an adviser's approval before commencing the course.

**Course Component:** Research

Prerequisites: B average, permission of supervisor.

**CVG 42601 Thesis (Part 1 of 2)**

Thesis on an approved research or design topic in Civil Engineering which will emphasize independent work. The thesis will be done under the direction of a faculty adviser and the student must obtain an adviser's approval before commencing the course. (Part 1 of 2)

**Course Component:** Research

Prerequisites: B average, permission of supervisor.

**CVG 42602 Thesis (Part 2 of 2) (6 units)**

Thesis on an approved research or design topic in Civil Engineering which will emphasize independent work. The thesis will be done under the direction of a faculty adviser and the student must obtain an adviser's approval before commencing the course. (Part 2 of 2)

**Course Component:** Research

Prerequisite: CVG 42601

**CVG 4907 Projet de conception en génie civil / Civil Engineering Design Project (3 crédits / 3 units)**

Projet en génie civil sous la direction de conseillers membres du corps professoral pendant la dernière année du programme. Le projet doit être basé sur la connaissance et les qualifications conformes aux normes de conception, de législation, de sciences économiques, de santé et de sécurité, d'environnement et autres facteurs pertinents. Un accent particulier est mis sur l'expérience de travail en équipe et sur l'apprentissage dans un contexte créatif, itératif et ouvert. / A civil engineering design project under the direction of faculty advisors for the final year of the program. The project is to be based on the knowledge and skills of design standards, legislation, economics, health and safety, environmental and other pertinent factors. A particular emphasis is placed on experience of teamwork and a creative, iterative and open-ended process.

**Volet / Course Component:** Cours magistral / Lecture

Prerequisite: CVG 4001.

**CVG 5100 Deep Foundations (3 units)**

Deep foundation types in North American practice (driven or bored piles, and slurry trench techniques); axial and lateral capacity and settlement analysis for single piles and pile groups; field inspection methods; pile dynamics; performance and analysis of static test loading. This course is equivalent to CIVJ 5000 at Carleton University.

**Course Component:** Lecture

**CVG 5106 Site Improvements (3 units)**

Description, design procedures and usage of current site improvement techniques, including preloading, earth reinforcement, dynamic consolidation, vibrocompaction, blasting densification, lime treatment, drains, and geotechnical fabrics. This course is equivalent to CIVJ 5006 at Carleton University.

**Course Component:** Lecture

**CVG 5111 Hydraulic Structures (3 units)**

Classification and function of hydraulic structures; analysis and design of hydraulic works for gravity dams, arch dams, earth fill and rock-fill dams; ancillary works including water intakes, various types of spillways, control structures, energy dissipation and stilling basin, bottom outlets. Advanced topic in channel design including transitions; hydraulic transients, free surface and free surge analysis; water towers and compensation basins; penstocks. Navigation locks. Coastal protection works and maritime structures. This course is equivalent to CIVJ 5501 at Carleton University.

**Course Component:** Lecture

**CVG 5112 Computational Hydrodynamics (3 units)**

Finite volume methods for advection, diffusion and shallow water equations using structured and unstructured grids, finite volume methods for incompressible Navier-Stokes equations (SIMPLE, SIMPLEC, PISO), error analysis: numerical diffusion and dispersion, truncation errors and Fourier analysis, introduction to turbulence modeling, introduction to methods for tracking free surfaces and moving beds, introduction to other methods in hydrodynamics: finite element, finite difference, Chebyshev and Fourier spectra, semi Lagrangian and vortex methods in hydrodynamics. This course is equivalent to CIVJ 5502 at Carleton University.

**Course Component:** Lecture

**CVG 5120 Water Resources Systems (3 units)**

Conservation of water resources. Multi-purpose project planning: study of domestic and foreign water development projects. Techniques for simulation, optimization, linear and dynamic programming. This course is equivalent to CIVJ 5506 at Carleton University.

**Course Component:** Lecture

**CVG 5123 Advanced Topics in Hydrology (3 units)**

Selected topics of current interest in surface and groundwater hydrology. This course is equivalent to CIVJ 5509 at Carleton University.

**Course Component:** Lecture

**CVG 5124 Coastal Engineering (3 units)**

Key concepts in coastal engineering: (1) wave mechanics and coastal hydrodynamics, (2) sediment transport and coastal morphodynamics and (3) coastal structures and coastal zone management. Wave mechanics and coastal hydrodynamics to include small-amplitude wave theory, finite amplitude wave theories (Stokes, cnoidal and solitary wave), wave generation, wave transformations, development and prediction, hydrodynamics of coastal circulation. Sediment transport and coastal morphodynamics to include: wave and current-induced sediment transport, coastal sediment processes, longshore and cross-shore beach morphologic transformations, etc. Coastal structures and coastal zone management to include: beach erosion control, coastal structures (dikes, breakwaters, groins, seawalls), beach nourishment, coastal pollution and control, nearshore area development. This course is equivalent to CIVJ 5605 at Carleton University.

**Course Component:** Lecture

**CVG 5125 Statistical Methods Hydrology (3 units)**

Concepts of probability and random variables applied to hydrology. Statistical distributions, their approximation and analysis. Statistical inference, including tests of significance and estimation theory. Linear and multivariate correlation and regression techniques. Data generation and simulation techniques for design of water-resource systems. Introduction to hydrologic and meteorologic time series. This course is equivalent to CIVJ 5601 at Carleton University.

**Course Component:** Lecture

**CVG 5142 Advanced Structural Dynamics (3 units)**

Dynamic behaviour of civil engineering structures under excitations due to earthquakes, wind, waves, etc. Advanced methods in dynamic analysis of structures. Prediction of structural response. Design considerations. This course is equivalent to CIVJ 5201 at Carleton University.

**Course Component:** Lecture

**CVG 5143 Advanced Structural Steel Design (3 units)**

Analysis of thin-walled beams; design applications including members under combined forces; analysis and design of beams under non-uniform torsion; limit state design methodology; comparative study of modern structural steel standards; formulating elastic and plastic interaction relations for members under combined forces; designing columns, beams, and beam columns for cross-sectional strengths; local buckling and global stability considerations; design of bracing systems. This course is equivalent to CIVJ 5202 at Carleton University.

**Course Component:** Lecture

**CVG 5144 Advanced Reinforced Concrete (3 units)**

Study of the elastic and inelastic response of reinforced concrete structures under monotonic and cyclic loading. Methods for predicting structural behaviour of concrete elements. The relationship between recent research results and building codes. This course is equivalent to CIVJ 5300 at Carleton University.

**Course Component:** Lecture

**CVG 5145 Theory of Elasticity (3 units)**

Stress-strain relations. Theories of plane stress and plane strain. Use of stress functions, energy and variational methods in the analysis of elastostatic problems. This course is equivalent to CIVJ 5203 at Carleton University.

**Course Component:** Lecture

**CVG 5146 Numerical Methods of Structural Analysis (3 units)**

Numerical procedures and methods of successive approximations for the solution of structural problems. Virtual work, principles of minimum potential and complementary energy. Applications of variation and finite difference techniques to the solutions of complicated problems in beams, plates and shells. This course is equivalent to CIVJ 5302 at Carleton University.

**Course Component:** Lecture

**CVG 5147 Theory of Plates and Shells (3 units)**

Stress distribution in flat plates of various shapes. Large deflection theory, numerical methods. Membrane theory, bending theory for cylindrical shells, bending theory for shells of revolution. This course is equivalent to CIVJ 5204 at Carleton University.

**Course Component:** Lecture

**CVG 5148 Prestressed Concrete Design (3 units)**

Materials, methods of prestressing, prestress losses, and anchorage zone stresses. Elastic analysis, design and behaviour of simple and continuous prestressed concrete beams, frames and slabs. Discussion of current design specifications. Ultimate strength of members. This course is equivalent to CIVJ 5305 at Carleton University.

**Course Component:** Lecture

**CVG 5149 Structural Stability (3 units)**

Elastic, inelastic, and torsional buckling of columns, beam column behaviour, plane and space frame stability, lateral torsional buckling of beams, global buckling of truss systems, plate and shell buckling, local buckling in tubulars, use of energy methods, matrix analysis, and finite element analysis in modeling stability problems, bracing requirements, standard provisions and design considerations in structural stability. This course is equivalent to CIVJ 5304 at Carleton University.

**Course Component:** Lecture

**CVG 5150 Advanced Concrete Technology (3 units)**

Cement: types, hydration, physical properties; aggregate: classification, grading, properties; fresh concrete: influence of basis constituents and admixtures on workability, mixing, placing; strength of hardened concrete; nature of strength, influence of constituents, curing methods; durability; chemical attack, frost action, thermal effects; elasticity, shrinkage and creep; special concrete; lightweight, high density; mix design; approaches, weigh batching, volume proportioning, special mixes; field and laboratory test methods. This course is equivalent to CIVJ 5206 at Carleton University.

**Course Component:** Lecture

**CVG 5151 Advanced Timber Design (3 units)**

Characteristic values for timber and engineered wood products, modification factors used in design; design of members subjected to combined bending axial loading; design for bi-axial bending; design of curved glued laminated beams, Timber-Concrete Composite (TCC) floor systems; lateral design (wind and seismic loading) for light-frame, CLT and hybrid structures; advanced connection design including design of proprietary connections.

**Course Component:** Lecture

**CVG 5153 Wind Engineering (3 units)**

The structure and climate of wind; wind loading on structures; wind induced dynamic problems of structures; environmental aerodynamics; dispersion of pollutant; analysis of wind data; experimental investigations. This course is equivalent to CIVJ 5209 at Carleton University.

**Course Component:** Lecture

**CVG 5154 Random Vibration (3 units)**

Descriptions of random data. Frequency domain analysis and time domain analysis. Stochastic response of structures; wind and earthquake excitation, etc. Data analysis techniques. Prediction for design purposes. Simulation of random processes. Special topics. This course is equivalent to CIVJ 5308 at Carleton University.

**Course Component:** Lecture

**CVG 5155 Earthquake Engineering (3 units)**

Nature and characteristics of earthquake motions. Non-linear response of single and multi-degree-of-freedom structures to seismic excitations. Modal superposition technique. Simplified procedures for dynamic structural analysis. Principles of earthquake resistant design. Strength, stiffness, ductility and energy absorption requirements of structures for seismic forces. Response spectra analysis. Current design procedures for aseismic design. Recent research on earthquake engineering. This course is equivalent to CIVJ 5306 at Carleton University.

**Course Component:** Lecture

**CVG 5156 Finite Element Methods (3 units)**

Review of basic matrix methods. Structural idealizations. The displacement versus the force method. Stiffness properties of structural elements. Finite elements in beam bending, plane stress and plate bending. This course is equivalent to CIVJ 5301 at Carleton University.

**Course Component:** Lecture

**CVG 5157 Finite Element Methods (3 units)**

Application of finite elements to folded plates, shells and continua. Convergence criteria and order of accuracy. Inertial and initial stress properties. Dynamic and buckling problems. Non-linear deflections and plasticity. This course is equivalent to CIVJ 5303 at Carleton University.

**Course Component:** Lecture

**CVG 5158 Elements of Bridge Engineering (3 units)**

Introduction; limit state design; highway bridge design loads; analysis and design of concrete decks; impact and dynamics; load capacity rating of existing bridges and construction in cold climate. This course is equivalent to CIVJ 5307 at Carleton University.

**Course Component:** Lecture

**CVG 5159 Long Span Structures (3 units)**

Mechanics of cables. Suspension bridges and cable-stayed bridges. Space structures. Design and construction of long span structures. Dynamics of long span bridges. Case studies. Future of long span structures. This course is equivalent to CIVJ 5309 at Carleton University.

**Course Component:** Lecture

**CVG 5160 Sediment Transport (3 units)**

An introduction to particle transport, with special emphasis on river engineering applications, including natural channel design. Sediment properties, initiation of motion, bed load, suspended load, fluvial dunes, alluvial channels, bank erosion and protection, natural channel design. Special topics include contaminated sediments, local scour, morphodynamic modelling, fluvial habitat. This course is equivalent to CIVJ 5503 at Carleton University.

**Course Component:** Lecture

**CVG 5161 Mechanics of Unsaturated Soils (3 units)**

Introduction to unsaturated soils, phases of an unsaturated soil, phase properties and relations, stress state variables for saturated and unsaturated soils. Measurement of soil suction: theory of soil suction, capillarity, measurements of total suction and matric suction. Flow Laws: flow of water and measurement of permeability, shear strength theory: history, failure envelope for unsaturated soils, triaxial and direct shear tests, typical results, simple testing procedures, volume change behavior including expansive soils behavior. Soil-water characteristic curve: its behavior and use in predicting the engineering properties of unsaturated soils, practical applications of the principles of unsaturated soils. This course is equivalent to CIVJ 5106 at Carleton University.

**Course Component:** Lecture

**CVG 5162 River Hydraulics (3 units)**

Advanced concepts of river hydraulics, with an emphasis on field measurement techniques and application of numerical models. Navier-Stokes equations, turbulence, flow resistance, numerical modelling of simplified momentum and continuity equations, field-based measurement and statistical analysis of velocity fields. Special topics include contaminant transport, morphodynamic modelling. This course is equivalent to CIVJ 5504 at Carleton University.

**Course Component:** Lecture

**CVG 5175 Numerical Methods for Geotechnical Engineers (3 units)**

Non-linear analysis of stresses and deformations using the effective stress concept; analysis of consolidation using the excess pore water pressure concept; flow through porous media; finite element, discrete element and finite difference methods; applications to foundations of structures, retaining walls, dams, tunnels, pipelines, human-made and natural slopes in rock and soil. This course is equivalent to CIVJ 5105 at Carleton University.

**Course Component:** Lecture

**CVG 5178 Ice Mechanics (3 units)**

Ice conditions in the Arctic; ice physics; classification of ice; mechanical properties of ice; mathematical modelling of creep and fracture behaviour of ice; offshore structures in arctic environments; ice forces acting on structures; ice induced vibrations; iceberg impact loads; physical modelling of ice-structure interaction; ice as a construction material; case histories. This course is equivalent to CIVJ 5108 at Carleton University.

**Course Component:** Lecture

**CVG 5180 Biological Nutrient Removal (3 units)**

Advanced theoretical, biological, and practical aspects of biological nutrient removal (BNR) (nitrification, denitrification and excess biological phosphorus) processes. Principles to be applied to the design and application of conventional and advanced BNR processes used for treatment of municipal and industrial wastewaters. Topics are as follows: microbiology and biochemistry fundamentals of BNR, nitrification process design of suspended growth and fixed film growth systems, denitrification process design of suspended growth and fixed film growth systems, excess biological phosphorus removal design including prefermentation. Design of 2, 3, 4 and 5 stage BNR systems. General activated sludge model and Simworks for BNR systems. Retrofit of existing plants and pilot plant testing for BNR. This course is equivalent to ENVJ 5909 at Carleton University.

**Course Component:** Lecture

**CVG 5181 Decentralized Wastewater Management (3 units)**

Fundamental principles and practical design applications of decentralized wastewater treatment for domestic and industrial sources. Management of decentralized wastewater systems; Pre-treatment systems; Soil infiltration systems; Advanced onsite technologies, constructed wetlands; Alternative collection systems; Wastewater reuse and septage management.

**Course Component:** Lecture

**CVG 5182 Water Resources Management (3 units)**

Global water supply and demand; Integrated water resources management; Modeling and optimization of water resources systems; Reservoir Management; Uncertainty modeling; Climate Change and water; Decision under uncertainty.

**Course Component:** Lecture

**CVG 5183 Mixing and Transport of Pollutants in Water Bodies (3 units)**

Typical models for selected water resources systems : Rivers, lakes, estuaries; Water quality parameters; Conservative parameters; Non conservative parameters; Laminar and turbulent flows; Dispersion; Pollution sources; Modeling; Simplified (integral) models; Dilution models; Three Dimensional models; Advection-Diffusion Equation; Analytical solution; Numerical solution; Non-conservative transport and Multi-component systems; Modeling approaches based on conservative and non-conservative transport and kinetics; Certain water quality parameters (Temperature, Salinity, etc.).

**Course Component:** Lecture

**CVG 5184 Construction Cost Estimating (3 units)**

General overview of construction cost estimating. Techniques and construction cost estimating process; Elements of project cost; Conceptual and detailed cost estimation methods; Risk assessment and range estimating; Work breakdown structure applied in building projects. Computer applications in building construction cost estimating and infrastructure projects.

**Course Component:** Lecture

**CVG 5185 Construction Life Cycle Analysis (3 units)**

General overview of analyzing the economics of construction projects by applying the concept of time value of money. Financing strategies for construction projects and profitability analysis; Correlation between Value Engineering, Life cycle cost analysis and assessment for construction projects. Break Even, Sensitivity and Risk analysis and their application to project life cycle analysis.

**Course Component:** Lecture

**CVG 5186 Project Information Management (3 units)**

Topics in contractual relationships between construction project teams. Different type of construction contracts and their application. Preparation of project documents. Evaluation of different types of project organization structure and associated project delivery systems. Bidding strategies. Network analysis using deterministic and stochastic methods for construction time and cost management.

**Course Component:** Lecture

**CVG 5187 Rock Mechanics (3 units)**

Rock exploration, laboratory and in-situ testing; rock mass classification; deformation and strength; failure criteria; stresses in rock; foundations on rock.

**Course Component:** Lecture

**CVG 5188 Loads on Structures (3 units)**

Overview of loads on buildings according to Canadian codes and standards. Dead and live loads; Snow loads; Wind loads; Earthquake loads; Loads on non-structural components; Vibrations. Selected topics in the practical design of building structures.

**Course Component:** Lecture

**CVG 5189 Blast Engineering (3 units)**

Overview of explosives and blast loads on structural and non-structural infrastructure components; dynamic analysis of elements under blast-induced shock waves and dynamic pressures; elastic and inelastic response; incremental equation of motion and nonlinear analysis; development of resistance functions; pressure-impulse (P-I) diagrams; design of blast-resistant buildings and building components, including glazed windows, curtain walls, and blast-resistant doors as per codes and standards; progressive collapse analysis; blast retrofits and blast-risk mitigation strategies.

**Course Component:** Lecture

**CVG 5190 Rehabilitation of Concrete Structures (3 units)**

Durability of concrete bridges and building structures in Canada; assessment and evaluation of damaged concrete structures; repair, rehabilitation, and strengthening techniques; applicable design codes and guidelines; monitoring technologies for structures; implications for infrastructure management.

**Course Component:** Lecture

**CVG 5191 Diagnosis and Prognosis of Concrete Infrastructure (3 units)**

Condition assessment of concrete infrastructure using experimental (i.e. visual, non-destructive, microscopic and mechanical) and analytical approaches; Overview of repair and maintenance techniques according to damage type and extent; "Serviceability performance" and "appraisal guides" for aging infrastructure; Design for durability through performance based design (PBD) approaches.

**Course Component:** Lecture

**CVG 5192 Characterization Methods for Materials (3 units)**

Modern materials characterization techniques especially with respect to civil engineering materials. Choosing the right characterization methods in order to determine the properties of materials such as chemical composition, atomic structure, and surface properties used in their research. Interpreting the results of each method as well as the insight into the interrelationships between characterization methods and their interdependency.

**Course Component:** Lecture

**CVG 5193 Instrumentation and Experimental Design for Civil Engineering (3 units)**

Introduction to instrumentation in civil engineering applications; Instrument types and performance; Strain gauges; Transducers; Measurement of position, velocity, acceleration, force, pressure, temperature and flow; Data collection and data acquisition systems; Diagnostics and calibration; Control (Closed versus Open-loop); Servomotor types and servo-valves.

**Course Component:** Lecture

**CVG 5212 Climate Change Impacts on Water Resources (3 units)**

Spatiotemporal distribution of water and its impact on human activities, including domestic and municipal consumption, hydropower generation, rain-fed and irrigated agriculture, design and operation of sewer systems, floodplain zoning, navigation, etc. Critical assessment of methodologies for climate change impacts estimation. Theoretical knowledge and hands-on applications experience needed to perform climate change analysis on a water resources system.

**Course Component:** Lecture



**CVG 5214 Sustainable and Resilient Infrastructure (3 units)**

Concepts of sustainability and resiliency as applied to civil engineering infrastructure. Discussion of evolving infrastructure needs and infrastructure risk profiles due to climate and societal change. Introduction to sustainability and resiliency assessment tools including non-stationary risk assessment, triple bottom line accounting, life cycle costs, and carbon accounting. Development of infrastructure design strategies to meet objectives for both sustainability and resiliency.

**Course Component:** Lecture

**CVG 5216 Sustainable and Resilient Infrastructure in Changing Climate (3 units)**

Development of a class of infrastructure with long-term sustainability and resiliency under various extreme events, particularly, the events introduced by changing climate. Climate change drivers, climate modelling and climate change impact studies. The concepts of sustainability, resiliency, and reliability. Climatic and flooding hazards. Uncertainty and non-stationarity processes as extreme events become more severe. Benefits of building sustainable and resilient infrastructures in terms of efficient capital and operational costs while providing society with healthier and more convenient infrastructure.

**Course Component:** Lecture

**CVG 5232 Unit Operations of Water Treatment Lab (1.5 unit)**

Bench-scale and pilot-scale experiments required to: a) assess the suitability of different physicochemical processes for particular applications, and b) design a full-scale facility. Conventional analytical techniques used in water treatment (pH, alkalinity, hardness, turbidity, color, spectrophotometric analysis). Process analysis techniques for process evaluation and scale-up including: zone sedimentation, batch flux settling tests, coagulation with iron and aluminum salts, flocculent sedimentation, filtration and fluidization, flotation. This course is equivalent to ENVJ 5911 at Carleton University.

**Course Component:** Lecture

CVG 5132 is corequisite to CVG 5232.

**CVG 5238 Advanced Water Treatment Process Lab (1.5 unit)**

Bench-scale and pilot-scale experiments required to: a) assess the suitability of different physicochemical processes for the removal of toxic and non-standard contaminants, and b) design a full-scale facility. Tracer tests and non-ideal reactor behaviour, activated carbon adsorption equilibria and kinetics, aeration. Total organic carbon analysis, spectrophotometry. Process analysis, techniques for process evaluation and scale-up including: aeration, analysis of non-ideal flow conditions. Tracer study of three basins, adsorption isotherm tests, activated carbon mini-column tests, oxidation kinetic tests. This course is equivalent to ENVJ 5912 at Carleton University.

**Course Component:** Lecture

CVG 5138 is corequisite to CVG 5238.

**CVG 5301 Soil and Water Conservation Engineering (3 units)**

The design, water quality and climate change impacts of soil and water conservation systems. Topics include: urban storm water management (including LID) erosion control practices, subsurface and surface drainage systems and irrigation technologies.

**Course Component:** Lecture

**CVG 5311 Bridge Design (3 units)**

Design of highway bridges according to the Canadian Highway Bridge Design Code (CHBDC). Comparisons with other bridge codes (e.g., the American Code - AASHTO, the European, the New Zealand, and the British bridge codes). The topics covered include the following: main structural components of highway bridges; types of highway bridges; serviceability and ultimate limit state design requirements; design loads (dead loads, traffic loads, seismic loads, and wind loads); load combinations; code specifications for loading due to traffic (design lane, characteristics of design truck, positions of design truck on bridge, etc.); dynamic effects due to traffic loads; practical approaches specified in CHBDC for determining forces and deflections in structural members; principles of capacity design in highway bridges. This course is equivalent to CIVJ 5310 at Carleton University.

**Course Component:** Lecture

**CVG 5312 Durability of Concrete Structures (3 units)**

i) Properties of cementitious materials (constituents of concrete; hydration of cement; structure of hardened concrete; transport processes in concrete); ii) deterioration of concrete (built-in problems; construction defects; cracking; dimensional stability; alkali-aggregate reaction; sulphate attack; corrosion of reinforcing steel; freezing-thawing cycles); (iii) evaluation of concrete structures (inspection; in-situ testing; laboratory testing); (iv) repair and maintenance of concrete (repair materials; repair procedures and techniques; prevention, protection and maintenance); and, (v) durability design (philosophy; modelling of deterioration processes; service life prediction; life-cycle cost analysis.) This course is equivalent to CIVJ 5311 at Carleton University.

**Course Component:** Lecture

**CVG 5313 Seismic Analysis and Design of Concrete Structures (3 units)**

Review of seismic hazards in Canada, building code provisions for earthquake loads, uniform hazard spectra, linear elastic modal response spectrum analysis, linear elastic time history analysis, equivalent static force procedure, advanced state-of-the-art nonlinear modeling techniques including the finite element method and fiber modeling, emerging methods such as performance-based earthquake engineering and displacement-based design, ductility concepts, plastic hinge formulations, capacity design philosophy for seismic resistance, seismic analysis and design of common seismic force resisting systems including slender and squat shear walls, moment resisting frames, coupled shear walls, and coupling beams, shear wallmoment resisting frame interaction, and lessons learned from recent earthquakes. This course is equivalent to CIVJ 5312 at Carleton University.

**Course Component:** Lecture

**CVG 5314 Geotechnical Hazards (3 units)**

Understanding of assessment, prevention, and mitigation of geotechnical hazards, overview of natural and man-made geo-hazards; concepts of hazards, disasters, vulnerability and risks; geotechnical hazards induced by problem soils: fundamentals, assessment, and mitigation; landslide hazards and risk assessment: fundamentals, solutions (prevention, stabilization) for landslides and slope instability; monitoring of landslides and slope; mining geotechnical hazards: hazards related to surface mining geotechnical facilities; hazards related to underground mining geotechnical facilities.

**Course Component:** Lecture

**CVG 5320 Fire Behaviour of Materials (3 units)**

Fundamentals and scientific aspects of the behaviour of materials during fires and the fire hazards of materials. Topics to be covered include material specifications, thermal and mechanical properties, structural fire response, residual strength, failure criteria, mechanisms of flame retardancy, and standards and testing protocols. This course is equivalent to CIVE 5615 at Carleton University.

**Course Component:** Lecture

**CVG 5321 Finite Elements in Field Problems (3 units)**

Use of Galerkin and Ritz finite element formulation to solve one and two dimensional field problems, steady state and time-dependent phenomena involving potentials, heat transfer, fluid flow, diffusion, and dispersion with emphasis on practical applications. Courses EVG 7402 CVG 5321 cannot be combined for units. This course is equivalent to CIVE 5107 at Carleton University.

**Course Component:** Lecture

Prerequisite: Basic knowledge of third year-level undergraduate engineering mathematics. Courses EVG 7402, CVG 5321 cannot be combined for units.

**CVG 5333 Research Methodology (3 units)**

Key components and strategies required to build a robust scientific research program in civil engineering including research questions, literature review, experiment design, data interpretation, scientific manuscripts, public speaking, ethics, and plagiarism.

**Course Component:** Lecture

**CVG 5366 Master's Seminar in Civil Engineering**

Attendance and participation in the monthly seminar. All students must make one presentation and continue to attend throughout the program. Graded S (Satisfactory) / NS (Not satisfactory).

**Course Component:** Seminar

**CVG 6000 Projet en génie civil / Civil Engineering Report (6 crédits / 6 units)**

Ce cours est équivalent à CIVE 5900 à la Carleton University. / This course is equivalent to CIVE 5900 at Carleton University.

**Volet / Course Component:** Recherche / Research

**CVG 6108 Directed Studies I (3 units)**

Special courses set up for one student on an exceptional basis. Limited to one in the Master's level and to two total Master's plus PhD. This course is equivalent to CIVE 5906 at Carleton University.

**Course Component:** Research

Permission of the Department is required.

**CVG 6109 Directed Studies II (3 units)**

Special courses set up for one student on an exceptional basis. Limited to one in the Master's level and to two total Master's plus PhD. This course is equivalent to CIVE 5907 at Carleton University.

**Course Component:** Research

Permission of the Department is required.

**CVG 6301 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6001 at Carleton University.

**Course Component:** Lecture

**CVG 6303 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6003 at Carleton University.

**Course Component:** Lecture

**CVG 6304 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6004 at Carleton University.

**Course Component:** Lecture

**CVG 6305 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6005 at Carleton University.

**Course Component:** Lecture

**CVG 6306 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6006 at Carleton University.

**Course Component:** Lecture

**CVG 6307 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6007 at Carleton University.

**Course Component:** Lecture

**CVG 6308 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6008 at Carleton University.

**Course Component:** Lecture

**CVG 6309 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6009 at Carleton University.

**Course Component:** Lecture

**CVG 6310 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6010 at Carleton University.

**Course Component:** Lecture

**CVG 6311 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6011 at Carleton University.

**Course Component:** Lecture

**CVG 6312 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6012 at Carleton University.

**Course Component:** Lecture

**CVG 6313 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6013 at Carleton University.

**Course Component:** Lecture

**CVG 6314 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6014 at Carleton University.

**Course Component:** Lecture

**CVG 6315 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6015 at Carleton University.

**Course Component:** Lecture

**CVG 6316 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6016 at Carleton University.

**Course Component:** Lecture

**CVG 6317 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6017 at Carleton University.

**Course Component:** Lecture

**CVG 6318 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6018 at Carleton University.

**Course Component:** Lecture

**CVG 6319 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 6320 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVJ 6020 at Carleton University.

**Course Component:** Lecture

**CVG 6508 Études dirigées I (3 crédits)**

Cours individuels créés seulement pour les cas exceptionnels. Un étudiant peut en suivre un au niveau de la maîtrise ou un total de deux pour les études de maîtrise et de doctorat.

**Volet :** Cours magistral

**CVG 6509 Études dirigées II (3 crédits)**

Cours individuels créés seulement pour les cas exceptionnels. Un étudiant peut en suivre un au niveau de la maîtrise ou un total de deux pour les études de maîtrise et de doctorat.

**Volet :** Cours magistral

**CVG 7100 Case Studies in Geotechnical (3 units)**

This course is equivalent to CIVE 5209 at Carleton University.

**Course Component:** Lecture

**CVG 7101 Advanced Soil Mechanics I (3 units)**

This course is equivalent to CIVE 5300 at Carleton University.

**Course Component:** Lecture

**CVG 7102 Advanced Soil Mechanics II (3 units)**

**Course Component:** Lecture

**CVG 7103 Pavement and Materials (3 units)**

This course is equivalent to CIVE 5303 at Carleton University.

**Course Component:** Lecture

**CVG 7104 Earth Retaining Structures (3 units)**

This course is equivalent to CIVE 5500 at Carleton University.

**Course Component:** Lecture

**CVG 7105 Foundation Engineering (3 units)**

This course is equivalent to CIVE 5501 at Carleton University.

**Course Component:** Lecture

**CVG 7106 In Situ Meth in Geomechanics (3 units)**

This course is equivalent to CIVE 5502 at Carleton University.

**Course Component:** Lecture

**CVG 7107 Numerical Methods in Geomechanics (3 units)**

This course is equivalent to CIVE 5503 at Carleton University.

**Course Component:** Lecture

**CVG 7108 Seepage and Water Flow Through Soils (3 units)**

This course is equivalent to CIVE 5504 at Carleton University.

**Course Component:** Lecture

**CVG 7109 Geotechnical Earthquake Engineering (3 units)**

This course is equivalent to CIVE 5505 at Carleton University.

**Course Component:** Lecture

**CVG 7110 Road Safety Analysis (3 units)**

Fundamental analytical techniques for road safety analysis, background of traffic safety analysis, network screening, before and after analysis, and surrogate measures of safety. This course is equivalent to CIVE 5310 at Carleton University.

**Course Component:** Lecture

**CVG 7111 Advanced Building Characterization, Conservation and Rehabilitation (3 units)**

Supporting concepts and techniques for the identification, documentation, and conservation of heritage and existing buildings; advanced workshops by experts from key disciplines and practice areas in heritage conservation. Includes: Experiential Learning Activity. This course is equivalent to CIVE 5603 at Carleton University

**Course Component:** Laboratory, Lecture

**CVG 7112 Wood structures and fire (3 units)**

Introduction to fire-safe design of wood buildings, brief review of wood products and wood design, prescriptive code requirements, determination of fire-resistance of wood structures through different methods. Includes: Experiential Learning Activity. This course is equivalent to CIVE 5616 at Carleton University.

**Course Component:** Laboratory, Lecture

**CVG 7113 Practical applications in fire protection (3 units)**

Introduction to the practical application of fire protection engineering from a consulting and a regulatory perspective. Main highlights include performance-based design, fire forensics, emergency preparedness and firefighting. This course is equivalent to CIVE 5617 at Carleton University.

**Course Component:** Lecture

**CVG 7114 Probability, Statistics, Stochastic Processes and Statistical Inference in Engineering (3 units)**

Fundamental of probability and statistics, (robust and ridge) regression, generalized linear models, sparse models, mixture models, stochastic processes, statistical inference and applications. Includes: Experiential Learning Activity. This course is equivalent to CIVE 5604 at Carleton University.

**Course Component:** Laboratory, Lecture

**CVG 7115 Structural Assessment of Historic Buildings (3 units)**

General concepts related to conservation of heritage structures; materials, construction techniques and structural components; classical structural analysis approaches; seismic behaviour, damage and collapse mechanisms of historic buildings; modern conservation criteria and practical implementation of repair or strengthening strategies. This course is equivalent to CIVE 5202 at Carleton University.

**Course Component:** Lecture

**CVG 7116 Fundamentals of Geomechanics (3 units)**

Tensor calculus, Cauchy stress, kinematics of continuum deformation (strain), elasticity for geomaterials, plasticity for geomaterials, constitutive models for soils, Cam-clay model. This course is equivalent to CIVE 5801 at Carleton University.

**Course Component:** Lecture

**CVG 7120 Introductory Elasticity (3 units)**

This course is equivalent to CIVE 5101 at Carleton University.

**Course Component:** Lecture

**CVG 7121 Advanced Elasticity (3 units)**

This course is equivalent to CIVE 5102 at Carleton University.

**Course Component:** Lecture

**CVG 7122 Finite Element Methods Stress Analysis (3 units)**

This course is equivalent to CIVE 5103 at Carleton University.

**Course Component:** Lecture

**CVG 7123 Earthquake Analysis and Design of Structures (3 units)**

This course is equivalent to CIVE 5104 at Carleton University.

**Course Component:** Lecture

**CVG 7124 Advanced Finite Element Analysis in Structural Mechanics (3 units)**

This course is equivalent to CIVE 5105 at Carleton University.

**Course Component:** Lecture

**CVG 7125 Theory of Structural Stability (3 units)**

This course is equivalent to CIVE 5203 at Carleton University.

**Course Component:** Lecture

**CVG 7126 Behaviour of Steel Structure (3 units)**

This course is equivalent to CIVE 5204 at Carleton University.

**Course Component:** Lecture

**CVG 7127 Analysis of Elastic Structures (3 units)**

This course is equivalent to CIVE 5205 at Carleton University.

**Course Component:** Lecture

**CVG 7128 Prestressed Concrete (3 units)**

This course is equivalent to CIVE 5206 at Carleton University.

**Course Component:** Lecture

**CVG 7129 Advanced Structural Design (3 units)**

**Course Component:** Lecture

**CVG 7130 Advanced Reinforced Concrete (3 units)**

This course is equivalent to CIVE 5208 at Carleton University.

**Course Component:** Lecture

**CVG 7131 Project Management (3 units)**

This course is equivalent to CIVE 5600 at Carleton University.

**Course Component:** Lecture

**CVG 7132 Computer-Aided Design of Building Structures (3 units)**

**Course Component:** Lecture

**CVG 7137 Dynamics of Structures (3 units)**

This course is equivalent to CIVE 5106 at Carleton University.

**Course Component:** Lecture

**CVG 7138 Engineered Masonry Behaviour and Design (3 units)**

This course is equivalent to CIVE 5200 at Carleton University.

**Course Component:** Lecture

**CVG 7139 Behaviour and Design of Steel Structures (3 units)**

**Course Component:** Lecture

**CVG 7140 Statistics, Probabilities and Decision-Making (3 units)**

This course is equivalent to CIVE 5601 at Carleton University.

**Course Component:** Lecture

**CVG 7141 Advanced Methods in Computer-Aided Design (3 units)**

This course is equivalent to CIVE 5602 at Carleton University.

**Course Component:** Lecture

**CVG 7142 Engineering Management (3 units)**

**Course Component:** Lecture

**CVG 7143 Design of Steel Bridges (3 units)**

This course is equivalent to CIVE 5605 at Carleton University.

**Course Component:** Lecture

**CVG 7144 Design of Concrete Bridges (3 units)**

This course is equivalent to CIVE 5606 at Carleton University.

**Course Component:** Lecture

**CVG 7145 Introduction to Bridge Design (3 units)**

This course is equivalent to CIVE 5607 at Carleton University.

**Course Component:** Lecture

**CVG 7150 Intercity Transportation, Planning and Management (3 units)**

This course is equivalent to CIVE 5304 at Carleton University.

**Course Component:** Lecture

**CVG 7151 Traffic Engineering (3 units)**

This course is equivalent to CIVE 5305 at Carleton University.

**Course Component:** Lecture

**CVG 7152 Highway Materials (3 units)**

This course is equivalent to CIVE 5306 at Carleton University.

**Course Component:** Lecture

**CVG 7153 Urban Transportation and Management (3 units)**

This course is equivalent to CIVE 5307 at Carleton University.

**Course Component:** Lecture

**CVG 7154 Geometric Design (3 units)**

This course is equivalent to CIVE 5308 at Carleton University.

**Course Component:** Lecture

**CVG 7155 Intercity Transportation Supply (3 units)**

This course is equivalent to CIVE 5309 at Carleton University.

**Course Component:** Lecture

**CVG 7156 Transportation Economics and Policy (3 units)**

This course is equivalent to CIVE 5401 at Carleton University.

**Course Component:** Lecture

**CVG 7158 Airport Planning (3 units)**

This course is equivalent to CIVE 5403 at Carleton University.

**Course Component:** Lecture

**CVG 7159 Transportation Terminal (3 units)**

This course is equivalent to CIVE 5402 at Carleton University.

**Course Component:** Lecture

**CVG 7160 Biofilm Processes in Waste-Water Treatment (3 units)**

This course is equivalent to ENVE 5001 at Carleton University.

**Course Component:** Lecture

**CVG 7163 Case Studies in Hydrogeology (3 units)**

This course is equivalent to ENVE 5302 at Carleton University.

**Course Component:** Lecture

**CVG 7164 Multiphase Flow and Contaminant Transport Modelling (3 units)**

**Course Component:** Lecture

**CVG 7170 Fundamentals of Fire Safety Engineering (3 units)**

This course is equivalent to CIVE 5609 at Carleton University.

**Course Component:** Lecture

**CVG 7171 Fire Dynamics I (3 units)**

This course is equivalent to CIVE 5610 at Carleton University.

**Course Component:** Lecture

**CVG 7172 Fire Dynamics II (3 units)**

This course is equivalent to CIVE 5613 at Carleton University.

**Course Component:** Lecture

**CVG 7173 People in Fires (3 units)**

This course is equivalent to CIVE 5611 at Carleton University.

**Course Component:** Lecture

**CVG 7174 Fire Modelling (3 units)**

This course is equivalent to CIVE 5612 at Carleton University.

**Course Component:** Lecture

**CVG 7175 Design for Fire Resistance (3 units)**

This course is equivalent to CIVE 5614 at Carleton University.

**Course Component:** Lecture

**CVG 7181 Nonlinear Analysis and Design of Advanced Earthquake-Resistant Structures (3 units)**

Nonlinear Analysis and Design of Advanced Earthquake-Resistant Structures. Design and construction of nonlinear structural models. Accounting for mass, material behavior, damping, and nonlinear geometry. Use of pushover and time history analysis methods. Design and modelling of structural systems using passive damping devices and isolation systems.

**Course Component:** Lecture

**CVG 7182 Introduction to Infrastructure Management (3 units)**

Infrastructure management and its relationship to facility and asset management; challenges facing infrastructure managers; tools for effective IM; concept of total quality management; economic analysis of maintenance, rehabilitation and reconstruction; use of life cycle cost analysis in decision making, development and use of IM systems.

**Course Component:** Lecture

**CVG 7183 Seepage Through Soils (3 units)**

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.

**Course Component:** Lecture

**CVG 7184 Blast Load Effects on Structures (3 units)**

Threats, risk analysis, vulnerability assessment; explosives: types and mechanisms; load determination; response of structural elements under blast loads, analysis and design for blast loads; blast mitigation, retrofit of structures; post-event assessment.

**Course Component:** Lecture

**CVG 7185 Topics in Fire Safety (3 units)**

Courses in special topics related to fire safety, not covered by other graduate courses.

**Course Component:** Lecture

**CVG 7300 Special Topics in Civil Engineering (3 units)**

This course is equivalent to CIVE 5705 at Carleton University.

**Course Component:** Laboratory, Lecture

**CVG 7301 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7302 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7303 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7304 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7305 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7306 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7307 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7308 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7309 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7310 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7311 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7312 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7313 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7314 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7315 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7316 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7317 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7318 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7319 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 7320 Special Topics in Civil Engineering (3 units)**

**Course Component:** Lecture

**CVG 8366 Doctoral Seminar in Civil Engineering**

Attendance and participation in the monthly seminar. All students must make one presentation and continue to attend throughout the program. Graded S (Satisfactory) / NS (Not satisfactory).

**Course Component:** Seminar

**CVG 9998 Examen général de doctorat / Comprehensive Examination (Phd)**

Ce cours est équivalent à CIVE 6902 à la Carleton University. / This course is equivalent to CIVE 6902 at Carleton University.

**Volet / Course Component:** Recherche / Research