Civil Engineering

This section presents the requirements for programs in:

- **M.A.Sc. Civil Engineering**
- **M. Eng. Civil Engineering**
- **Ph.D. Civil Engineering**

Program Requirements

Study at the master's level can be pursued through either a thesis leading to a M.A.Sc., a project option leading to a M.Eng., or a course work option leading to a M.Eng. Requirements are stated in terms of Carleton University credits.

M.A.Sc. Civil Engineering (5.0 credits)

Requirements - Master's degree by thesis (5.0 credits)

1. 2.5 credits in courses	2.5
2. 2.5 credits in:	2.5
CIVE 5909 [2.5] M.A.Sc. Thesis	
3. Participation in the graduate student seminar series:	
CIVE 5901 [0.0] Master's Seminar	
4. Successful oral defence of the thesis	
Total Credits	5.0

M. Eng. Civil Engineering (5.0 credits)

Requirements - Master's degree by project (5.0 credits)

1. 4.0 credits in courses	4.0
2. 1.0 credit in:	1.0
CIVE 5900 [1.0] Civil Engineering Project	
Total Credits	5.0

Requirements - Master's degree by course work (5.0 credits)

1. 5.0 credits in courses	5.0

Ph.D. Civil Engineering (10.0 credits)

Requirements are stated in terms of Carleton University credits.

Requirements:

1. 2.0 credits in courses	2.0
2. Participation in the graduate student seminar series:	0.0
CIVE 6901 [0.0] Ph.D. Seminar	
3. Successful completion of written and oral comprehensive examinations in subject areas determined by the student's advisory committee:	0.0
CIVE 6902 [0.0] Ph.D. Comprehensive Examination	
4. Successful completion of a thesis proposal examination	0.0
5. 8.0 credits in:	8.0
CIVE 6909 [8.0] Ph.D. Thesis	
6. Successful oral defence of the thesis. The examination board for all theses will include an external examiner, and, when possible, professors from both departments.	0.0
Total Credits	10.0

Note

- Subject to approval of his/her advisory committee, a Ph.D. student may take, or be required to take, courses in other disciplines.

Graduate Courses

In all programs, the student may choose graduate courses from either university with the approval of the adviser or the advisory committee. Graduate courses are listed below, grouped by subject area. Course descriptions may be found in the departmental section of the calendar concerned. All courses are of one term duration. The codes given in parentheses are those used by the University of Ottawa. Courses beginning with "CIVE" and 'ENVE' are offered at Carleton University and those beginning with "CIVJ" and 'ENVJ' are offered at the University of Ottawa. Not all courses listed are necessarily given during one academic year. Courses taken outside the Institute will not count towards the degree requirements unless approved by the adviser or the advisory committee and the program's Associate Chair (graduate affairs). In all programs, at least one half of the course work must be taken from the Institute.

Geotechnical Engineering

Geotechnical Engineering

CIVE 5209 (CVG 7100)	Geotechnical Case Studies
CIVE 5300 (CVG 7101)	Advanced Soil Mechanics
CIVE 5500 (CVG 7104)	Earth Retaining Structures
CIVE 5501 (CVG 7105)	Advanced Foundation Engineering
CIVE 5502 (CVG 7106)	In-Situ Geotechnique
CIVE 5503 (CVG 7107)	Numerical Methods in Geomechanics
CIVE 5505 (CVG 7109)	Geotechnical Earthquake Engineering
CIVE 5800 (CVG 7305)	Topics in Geotechnique
CIVE 5801 (CVG 7306)	Topics in Geotechnique
CIVE 5802 (CVG 7307)	Topics in Geotechnique
CIVE 5803 (CVG 7308)	Topics in Geotechnique
CIVE 5804 (CVG 7309)	Topics in Geotechnique
CIVJ 5000 (CVG 5100)	Deep Foundations
CIVJ 5006 (CVG 5106)	Site Improvements
CIVJ 5008 (CVG 5108)	Pile Dynamics
CIVJ 5105 (CVG 5175)	Numerical Methods for Geotechnical Engineering
CIVJ 5106 (CVG 5161)	Mechanics of Unsaturated Soils
CIVJ 5107 (CVG 5177)	Offshore Geotechnique
CIVJ 5108 (CVG 5178)	Ice Mechanics
CIVJ 5109 (CVG 5109)	Geotechnical Hazards

Structural Engineering

Course	Title
CIVE 5101 (CVG 7120)	Solid Mechanics
CIVE 5102 (CVG 7121)	Advanced Elasticity
CIVE 5103 (CVG 7122)	Finite Element Analysis 1
CIVE 5104 (CVG 7123)	Earthquake Engineering and Analysis
CIVE 5105 (CVG 7124)	Finite Element Analysis 2
CIVE 5106 (CVG 7137)	Dynamics of Structures
CIVE 5107 (CVG 5321)	Finite Elements in Field Problems
CIVE 5108	Nonlinear Analysis and Design of Advanced Earthquake-Resistant Structures
CIVE 5200 (CVG 7138)	Masonry Behaviour and Design
CIVE 5203 (CVG 7125)	Theory of Structural Stability
CIVE 5204 (CVG 7126)	Advanced Steel Structures
CIVE 5205 (CVG 7127)	Advanced Structural Analysis
CIVE 5206 (CVG 7128)	Prestressed Concrete
CIVE 5208 (CVG 7130)	Advanced Reinforced Concrete
CIVE 5507	Blast Load Effects on Structures
CIVE 5600 (CVG 7131)	Project Management
CIVE 5601 (CVG 7140)	Engineering, Statistics, and Probabilities
CIVE 5602 (CVG 7141)	Advanced Computer-Aided Design
CIVE 5605 (CVG 7143)	Design of Steel Bridges
CIVE 5606 (CVG 7144)	Design of Concrete Bridges
CIVE 5607 (CVG 7145)	Introduction to Bridge Design
CIVE 5705 (CVG 7300)	Topics in Structures
CIVE 5706 (CVG 7301)	Topics in Structures
CIVE 5707 (CVG 7302)	Topics in Structures
CIVE 5708 (CVG 7303)	Topics in Structures
CIVE 5709 (CVG 7304)	Topics in Structures
CIVJ 5201 (CVG 5142)	Advanced Structural Dynamics
CIVJ 5202 (CVG 5143)	Advanced Structural Steel Design
CIVJ 5300 (CVG 5144)	Advanced Reinforced Concrete Design
CIVJ 5203 (CVG 5145)	Theory of Elasticity
CIVJ 5302 (CVG 5146)	Numerical Methods of Structural Analysis
CIVJ 5204 (CVG 5147)	Theory of Plates and Shells
CIVJ 5305 (CVG 5148)	Prestressed Concrete Design
CIVJ 5304 (CVG 5149)	Structural Stability
CIVJ 5206 (CVG 5150)	Advanced Concrete Technology
CIVJ 5209 (CVG 5153)	Wind Engineering
CIVJ 5306 (CVG 5155)	Earthquake Engineering
CIVJ 5301 (CVG 5156)	Finite Element Methods I
CIVJ 5303 (CVG 5157)	Finite Element Methods II
CIVJ 5307 (CVG 5158)	Elements of Bridge Engineering
CIVJ 5308 (CVG 5154)	Random Vibrations
CIVJ 5309 (CVG 5159)	Long Span Structures
CIVJ 5310 (CVG 5311)	Bridge Design
CIVJ 5311 (CVG 5312)	Durability of Concrete Structures
CIVJ 5312 (CVG 5313)	Seismic Analysis and Design of Concrete Structures

Fire Safety Engineering

Course	Title
CIVE 5609 (CVG 7170)	Fundamentals of Fire Safety Engineering
CIVE 5610 (CVG 7171)	Fire Dynamics I
CIVE 5611 (CVG 7173)	People in Fires
CIVE 5612 (CVG 7174)	Fire Modeling
CIVE 5613 (CVG 7172)	Fire Dynamics II
CIVE 5614 (CVG 7175)	Design for Fire Resistance
CIVE 5615 (CVG 5320)	Fire Behaviour of Materials
CIVE 5810	Topics in Fire Safety

Transportation Engineering

Course	Title
CIVE 5303 (CVG 7103)	Pavements and Materials
CIVE 5304 (CVG 7150)	Intercity Transportation
CIVE 5305 (CVG 7151)	Traffic Engineering
CIVE 5306 (CVG 7152)	Highway Materials
CIVE 5307 (CVG 7153)	Urban Transportation
CIVE 5308 (CVG 7154)	Highway Geometric Design

CIVE 5309 (CVG 7155)	Transportation Supply
CIVE 5401 (CVG 7156)	Transportation Economics
CIVE 5402 (CVG 7159)	Transportation Terminals
CIVE 5403 (CVG 7158)	Airport Planning
CIVE 5404	Introduction to Infrastructure Management
CIVE 5805 (CVG 7310)	Topics in Transportation
CIVE 5806 (CVG 7311)	Topics in Transportation
CIVE 5807 (CVG 7312)	Topics in Transportation
CIVE 5808 (CVG 7313)	Topics in Transportation
CIVE 5809 (CVG 7314)	Topics in Transportation

Water Resources Engineering

CIVJ 5501 (CVG 5111)	Hydraulic Structures
CIVJ 5502 (CVG 5112)	Computational Hydrodynamics
CIVJ 5803 (CVG 5119)	Computational Hydraulics
CIVJ 5506 (CVG 5120)	Water Resources Systems
CIVJ 5509 (CVG 5123)	Advanced Topics in Hydrology
CIVJ 5605 (CVG 5124)	Coastal Engineering
CIVJ 5601 (CVG 5125)	Statistical Methods in Hydrology
CIVJ 5602 (CVG 5126)	Stochastic Hydrology
CIVJ 5603 (CVG 5127)	Hydrologic Systems Analysis
CIVJ 5604 (CVG 5128)	Water Resources Planning and Policy
CIVJ 5606 (CVG 5131)	River Engineering
CIVJ 5503 (CVG 5160)	Sediment Transport
CIVJ 5504 (CVG 5162)	River Hydraulics

Environmental Engineering

Environmental Engineering

ENVE 5001 (CVG 7160)	Biofilm Processes
ENVE 5003 (EVG 7143)	Advanced Ultraviolet Processes
ENVE 5004 (EVG 7144)	Advanced Wastewater Treatment
ENVE 5101 (EVG 5101)	Air Pollution Control
ENVE 5102 (CVG 7161)	Traffic-Related Air Pollution

ENVE 5103 (CVG 7162)	Air Quality Modeling
ENVE 5104 (EVG 7104)	Indoor Environmental Quality
ENVE 5105 (EVG 7105)	Atmospheric Aerosols
ENVE 5106 (EVG 7106)	Atmospheric Chemical Transport Modelling
ENVE 5201 (EVG 7201)	Geo-Environmental Engineering
ENVE 5203 (EVG 5203)	Hazardous and Radioactive Wastes
ENVE 5204 (EVG 7134)	Resource Industry Waste Management
ENVE 5205 (EVG 7132)	Sludge Treatment and Disposal
ENVE 5301 (EVG 7301)	Contaminant Hydrogeology
ENVE 5302 (CVG 7163)	Case Studies in Hydrogeology
ENVE 5303 (EVG 7303)	Multiphase Flow in Soils
ENVE 5401 (EVG 7401)	Environmental Impacts of Major Projects
ENVE 5402 (EVG 7402)	Finite Elements in Field Problems
ENVE 5701 (EVG 6301)	Topics in Environmental Engineering
ENVE 5702 (EVG 6302)	Topics in Environmental Engineering
ENVE 5703 (EVG 6303)	Topics in Environmental Engineering
ENVE 5704 (EVG 6304)	Topics in Environmental Engineering
ENVE 5705 (EVG 6305)	Topics in Environmental Engineering
ENVJ 5101 (CHG 4301)	Air Pollution Control Process
ENVJ 5700 (CVG 5139)	Environmental Assessment of Civil Engineering Projects
ENVJ 5900 (CVG 5130)	Wastewater Treatment Process Design
ENVJ 5901 (CVG 5132)	Unit Operations of Water Treatment
ENVJ 5902 (CVG 5138)	Advanced Water Treatment
ENVJ 5903 (CVG 5331)	Sludge Utilization and Disposal
ENVJ 5905 (CVG 5137)	Water and Wastewater Treatment Process Analysis
ENVJ 5906 (CVG 5133)	Solid Waste Disposal
ENVJ 5907 (CVG 5134)	Chemical Analysis for Environmental Engineering
ENVJ 5908 (CVG 5179)	Anaerobic Digestion
ENVJ 5909 (CVG 5180)	Biological Nutrient Removal
ENVJ 5911 (CVG 5232)	Unit Operations of Water Treatment Lab

ENVJ 5912 (CVG 5238)	Advanced Water Treatment Processes Lab

Studies and Seminars

CIVE 5901 (CVG 7314)	Master's Seminar
CIVE 5906 (CVG 6108)	Directed Studies 1
CIVE 6906 (CVG 6109)	Directed Studies 2
CIVJ 6000 (CVG 6300)	Special Topics in Civil Engineering
CIVJ 6001 (CVG 6301)	Special Topics in Civil Engineering
CIVJ 6002 (CVG 6302)	Special Topics in Civil Engineering
CIVJ 6003 (CVG 6303)	Special Topics in Civil Engineering
CIVJ 6004 (CVG 6304)	Special Topics in Civil Engineering
CIVJ 6005 (CVG 6305)	Special Topics in Civil Engineering
CIVJ 6006 (CVG 6306)	Special Topics in Civil Engineering
CIVJ 6007 (CVG 6307)	Special Topics in Civil Engineering
CIVJ 6008 (CVG 6308)	Special Topics in Civil Engineering
CIVJ 6009 (CVG 6309)	Special Topics in Civil Engineering
CIVJ 6010 (CVG 6310)	Special Topics in Civil Engineering
CIVJ 6011 (CVG 6311)	Special Topics in Civil Engineering
CIVJ 6012 (CVG 6312)	Special Topics in Civil Engineering
CIVJ 6013 (CVG 6313)	Special Topics in Civil Engineering
CIVJ 6014 (CVG 6314)	Special Topics in Civil Engineering
CIVJ 6015 (CVG 6315)	Special Topics in Civil Engineering
CIVJ 6016 (CVG 6316)	Special Topics in Civil Engineering
CIVJ 6017 (CVG 6317)	Special Topics in Civil Engineering
CIVJ 6018 (CVG 6318)	Special Topics in Civil Engineering
CIVJ 6019 (CVG 6019)	Special Topics in Civil Engineering
CIVJ 6020 (CVG 6320)	Special Topics in Civil Engineering
CIVE 6901	Ph.D. Seminar

Projects and Theses

CIVE 5900 (CVG 6000)	Civil Engineering Project
CIVE 5909 (CVG 5909)	M.A.Sc. Thesis
CIVE 6902 (CVG 9998)	Ph.D. Comprehensive Examination
CIVE 6909 (CVG 9999)	Ph.D. Thesis

Admission

The normal requirement for admission to a master's program is a bachelor's degree with at least high honours standing in civil engineering.

1. Graduates from engineering programs other than civil engineering, or Honours science programs with a mathematics content equivalent to the civil engineering program will have to take a minimum of four qualifying undergraduate civil engineering courses in their area of graduate specialty.
2. Graduates from other science programs will have to take all the core engineering undergraduate mathematics courses in addition to the requirements specified in (1) above.

The undergraduate courses required will be specified in the Certificate of Admission.

Undergraduate civil engineering courses will not be accepted towards a graduate degree. Graduate students may still be required to take undergraduate courses for credit to fulfil the admission requirements.

No more than one half of the program credit requirements or that stipulated in the regulations of the university in which the student is registered, whichever is less, can be transferred at admission.

Accelerated Pathway

The accelerated pathway in Civil Engineering is a flexible and individualized plan of graduate study. Students in the final year of Bachelor of Engineering in Civil, Environmental, or Architectural Conservation and Sustainability Engineering with demonstrated excellent aptitude for graduate studies and research may qualify for this option.

Students with a CGPA of 10.0 or higher, going into their final year of undergraduate study, and intending to apply to a Master's degree in Civil Engineering in the following academic year should consult with both the Undergraduate and Graduate Associate Chairs to determine if the accelerated pathway is appropriate for them and to confirm their selection of courses.

Upon approval for the accelerated pathway, students will replace a maximum of 1.0 credit of their engineering electives with 5000 level CIVE or ENVE courses. Students will receive advanced standing for the approved 5000 level courses in which they receive a grade of A- or higher.

Admission

The normal requirement for admission into the Ph.D. program is a master's degree with thesis in civil engineering. Students who have been admitted to a master's program may be permitted to transfer into the Ph.D. program if they demonstrate:

1. outstanding academic performance by completing at least 2.5 credits of course work with a CGPA of A- of higher, and

2. significant promise for advanced research and the ability to defend their Ph.D. proposal in the first year of their Ph.D. program.

Regulations

See the General Regulations section of this Calendar.

Civil Engineering - Joint (CIVJ) Courses

CIVJ 5000 [0.5 credit] (CVG 5100)
Deep Foundations

CIVJ 5003 [0.5 credit]
Dam Engineering

CIVJ 5005 [0.5 credit]
Adsorption Separation Process

CIVJ 5006 [0.5 credit] (CVG 5106)
Site Improvements

CIVJ 5008 [0.5 credit] (CVG 5108)
Pile Dynamics

CIVJ 5102 [0.5 credit]
Behaviour of Soil and Rock

CIVJ 5104 [0.5 credit]
Soil Plasticity

CIVJ 5105 [0.5 credit] (CVG 5175)
Numerical Methods for Geotechnical Engineering

CIVJ 5106 [0.5 credit] (CVG 5161)
Mechanics of Unsaturated Soils

CIVJ 5107 [0.5 credit] (CVG 5177)
Offshore Geotechnique

CIVJ 5108 [0.5 credit] (CVG 5178)
Ice Mechanics

CIVJ 5109 [0.5 credit] (CVG 5109)
Geotechnical Hazards

CIVJ 5201 [0.5 credit] (CVG 5142)
Advanced Structural Dynamics

CIVJ 5202 [0.5 credit] (CVG 5143)
Advanced Structural Steel Design

CIVJ 5203 [0.5 credit] (CVG 5145)
Theory of Elasticity

CIVJ 5204 [0.5 credit] (CVG 5147)
Theory of Plates and Shells

CIVJ 5206 [0.5 credit] (CVG 5150)
Advanced Concrete Technology

CIVJ 5209 [0.5 credit] (CVG 5153)
Wind Engineering

CIVJ 5300 [0.5 credit] (CVG 5144)
Advanced Reinforced Concrete Design

CIVJ 5301 [0.5 credit] (CVG 5156)
Finite Element Methods I

CIVJ 5302 [0.5 credit] (CVG 5146)
Numerical Methods of Structural Analysis

CIVJ 5303 [0.5 credit] (CVG 5157)
Finite Element Methods II

CIVJ 5304 [0.5 credit] (CVG 5149)
Structural Stability

CIVJ 5305 [0.5 credit] (CVG 5148)
Prestressed Concrete Design

CIVJ 5306 [0.5 credit] (CVG 5155)
Earthquake Engineering

CIVJ 5307 [0.5 credit] (CVG 5158)
Elements of Bridge Engineering

CIVJ 5308 [0.5 credit] (CVG 5154)
Random Vibrations

CIVJ 5309 [0.5 credit] (CVG 5159)
Long Span Structures
Includes: Experiential Learning Activity

CIVJ 5310 [0.5 credit] (CVG 5311)
Bridge Design

CIVJ 5311 [0.5 credit] (CVG 5312)
Durability of Concrete Structures

CIVJ 5312 [0.5 credit] (CVG 5313)
Seismic Analysis and Design of Concrete Structures
Includes: Experiential Learning Activity

CIVJ 5500 [0.5 credit]
Deep Foundations

CIVJ 5501 [0.5 credit] (CVG 5111)
Hydraulic Structures

CIVJ 5502 [0.5 credit] (CVG 5112)
Computational Hydrodynamics

CIVJ 5503 [0.5 credit] (CVG 5160)
Sediment Transport

CIVJ 5504 [0.5 credit] (CVG 5162)
River Hydraulics

CIVJ 5506 [0.5 credit] (CVG 5120)
Water Resources Systems
Includes: Experiential Learning Activity

CIVJ 5508 [0.5 credit]
Groundwater and Seepage

CIVJ 5509 [0.5 credit] (CVG 5123)
Advanced Topics in Hydrology

CIVJ 5601 [0.5 credit] (CVG 5125)
Statistical Methods in Hydrology

CIVJ 5602 [0.5 credit] (CVG 5126)
Stochastic Hydrology

CIVJ 5603 [0.5 credit] (CVG 5127)
Hydrologic Systems Analysis

CIVJ 5604 [0.5 credit] (CVG 5128)
Water Resources Planning and Policy

CIVJ 5605 [0.5 credit] (CVG 5124)
Coastal Engineering

CIVJ 5606 [0.5 credit] (CVG 5131)
River Engineering

CIVJ 5607 [0.5 credit]
Irrigation and Drainage

CIVJ 5803 [0.5 credit] (CVG 5119)
Computational Hydraulics

CIVJ 5901 [0.5 credit]
Unit Op of Water Treatment

CIVJ 5904 [0.5 credit]
Water and Wastewater Labs

CIVJ 5905 [0.5 credit]
Water and Wastewater Proc

CIVJ 5906 [0.5 credit]
Solid Waste Disposal

CIVJ 5907 [0.5 credit]
Chemistry of Enviro Engin

CIVJ 6000 [0.5 credit] (CVG 6300)
Special Topics in Civil Engineering

CIVJ 6001 [0.5 credit] (CVG 6301)
Special Topics in Civil Engineering

CIVJ 6002 [0.5 credit] (CVG 6302)
Special Topics in Civil Engineering

CIVJ 6003 [0.5 credit] (CVG 6303)
Special Topics in Civil Engineering

CIVJ 6004 [0.5 credit] (CVG 6304)
Special Topics in Civil Engineering

CIVJ 6005 [0.5 credit] (CVG 6305)
Special Topics in Civil Engineering

CIVJ 6006 [0.5 credit] (CVG 6306)
Special Topics in Civil Engineering

CIVJ 6007 [0.5 credit] (CVG 6307)
Special Topics in Civil Engineering

CIVJ 6008 [0.5 credit] (CVG 6308)
Special Topics in Civil Engineering

CIVJ 6009 [0.5 credit] (CVG 6309)
Special Topics in Civil Engineering

CIVJ 6010 [0.5 credit] (CVG 6310)
Special Topics in Civil Engineering

CIVJ 6011 [0.5 credit] (CVG 6311)
Special Topics in Civil Engineering

CIVJ 6012 [0.5 credit] (CVG 6312)
Special Topics in Civil Engineering

CIVJ 6013 [0.5 credit] (CVG 6313)
Special Topics in Civil Engineering

CIVJ 6014 [0.5 credit] (CVG 6314)
Special Topics in Civil Engineering

CIVJ 6015 [0.5 credit] (CVG 6315)
Special Topics in Civil Engineering

CIVJ 6016 [0.5 credit] (CVG 6316)
Special Topics in Civil Engineering

CIVJ 6017 [0.5 credit] (CVG 6317)
Special Topics in Civil Engineering

CIVJ 6018 [0.5 credit] (CVG 6318)
Special Topics in Civil Engineering

CIVJ 6019 [0.5 credit] (CVG 6019)
Special Topics in Civil Engineering

CIVJ 6020 [0.5 credit] (CVG 6320)
Special Topics in Civil Engineering

Civil Engineering (CIVE) Courses

CIVE 5101 [0.5 credit] (CVG 7120)
Solid Mechanics
Cartesion tensor notation; stresses and strains in a continuum; transformations, invariants; equations of motion; constitutive relations; generalized Hooke's Law, bounds for elastic constant: strain energy, superposition, uniqueness; formulation of plane stress and plane strain problems; energy principles, variational methods; plasticity.

CIVE 5102 [0.5 credit] (CVG 7121)
Advanced Elasticity
Continuation of topics introduced in CIVE 5101. Complex variable solutions: torsional and thermal stresses; axially symmetric three-dimensional problems, Love's strain potential, Boussinesq-Galerkian stress functions; problems related to infinite and semi-infinite domains. Introduction to numerical methods of stress analysis, comparison of solutions.
Prerequisite(s): CIVE 5101 or permission of the Department.

CIVE 5103 [0.5 credit] (CVG 7122)
Finite Element Analysis 1
Advanced finite element methods for linear systems. The relationship with variational and Galerkin formulations, system of linear equations, polynomial interpolation, numerical integration, and theory of elasticity is explored. Isoparametric formulations for structural and continuum elements are examined. Introduction to linear dynamics and nonlinear problems.

CIVE 5104 [0.5 credit] (CVG 7123)
Earthquake Engineering and Analysis
Advanced vibration analysis techniques; Rayleigh-Ritz procedure; subspace iteration; derived Ritz coordinates; proportional and non-proportional damping; introduction to seismology; earthquake response analysis via time and frequency domain; response spectrum approach; multiple input excitations; design considerations and code requirements; other advanced topics in earthquake engineering.
Prerequisite(s): CIVE 5106 or permission of the Department.

CIVE 5105 [0.5 credit] (CVG 7124)
Finite Element Analysis 2
Variational and Galerkin formulations: assumed displacement, assumed stress and hybrid elements; plate bending: convergence, completeness and conformity, patch test, Kirchhoff and Mindlin plate theories, nonlinear elasticity and plasticity; geometric non-linearity, Eulerian and Lagrangian formulations; incremental and iterative schemes, finite elements in dynamics.
Prerequisite(s): CIVE 5103 or permission of the Department.

CIVE 5106 [0.5 credit] (CVG 7137)
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.

CIVE 5107 [0.5 credit] (CVG 5321)
Finite Elements in Field Problems
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. Basic knowledge of third year-level undergraduate engineering mathematics/physics required.
Also listed as ENVE 5402.

CIVE 5108 [0.5 credit]
Nonlinear Analysis and Design of Advanced Earthquake-Resistant Structures
Design and construction of nonlinear structural models. Accounting for mass, material behaviour, 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.

CIVE 5200 [0.5 credit] (CVG 7138)
Masonry Behaviour and Design
Properties of masonry materials and assemblages. Behaviour 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 on a practice-oriented approach.
Also offered at the undergraduate level, with different requirements, as CIVE 4403, for which additional credit is precluded.

CIVE 5203 [0.5 credit] (CVG 7125)
Theory of Structural Stability
Elastic and inelastic behaviour 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(s): CIVE 5205 or equivalent.

CIVE 5204 [0.5 credit] (CVG 7126)
Advanced Steel Structures
Limit states design philosophy; material behaviour; tension members; plate buckling; torsion; lateral torsional buckling; beams, axially loaded columns and beam-column behaviour; brittle fracture and fatigue; frame stability and second order effects.

CIVE 5205 [0.5 credit] (CVG 7127)
Advanced Structural Analysis
Matrix structural analysis; force and displacement method of analysis for planar and space structures; symmetric and anti-symmetric structures; analysis of nonlinear structures: geometric and material nonlinearities; large displacement theory and iteration strategy.

CIVE 5206 [0.5 credit] (CVG 7128)
Prestressed Concrete
Behaviour and analysis of prestressed concrete elements subjected to axial loads, flexure and shear: material properties; prestressing systems; linear and non-linear behaviour; deflections; compression-field approaches; disturbed regions; restraint of deformations; design requirements; applications to pressure vessels, bridges and frames.

CIVE 5208 [0.5 credit] (CVG 7130)
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.

CIVE 5209 [0.5 credit] (CVG 7100)
Geotechnical Case Studies
The critical study of case histories relating to current procedures of design and construction in geotechnical engineering. The importance of instrumentation and monitoring field behaviour will be stressed. In-situ testing. Includes: Experiential Learning Activity

CIVE 5300 [0.5 credit] (CVG 7101)
Advanced Soil Mechanics
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; failure and yield criteria.

CIVE 5303 [0.5 credit] (CVG 7103)
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.

CIVE 5304 [0.5 credit] (CVG 7150)
Intercity Transportation
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.

CIVE 5305 [0.5 credit] (CVG 7151)
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.

CIVE 5306 [0.5 credit] (CVG 7152)
Highway Materials
Materials characterization and strength evaluation of soils, stabilized soils, aggregates, and asphalt concrete. Effects of low temperatures and frost on materials behaviour.

CIVE 5307 [0.5 credit] (CVG 7153)
Urban Transportation
Urban transportation systems, planning and management. Urban development models, an introduction. Urban transportation policy.

CIVE 5308 [0.5 credit] (CVG 7154)
Highway Geometric Design
Principles of highway geometric design. Components of the highway system, their interrelationships, abilities, limitations, and their relations with the design elements. Safety and human factors, and their interaction with the highway elements. New and evolving concepts.

CIVE 5309 [0.5 credit] (CVG 7155)
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.

CIVE 5401 [0.5 credit] (CVG 7156)
Transportation Economics
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.

CIVE 5402 [0.5 credit] (CVG 7159)
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.

CIVE 5403 [0.5 credit] (CVG 7158)
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.

CIVE 5404 [0.5 credit]
Introduction to Infrastructure Management
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.

CIVE 5500 [0.5 credit] (CVG 7104)
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.

CIVE 5501 [0.5 credit] (CVG 7105)
Advanced 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.

CIVE 5502 [0.5 credit] (CVG 7106)
In-Situ Geotechnique
Subsurface exploration program. Soil and rock sampling. Geo-physical methods. Mechanical and hydraulic properties of soil and rock. Determination of strength and deformability. Critical evaluation of vane, pressuremeter, screw plate, dilatometer, borehole shear and plate load tests. Pumping, recharge and packer tests. In-situ stress measurements.

CIVE 5503 [0.5 credit] (CVG 7107)
Numerical Methods in Geomechanics
Advanced theories of soil and rock behaviour. Plasticity models. Generalized failure criteria. Critical state and cap models. Dilatancy effects. Associative and non-associative flow rules. Hardening rules. Consolidation, visco-elasticity, creep behaviour. Finite element formulation. Iterative schemes. Time marching schemes. Solution of typical boundary value problems.
Prerequisite(s): CIVE 5101, CIVE 5103, or permission of the Department.

CIVE 5504 [0.5 credit]
Seepage 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.
Precludes additional credit for ENVE 5301.

CIVE 5505 [0.5 credit] (CVG 7109)
Geotechnical Earthquake Engineering
Seismic hazards, earthquakes and ground motion, wave propagation, ground response analysis, soil properties for dynamic analysis: laboratory tests, in-situ tests, modulus and damping curves, liquefaction susceptibility, post liquefaction response, seismic effects on slope stability, retaining structures.
Precludes additional credit for CIVE 5801 (2001-2003).

CIVE 5507 [0.5 credit]
Blast Load Effects on Structures
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.
Also listed as IPIS 5507.

CIVE 5600 [0.5 credit] (CVG 7131)
Project Management
Managing building development, design, and construction including interrelationships among owners, developers, financing sources, designers, contractors, and users; project manager role and tasks; project objectives; feasibility analyses; budgets and financing; government regulations; environmental and social constraints; cost, time, and content quality controls and processes; human factors.

CIVE 5601 [0.5 credit] (CVG 7140)
Engineering, Statistics, and Probabilities
Review of basic concepts in statistics and probabilities. Bayes' Theorem. Distributions. Parameter estimation. Goodness-of-fit. Regression and correlation. OC curves. Monte Carlo simulation. ANOVA. Probability-based design criteria. System reliability. Selected applications in structures, transportation and geomechanics. Use of computer software. Emphasis on problem solving.

CIVE 5602 [0.5 credit] (CVG 7141)
Advanced 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.
Also offered at the undergraduate level, with different requirements, as CIVE 4500, for which additional credit is precluded.

CIVE 5605 [0.5 credit] (CVG 7143)
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.

CIVE 5606 [0.5 credit] (CVG 7144)
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, introduction to prestressed concrete bridges, design of bridge piers and abutments. In all cases the relevant provisions of Canadian bridge codes are discussed.

CIVE 5607 [0.5 credit] (CVG 7145)
Introduction to Bridge Design
Limit states design of highway bridges; methods of analysis, design and evaluation procedures of superstructure components; design codes; design loads and load factors; concrete deck design; load distributions; computer analysis; impact and dynamics; fatigue and brittle fracture; construction bracing; load capacity rating of existing bridges.

CIVE 5609 [0.5 credit] (CVG 7170)
Fundamentals of Fire Safety Engineering
The fire safety system, including social, economic and environmental issues; description of the fire safety regulatory system and the governing building codes and standards. This includes the global fire safety system in a facility and active fire protection systems; detection, suppression, smoke management.
Precludes additional credit for CIVE 5707 (2001-2002).

CIVE 5610 [0.5 credit] (CVG 7171)
Fire Dynamics I
Fundamentals of combustion including material and energy balances, chemical thermodynamics, kinetics, premixed and diffusive burning. Advanced topics in the theory of combustion, flame propagation, efficiency of combustion, and the physico-chemical properties of combustible material.
Precludes additional credit for CIVE 5705 (2001-2003).

CIVE 5611 [0.5 credit] (CVG 7173)
People in Fires
Review of the work presented by the founders in the field of human behaviour in fire. Introduction to the basic notions of perception, cognition, information processing, decision-making and problem solving. Behavioural concepts such as panic, commitment, affiliation, familiarity and role are discussed.
Precludes additional credit for CIVE 5708 (2001-2003).

CIVE 5612 [0.5 credit] (CVG 7174)
Fire Modeling
Fire modeling and its role in fire safety engineering. Review of the main modeling techniques used in Fire Safety Engineering: network, zone and Computational Fluid Dynamics (CFD).
Precludes additional credit for CIVE 5802 (2002-2003).

CIVE 5613 [0.5 credit] (CVG 7172)
Fire Dynamics II
Fire dynamics from ignition through heat transfer to growth and spread of fires and their suppression. Factors such as containment and its role in the dynamics of fires and explosions are covered.
Precludes additional credit for CIVE 5803 (2002-2003).
Prerequisite(s): CIVE 5610 Fire Dynamics I.

CIVE 5614 [0.5 credit] (CVG 7175)
Design for Fire Resistance
Behaviour of materials and structures at elevated temperatures; fire-resistance tests; fire-resistance ratings; building code requirements; real-world fires; assessing the fire resistance of steel, concrete and wood building assemblies.
Precludes additional credit for CIVE 5709 (2001-2003).

CIVE 5615 [0.5 credit] (CVG 5320)
Fire Behaviour of Materials
Fundamentals and scientific aspects of materials behaviour during fires, material specifications, thermal and mechanical properties, fire hazards of materials, structural fire response, residual strength, failure criteria, mechanisms of flame retardancy, and standards and testing protocols.

CIVE 5705 [0.5 credit] (CVG 7300)
Topics in Structures
Courses in special topics related to building design and construction, not covered by other graduate courses.

CIVE 5706 [0.5 credit] (CVG 7301)
Topics in Structures
Courses in special topics related to building design and construction, not covered by other graduate courses.

CIVE 5707 [0.5 credit] (CVG 7302)
Topics in Structures
Courses in special topics related to building design and construction, not covered by other graduate courses.

CIVE 5708 [0.5 credit] (CVG 7303)
Topics in Structures
Courses in special topics related to building design and construction, not covered by other graduate courses.

CIVE 5709 [0.5 credit] (CVG 7304)
Topics in Structures
Courses in special topics related to building design and construction, not covered by other graduate courses.

CIVE 5800 [0.5 credit] (CVG 7305)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5801 [0.5 credit] (CVG 7306)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5802 [0.5 credit] (CVG 7307)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5803 [0.5 credit] (CVG 7308)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5804 [0.5 credit] (CVG 7309)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5805 [0.5 credit] (CVG 7310)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5806 [0.5 credit] (CVG 7311)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5807 [0.5 credit] (CVG 7312)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5808 [0.5 credit] (CVG 7313)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5809 [0.5 credit] (CVG 7314)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5810 [0.5 credit]
Topics in Fire Safety
Courses in special topics related to fire safety, not covered by other graduate courses.

CIVE 5900 [1.0 credit] (CVG 6000)
Civil Engineering Project
Students enrolled in the program M.Eng. by project will conduct an engineering study, analysis, or design project under the general supervision of a member of the Department.
Includes: Experiential Learning Activity

CIVE 5901 [0.0 credit] (CVG 7314)
Master's Seminar
The series consists of presentations by graduate students or external speakers. Graduate students in the Civil Engineering program are required to participate in these seminar series by attending all seminars and making at least one presentation during their graduate studies.

CIVE 5906 [0.5 credit] (CVG 6108)
Directed Studies 1
Prerequisite(s): open only to students in a Civil Engineering Master's program.

CIVE 5909 [2.5 credits] (CVG 5909)
M.A.Sc. Thesis
Includes: Experiential Learning Activity

CIVE 6901 [0.0 credit]
Ph.D. Seminar
The series consists of presentations by graduate students or external speakers. Graduate students in the Civil Engineering program are required to participate in these seminar series by attending all seminars and making at least one presentation during their graduate studies.

CIVE 6902 [0.0 credit] (CVG 9998)
Ph.D. Comprehensive Examination
Graduate students at the Doctoral level in the Civil Engineering program are required to successfully complete written and oral comprehensive examinations in subject areas determined by the student's advisory committee.

CIVE 6906 [0.5 credit] (CVG 6109)
Directed Studies 2
Prerequisite(s): open only to students in the Civil Engineering Ph.D. program.

CIVE 6909 [8.0 credits] (CVG 9999)
Ph.D. Thesis
Includes: Experiential Learning Activity