## Civil Engineering

This section presents the requirements for programs in:

- M.A.Sc. Civil Engineering
- M.A.Sc. Civil Engineering with Collaborative Specialization in Climate Change
- M. Eng. Civil Engineering
- M.Eng. Civil Engineering with Collaborative Specialization in Climate Change
- 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 listed below (other courses may be taken with prior departmental approval)
2. 2.5 credits in:
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.A.Sc. Civil Engineering with Collaborative Specialization in Climate Change (6.0 credits)

**Requirements**

1. 1.0 credit in:
   - CLIM 5000 [1.0] Climate Collaboration
2. 0.0 credit in:
   - CLIM 5800 [0.0] Climate Seminar Series
3. 4.0 credits in technical engineering courses
4. 1.0 credit in:
   - CIVE 5900 [1.0] Master's Seminar (in the specialization)

**Total Credits** 6.0

### M. Eng. Civil Engineering (5.0 credits)

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

1. 4.0 credits in courses listed below (other courses may be taken with prior departmental approval)
2. 1.0 credit in:
   - 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 listed below

**Total Credits** 5.0

### Ph.D. Civil Engineering (2.0 credits)

**Requirements**

1. 2.0 credits in courses
2. Participation in the graduate student seminar series: Ph.D. Seminar
3. Successful completion of written and oral comprehensive examinations in subject areas determined by the student's advisory committee:
   - CIVE 6902 [0.0] Ph.D. Comprehensive Examination
4. Successful completion of a thesis proposal examination
5. 0.0 credits in:
   - CIVE 6909 [0.0] 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.

**Total Credits** 2.0

### Note

- Subject to approval of their advisory committee and the Associate Chair (Graduate Studies) of the department, 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 (i.e., course codes other than CIVE, ENVE, CIVJ, or ENVJ) will not count towards the degree requirements. However, thesis students may take courses outside the Institute if prior approval is obtained from the thesis supervisor or the advisory committee, and the program's Associate Chair (Graduate studies). In all programs, at least one-half of the course work must be taken from the Institute regardless of the number of courses completed at another University (applicable to transfer students). Advanced standing (i.e., credit for courses taken elsewhere) is only granted at the time of admission.

### Geotechnical Engineering

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<th>Course Code</th>
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<td>Geotechnical Case Studies</td>
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<td>CIVE 5300 (CVG 7101)</td>
<td>Advanced Soil Mechanics</td>
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<td>CIVE 5506</td>
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<td>CIVE 5804 (CVG 7309)</td>
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### Structural Engineering

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<td>CIVE 5103 (CVG 7122)</td>
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<td>CIVE 5104 (CVG 7123)</td>
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<td>CIVE 5105 (CVG 7124)</td>
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<td>CIVE 5106 (CVG 7137)</td>
<td>Dynamics of Structures</td>
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<tr>
<td>CIVE 5108 (CVG 7181)</td>
<td>Nonlinear Analysis and Design of Advanced Earthquake-Resistant Structures</td>
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<td>CIVE 5109</td>
<td>Estimation and Identification in Dynamics using Data</td>
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<td>CIVE 5200 (CVG 7138)</td>
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<tr>
<td>CIVE 5202</td>
<td>Structural Assessment of Historic Buildings</td>
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<td>CIVE 5204 (CVG 7126)</td>
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<td>CIVE 5206 (CVG 7128)</td>
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<td>CIVE 5208 (CVG 7130)</td>
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<td>CIVE 5507 (CVG 7184)</td>
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<td>CIVE 5603</td>
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<td>CIVE 5203 (CVG 5145)</td>
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<td>CIVE 5302 (CVG 5146)</td>
<td>Numerical Methods of Structural Analysis</td>
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<td>CIVE 5204 (CVG 5147)</td>
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<td>CIVE 5209 (CVG 5153)</td>
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<td>CIVE 5303 (CVG 5157)</td>
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<td>CIVJ 5307 (CVG 5158)</td>
<td>Elements of Bridge Engineering</td>
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<tr>
<td>CIVJ 5308 (CVG 5154)</td>
<td>Random Vibrations</td>
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<td>CIVJ 5309 (CVG 5159)</td>
<td>Long Span Structures</td>
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<td>CIVJ 5310 (CVG 5311)</td>
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<td>Durability of Concrete Structures</td>
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<td>Seismic Analysis and Design of Concrete Structures</td>
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<td>CIVE 5612 (CVG 7174)</td>
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<td>CIVE 5613 (CVG 7172)</td>
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<td>CIVE 5614 (CVG 7175)</td>
<td>Design for Fire Resistance</td>
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<td>CIVE 5615 (CVG 5320)</td>
<td>Fire Behaviour of Materials</td>
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<td>CIVE 5616</td>
<td>Wood Structures and Fire</td>
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<td>CIVE 5617</td>
<td>Practical Applications of Fire Protection</td>
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<td>CIVE 5810 (CVG 7185)</td>
<td>Topics in Fire Safety</td>
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<td>CIVE 5811</td>
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<td>CIVE 5814</td>
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<td>CIVE 5305 (CVG 7151)</td>
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<td>CIVE 5307 (CVG 7153)</td>
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<td>CIVE 5308 (CVG 7154)</td>
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<td>CIVE 5403 (CVG 7158)</td>
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<td>CIVE 5805 (CVG 7310)</td>
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<td>CIVE 5806 (CVG 7311)</td>
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<td>CIVE 5807 (CVG 7312)</td>
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<td>CIVE 5808 (CVG 7313)</td>
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<td>CIVE 5809 (CVG 7314)</td>
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<th>CIVJ 5501 (CVG 5111)</th>
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<td>CIVJ 5502 (CVG 5112)</td>
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<td>CIVJ 5212 (CVG 5212)</td>
<td>Climate Change Impacts on Water Resources</td>
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<td>CIVJ 5183 (CVG 5183)</td>
<td>Mixing and Transport of Pollutants in Water Bodies</td>
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<td>CIVJ 5503 (CVG 5160)</td>
<td>Sediment Transport</td>
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<td>CIVJ 5504 (CVG 5162)</td>
<td>River Hydraulics</td>
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**Environmental Engineering**

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<td>Filtration and Membranes in Water Treatment</td>
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<td>ENVE 5105 (EVG 7105)</td>
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<td>ENVE 5106 (EVG 7106)</td>
<td>Atmospheric Chemical Transport Modelling</td>
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<td>ENVE 5107 (EVG 7003)</td>
<td>Radiative Transfer and Remote Sensing</td>
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<td>ENVE 5200 (EVG 7200)</td>
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<td>ENVE 5201 (EVG 7201)</td>
<td>Geo-Environmental Engineering</td>
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<td>ENVE 5204 (EVG 7134)</td>
<td>Resource Industry Waste Management</td>
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<td>ENVE 5205 (EVG 7132)</td>
<td>Sludge Treatment and Disposal</td>
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<td>ENVE 5206</td>
<td>Energy and Resource Recovery from Waste</td>
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<td>ENVE 5301 (EVG 7301)</td>
<td>Contaminant Hydrogeology</td>
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<td>ENVE 5303 (EVG 7303)</td>
<td>Multiphase Flow in Soils</td>
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<td>ENVE 5701 (EVG 7001)</td>
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<td>ENVE 5702 (EVG 7002)</td>
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<td>ENVE 5703 (EVG 7003)</td>
<td>Topics in Environmental Engineering</td>
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<td>ENVE 5704 (EVG 7004)</td>
<td>Topics in Environmental Engineering</td>
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<td>ENVE 5705 (EVG 7005)</td>
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<td>ENVJ 5001 (EVG 5001)</td>
<td>Biofilm Processes in Wastewater Treatment</td>
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<td>ENVJ 5301 (EVG 5301)</td>
<td>Soil and Water Conservation Engineering</td>
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<td>ENVJ 5302 (EVG 5302)</td>
<td>Decentralized Wastewater Management</td>
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Civil Engineering

CIVJ 5000 (CVG 6300) Special Topics in Civil Engineering
CIVJ 5001 (CVG 6301) Special Topics in Civil Engineering
CIVJ 5002 (CVG 6302) Special Topics in Civil Engineering
CIVJ 5003 (CVG 6303) Special Topics in Civil Engineering
CIVJ 5004 (CVG 6304) Special Topics in Civil Engineering
CIVJ 5005 (CVG 6305) Special Topics in Civil Engineering
CIVJ 5006 (CVG 6306) Special Topics in Civil Engineering
CIVJ 5007 (CVG 6307) Special Topics in Civil Engineering
CIVJ 5008 (CVG 6308) Special Topics in Civil Engineering
CIVJ 5009 (CVG 6309) Special Topics in Civil Engineering

CIVJ 6000 (CVG 6310) Special Topics in Civil Engineering
CIVJ 6001 (CVG 6311) Special Topics in Civil Engineering
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CIVJ 6005 (CVG 6315) Special Topics in Civil Engineering
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CIVJ 6007 (CVG 6317) Special Topics in Civil Engineering
CIVJ 6008 (CVG 6318) Special Topics in Civil Engineering
CIVJ 6009 (CVG 6319) Special Topics in Civil Engineering
CIVJ 6010 (CVG 6320) Special Topics in Civil Engineering

Projects and Theses
CIVJ 5000 Master's Seminar
CIVJ 5001 M.A.Sc. Thesis
CIVJ 6000 Ph.D. Comprehensive Examination
CIVJ 6001 Ph.D. Proposal
CIVJ 6002 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 fulfill 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.

Regularly Scheduled Break
For immigration purposes, the summer term (May to August) for the M.Eng. Civil Engineering (coursework and project pathways) is considered a regularly scheduled break approved by the University. Students should resume full-time studies in September.

Note: a Regularly Scheduled Break as described for immigration purposes does not supersede the requirement for continuous registration in Thesis, Research Essay, or Independent Research Project as described in Section 8.2 of the Graduate General Regulations.

Civil Engineering - Joint (CIVJ) Courses

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

CIVJ 5106 [0.5 credit] (CVG 5161)
Mechanics of Unsaturated Soils
Introduction to unsaturated soils, phase properties and relations, stress state variables. Measurement & theory of soil suction, capillarity, permeability, shear strength, failure envelope for unsaturated soils, triaxial and direct shear tests, volume change behaviour.

CIVJ 5109 [0.5 credit] (CVG 5314)
Geotechnical Hazards
Assessment, prevention, and mitigation of geotechnical hazards, Natural and man-made geohazards; 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.

CIVJ 5110 [0.5 credit] (CVG 5187)
Rock Mechanics
Rock exploration, laboratory and in-situ testing, rock mass classification, deformation and strength, failure criteria, stresses in rock, foundations on rock.

CIVJ 5181 [0.5 credit] (CVG 5181)
Decentralized Wastewater Management
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.
Also listed as ENVJ 5302.
Precludes additional credit for CIVJ 7181.

CIVJ 5182 [0.5 credit] (CVG 5182)
Water Resources Management
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.
Also listed as ENVJ 5182.

CIVJ 5183 [0.5 credit] (CVG 5183)
Mixing and Transport of Pollutants in Water Bodies
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 models, dilution models, three-dimensional models, advection-diffusion equation, analytical/numerical solution, non-conservative transport and multi-component systems.
Also listed as ENVJ 5183.
Precludes additional credit for CIVJ 7183.
CIVJ 5184 [0.5 credit] (CVG 5184)
Construction Cost Estimating
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.

CIVJ 5185 [0.5 credit] (CVG 5185)
Construction Life Cycle Analysis
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. Breakeven, sensitivity and risk analysis.

CIVJ 5186 [0.5 credit] (CVG 5186)
Project Information Management

CIVJ 5188 [0.5 credit] (CVG 5188)
Loads on structures
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.

CIVJ 5189 [0.5 credit] (CVG5189)
Blast Engineering
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; blast-resistant building design.

CIVJ 5190 [0.5 credit] (CVG 5190)
Rehabilitation of Concrete Structures
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. Lecture three hours a week

CIVJ 5191 [0.5 credit] (CVG 5191)
Diagnosis and Prognosis of Concrete Infrastructure
Condition assessment of concrete infrastructure using experimental (i.e. visual, nondestructive, 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 approaches. Lecture three hours a week

CIVJ 5192 [0.5 credit] (CVG 5192)
Characterization Methods for Materials
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.

CIVJ 5193 [0.5 credit] (CVG 5193)
Instrumentation and Experimental Design for Civil Engineering
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, closed versus open-loop control; servomotor types and servo-valves.

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

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

CIVJ 5203 [0.5 credit] (CVG 5145)
Theory of Elasticity
Stress-strain relations. Theories of plane stress and plane strain. Use of stress functions, energy and variational methods in the analysis of elastostatic problems.

CIVJ 5204 [0.5 credit] (CVG 5147)
Theory of Plates and Shells
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.
CIVJ 5206 [0.5 credit] (CVG 5150)  
Advanced Concrete Technology  
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.

CIVJ 5207 [0.5 credit] (CVG 5216)  
Sustainable and Resilient Infrastructure in Changing Climate  
Development of infrastructure with long-term sustainability and resiliency under various extreme events; 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.

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

CIVJ 5212 [0.5 credit] (CVG 5212)  
Climate Change Impacts on Water Resources  
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.  
Also listed as ENVJ 5212.  
Precludes additional credit for CIVJ 7282.

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

CIVJ 5301 [0.5 credit] (CVG 5156)  
Finite Element Methods I  
Precludes additional credit for CIVJ 5103.

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

CIVJ 5303 [0.5 credit] (CVG 5157)  
Finite Element Methods II  
Precludes additional credit for CIVE 5105.

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

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  
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.

CIVJ 5308 [0.5 credit] (CVG 5154)  
Random Vibrations  
CIVJ 5309 [0.5 credit] (CVG 5159)
Long Span Structures

CIVJ 5310 [0.5 credit] (CVG 5311)
Bridge Design
Design of highway bridges, Canadian Highway Bridge Design Code (CHBDC). Comparisons with other bridge codes (AASHTO, the European, the New Zealand, and the British). Structural components of long span bridges, types of highway bridges, serviceability and ultimate limit state design requirements, design loads.

CIVJ 5311 [0.5 credit] (CVG 5312)
Durability of Concrete Structures
Properties of cementitious materials (constituents of concrete, hydration of cement, structure of hardened concrete, transport processes in concrete); deterioration of concrete (built-in problems, construction defects, cracking, dimensional stability, alkali-aggregate reaction, sulphate attack, corrosion of reinforcing steel, freezing-thawing cycles); evaluation of concrete structures.

CIVJ 5312 [0.5 credit] (CVG 5313)
Seismic Analysis and Design of Concrete Structures
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 (FEM and fiber modeling), performance-based earthquake engineering and displacement-based design. Includes: Experiential Learning Activity

CIVJ 5503 [0.5 credit] (CVG 5160)
Sediment Transport
Introduction to particle transport with 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.

CIVJ 5504 [0.5 credit] (CVG 5162)
River Hydraulics
Advanced concepts of river hydraulics, with an emphasis on field measurement techniques and application of numerical models. Navier-Stokes equations, turbulence, flow resistance, numerical modeling of simplified momentum and continuity equations, field-based measurement and statistical analysis of velocity fields. Special topics include contaminant transport, morphodynamic modeling.

CIVJ 5505 [0.5 credit] (CVG 5124)
Coastal Engineering
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).

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

CIVJ 5502 [0.5 credit] (CVG 5112)
Computational Hydrodynamics
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 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.  
Precludes additional credit for CIVJ 5301.

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.  
Precludes additional credit for CIVJ 5303.  
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 5108 [0.5 credit] (CVG 7181)  
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 5109 [0.5 credit]  
Estimation and Identification in Dynamics using Data  
Dynamical systems and their computational models, probability and stochastic processes, stochastic dynamical systems, state estimation in linear dynamics using Kalman filtering, state estimation of nonlinear dynamical systems, system identification using combined state and parameter estimation, application to engineering.  
Includes: Experiential Learning Activity
CIVE 5200 [0.5 credit] (CVG 7138)
Masonry Behaviour and Design
Also offered at the undergraduate level, with different requirements, as CIVE 4403, for which additional credit is precluded.

CIVE 5202 [0.5 credit]
Structural Assessment of Historic Buildings
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.
Also listed as BLDG 5202.

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 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 Mechanics of Reinforced Concrete
Review of various analytical methods, constitutive models, and failure criteria for reinforced concrete structures; performance assessment and forensic analysis; nonlinear finite element analysis 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 5305 [0.5 credit] (CVG 7151)
Traffic Engineering

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 5310 [0.5 credit]
Road Safety Analysis
Fundamental analytical techniques for road safety analysis, background of traffic safety analysis, network screening, before and after analysis, and surrogate measures of safety.

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 5500 [0.5 credit] (CVG 7104)
Earth Retaining Structures
CIVE 5501 [0.5 credit] (CVG 7105)  
Advanced Foundation Engineering  

CIVE 5503 [0.5 credit] (CVG 7107)  
Numerical Methods in Geomechanics  
Prerequisite(s): CIVE 5101, CIVE 5103, or permission of the Department.

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.  

CIVE 5506 [0.5 credit]  
Fundamentals of Geomechanics  
Tensor calculus, Cauchy stress, kinematics of continuum deformation (strain), elasticity for geomaterials, plasticity for geomaterials, constitutive models for soils, Cam-clay model.

CIVE 5507 [0.5 credit] (CVG 7184)  
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.  
Prerequisite(s): those enrolled in the M.IPIS program must have prior knowledge of structural steel and reinforced concrete design, typically obtained through the completion of an undergraduate engineering degree.

CIVE 5603 [0.5 credit]  
Advanced Building Characterization, Conservation and Rehabilitation  
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  
Also listed as BLDG 5201.

CIVE 5604 [0.5 credit]  
Probability, Statistics, Stochastic Processes and Statistical Inference in Engineering  
Fundamental of probability and statistics, (robust and ridge) regression, generalised linear models, sparse models, mixture models, stochastic processes, statistical inference and applications.  
Includes: Experiential Learning Activity

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.  

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.  

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 5616 [0.5 credit]
Wood Structures and Fire
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

CIVE 5617 [0.5 credit]
Practical Applications of Fire Protection
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. Includes: Experiential Learning Activity

CIVE 5700 [0.5 credit] (CVG 7305)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5701 [0.5 credit] (CVG 7306)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5702 [0.5 credit] (CVG 7307)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5703 [0.5 credit] (CVG 7308)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5704 [0.5 credit] (CVG 7309)
Topics in Geotechnique
Courses in special topics in geotechnical engineering, not covered by other graduate courses.

CIVE 5705 [0.5 credit] (CVG 7310)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5706 [0.5 credit] (CVG 7311)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5707 [0.5 credit] (CVG 7312)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5708 [0.5 credit] (CVG 7313)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5709 [0.5 credit] (CVG 7314)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5710 [0.5 credit] (CVG 7315)
Topics in Transportation
Courses in special topics in transportation engineering, not covered by other graduate courses.

CIVE 5711 [0.5 credit]
Topics in Fire Safety
Courses in special topics related to fire safety, not covered by other graduate courses.

CIVE 5712 [0.5 credit]
Topics in Fire Safety
Courses in special topics related to fire safety, not covered by other graduate courses.
CIVE 5812 [0.5 credit]
Topics in Fire Safety
Courses in special topics related to fire safety, not covered by other graduate courses.

CIVE 5813 [0.5 credit]
Topics in Fire Safety
Courses in special topics related to fire safety, not covered by other graduate courses.

CIVE 5814 [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 6903 [0.0 credit]
Ph.D. Proposal
Graduate students at the Doctoral level in the Civil Engineering program are required to successfully complete a PhD Thesis Proposal which consists of a written proposal and a successful defence of the proposal. Students should register in term they will defend their proposal.
Prerequisite(s): CIVE 6909 (taken concurrently).

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 [0.0 credit] (CVG 9999)
Ph.D. Thesis
Includes: Experiential Learning Activity