# 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:
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:
   - 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 (2.0 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:
   - CIVE 6902 [0.0] Ph.D. Comprehensive Examination
4. Successful completion of a thesis proposal examination: 0.0
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 his/her advisory committee, a Ph.D. student may take, or be required to take, courses in other disciplines.

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## 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

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<th>Course</th>
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<tr>
<td>CIVE 5209</td>
<td>Geotechnical Case Studies</td>
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<tr>
<td>CIVE 5300</td>
<td>Advanced Soil Mechanics</td>
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<td>CIVE 5500</td>
<td>Earth Retaining Structures</td>
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<td>CIVE 5501</td>
<td>Advanced Foundation Engineering</td>
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<td>CIVE 5502</td>
<td>In-Situ Geotechnique</td>
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<td>CIVE 5503</td>
<td>Numerical Methods in Geomechanics</td>
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<td>CIVE 5505</td>
<td>Geotechnical Earthquake Engineering</td>
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<td>CIVE 5800</td>
<td>Topics in Geotechnique</td>
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<td>CIVE 5802</td>
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<td>CIVE 5804</td>
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<td>CIVE 5805</td>
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<td>CIVE 5506</td>
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<td>CIVE 5508</td>
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<td>CIVJ 5105</td>
<td>Numerical Methods for Geotechnical Engineering</td>
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<td>CIVJ 5106</td>
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<td>CIVJ 5107</td>
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<td>CIVJ 5108</td>
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<td>CIVJ 5109</td>
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<tr>
<td>CIVE 5101 (CVG 7120)</td>
<td>Solid Mechanics</td>
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<td>CIVE 5102 (CVG 7121)</td>
<td>Advanced Elasticity</td>
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<tr>
<td>CIVE 5103 (CVG 7122)</td>
<td>Finite Element Analysis 1</td>
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<td>CIVE 5104 (CVG 7123)</td>
<td>Earthquake Engineering and Analysis</td>
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<tr>
<td>CIVE 5105 (CVG 7124)</td>
<td>Finite Element Analysis 2</td>
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<tr>
<td>CIVE 5106 (CVG 7137)</td>
<td>Dynamics of Structures</td>
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<td>CIVE 5107 (CVG 7138)</td>
<td>Finite Elements in Field Problems</td>
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<td>CIVE 5108 (CVG 7181)</td>
<td>Nonlinear Analysis and Design of Advanced Earthquake-Resistant Structures</td>
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<td>CIVE 5200 (CVG 7139)</td>
<td>Masonry Behaviour and Design</td>
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<tr>
<td>CIVE 5203 (CVG 7125)</td>
<td>Theory of Structural Stability</td>
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<tr>
<td>CIVE 5204 (CVG 7126)</td>
<td>Advanced Steel Structures</td>
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<tr>
<td>CIVE 5205 (CVG 7127)</td>
<td>Advanced Structural Analysis</td>
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<tr>
<td>CIVE 5206 (CVG 7128)</td>
<td>Prestressed Concrete</td>
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<td>CIVE 5208 (CVG 7130)</td>
<td>Advanced Reinforced Concrete</td>
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<tr>
<td>CIVE 5507 (CVG 7184)</td>
<td>Blast Load Effects on Structures</td>
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<tr>
<td>CIVE 5600 (CVG 7131)</td>
<td>Project Management</td>
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<tr>
<td>CIVE 5601 (CVG 7140)</td>
<td>Engineering, Statistics, and Probabilities</td>
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<tr>
<td>CIVE 5602 (CVG 7141)</td>
<td>Advanced Computer-Aided Design</td>
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<tr>
<td>CIVE 5603</td>
<td>Advanced Building Characterization, Conservation and Rehabilitation</td>
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<tr>
<td>CIVE 5605 (CVG 7143)</td>
<td>Design of Steel Bridges</td>
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<tr>
<td>CIVE 5606 (CVG 7144)</td>
<td>Design of Concrete Bridges</td>
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<tr>
<td>CIVE 5607 (CVG 7145)</td>
<td>Introduction to Bridge Design</td>
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<tr>
<td>CIVE 5705 (CVG 7300)</td>
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<td>CIVE 5706 (CVG 7301)</td>
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<td>CIVE 5709 (CVG 7304)</td>
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<tr>
<td>CIVJ 5201 (CVG 5142)</td>
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<td>CIVJ 5202 (CVG 5143)</td>
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<td>CIVJ 5300 (CVG 5144)</td>
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<td>CIVJ 5203 (CVG 5145)</td>
<td>Theory of Elasticity</td>
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<td>CIVJ 5302 (CVG 5146)</td>
<td>Numerical Methods of Structural Analysis</td>
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<td>CIVJ 5204 (CVG 5147)</td>
<td>Theory of Plates and Shells</td>
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<td>CIVJ 5305 (CVG 5148)</td>
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<tr>
<td>CIVJ 5304 (CVG 5149)</td>
<td>Structural Stability</td>
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<tr>
<td>CIVJ 5206 (CVG 5150)</td>
<td>Advanced Concrete Technology</td>
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<td>CIVJ 5209 (CVG 5153)</td>
<td>Wind Engineering</td>
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<td>CIVJ 5306 (CVG 5155)</td>
<td>Earthquake Engineering</td>
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<tr>
<td>CIVJ 5301 (CVG 5156)</td>
<td>Finite Element Methods I</td>
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<td>CIVJ 5303 (CVG 5157)</td>
<td>Finite Element Methods II</td>
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<tr>
<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>CIVJ 5311 (CVG 5312)</td>
<td>Durability of Concrete Structures</td>
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<tr>
<td>CIVJ 5312 (CVG 5313)</td>
<td>Seismic Analysis and Design of Concrete Structures</td>
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### Fire Safety Engineering

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<td>CIVE 5609 (CVG 7170)</td>
<td>Fundamentals of Fire Safety Engineering</td>
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<tr>
<td>CIVE 5610 (CVG 7171)</td>
<td>Fire Dynamics I</td>
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<tr>
<td>CIVE 5611 (CVG 7173)</td>
<td>People in Fires</td>
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<td>CIVE 5612 (CVG 7174)</td>
<td>Fire Modeling</td>
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<td>CIVE 5613 (CVG 7172)</td>
<td>Fire Dynamics II</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 5810 (CVG 7185)</td>
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### Transportation Engineering

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<tr>
<td>CIVE 5303 (CVG 7103)</td>
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<td>CIVE 5304 (CVG 7150)</td>
<td>Intercity Transportation</td>
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<td>CIVE 5305 (CVG 7151)</td>
<td>Traffic Engineering</td>
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<td>CIVE 5306</td>
<td>Highway Materials</td>
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<tr>
<td>CIVE 5307</td>
<td>Urban Transportation</td>
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<tr>
<td>CIVE 5308</td>
<td>Highway Geometric Design</td>
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<td>CIVE 5309</td>
<td>Transportation Supply</td>
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<tr>
<td>CIVE 5310</td>
<td>Road Safety Analysis</td>
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<tr>
<td>CIVE 5401</td>
<td>Transportation Economics</td>
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<tr>
<td>CIVE 5402</td>
<td>Transportation Terminals</td>
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<tr>
<td>CIVE 5403</td>
<td>Airport Planning</td>
</tr>
<tr>
<td>CIVE 5404</td>
<td>Introduction to Infrastructure Management</td>
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<td>CIVE 5805</td>
<td>Topics in Transportation</td>
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<tr>
<td>CIVJ 5501</td>
<td>Hydraulic Structures</td>
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<tr>
<td>CIVJ 5502</td>
<td>Computational Hydrodynamics</td>
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<tr>
<td>CIVJ 5803</td>
<td>Computational Hydraulics</td>
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<tr>
<td>CIVJ 5506</td>
<td>Water Resources Systems</td>
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<td>CIVJ 5509</td>
<td>Advanced Topics in Hydrology</td>
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<td>CIVJ 5605</td>
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<td>CIVJ 5601</td>
<td>Statistical Methods in Hydrology</td>
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<td>Stochastic Hydrology</td>
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<td>CIVJ 5603</td>
<td>Hydrologic Systems Analysis</td>
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<td>CIVJ 5604</td>
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<td>CIVJ 5503</td>
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<td>CIVJ 5504</td>
<td>River Hydraulics</td>
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<td>ENVE 5001</td>
<td>Biofilm Processes</td>
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<td>ENVE 5003</td>
<td>Advanced Ultraviolet Processes</td>
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<td>ENVE 5004</td>
<td>Advanced Wastewater Treatment</td>
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<td>ENVE 5101</td>
<td>Air Pollution Control</td>
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<td>ENVE 5102</td>
<td>Traffic-Related Air Pollution</td>
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<td>ENVE 5103</td>
<td>Air Quality Modeling</td>
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<td>ENVE 5104</td>
<td>Indoor Environmental Quality</td>
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<td>ENVE 5105</td>
<td>Atmospheric Aerosols</td>
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<td>Atmospheric Chemical Transport Modelling</td>
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<td>ENVE 5200</td>
<td>Climate Change and Engineering</td>
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<td>ENVE 5201</td>
<td>Geo-Environmental Engineering</td>
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<td>ENVE 5203</td>
<td>Hazardous and Radioactive Wastes</td>
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<td>Resource Industry Waste Management</td>
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<td>ENVE 5301</td>
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<td>ENVE 5302</td>
<td>Case Studies in Hydrogeology</td>
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<td>Multiphase Flow in Soils</td>
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<td>ENVJ 5700</td>
<td>Environmental Assessment of Civil Engineering Projects</td>
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<td>ENVJ 5900</td>
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<td>ENVJ 5901</td>
<td>Unit Operations of Water Treatment</td>
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<td>ENVJ 5902</td>
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<td>ENVJ 5903</td>
<td>Sludge Utilization and Disposal</td>
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<td>ENVJ 5907</td>
<td>Chemistry for Environmental Engineering</td>
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<td>ENVJ 5908</td>
<td>Anaerobic Digestion</td>
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<tr>
<td>ENVJ 5909</td>
<td>Biological Nutrient Removal</td>
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</table>
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 a 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 is considered a regularly scheduled break approved by the University. Students should resume full-time studies in September.

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 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 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 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

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] (EVG 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 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 5101 [0.5 credit] (CVG 7120)  
Solid Mechanics
Cartesian 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.

CIVJ 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.

CIVJ 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] (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 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 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**

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 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 5401 [0.5 credit] (CVG 7156)
**Transportation Economics**

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] (CVG 7182)
**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**

CIVE 5501 [0.5 credit] (CVG 7105)
**Advanced Foundation Engineering**
CIVE 5502 [0.5 credit] (CVG 7106)
In-Situ Geotechnique

CIVE 5503 [0.5 credit] (CVG 7107)
Numerical Methods in Geomechanics

CIVE 5504 [0.5 credit] (CVG 7183)
Seepage Through Soils

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] (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.

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

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 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

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 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 noncomposite 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.  

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 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] (CVG 7185)  
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 [0.0 credit] (CVG 9999)  
Ph.D. Thesis  
Includes: Experiential Learning Activity