

# Department of Civil and Environmental Engineering

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## Graduate Programs

### Master of Engineering and Master of Science Programs

The Department of Civil and Environmental Engineering (CEE) offers the degree of Master of Engineering (ME) with the following majors and concentrations:

- Major: Civil Engineering (CE) Concentration: Construction Engineering and Management, Geotechnical, Materials, Structural and Transportation
- Major: Environmental and Water Resources Engineering (EWRE) Concentration: Environmental Engineering and Water Resources Engineering

Also offered is a program leading to the degree of Master of Science (MS) in Environmental Science with the following major:

- Major: Environmental Technology (ET) The master's degree programs equip students with the necessary tools for professional practice and/or the pursuit of higher education.

### Doctor of Philosophy Programs

The Department of Civil and Environmental Engineering (CEE) offers the degree of Doctor of Philosophy (PhD) with the following majors and concentrations:

- Major: Civil Engineering (CE) Concentration: Construction Engineering and Management, Geotechnical, Materials and Transportation
- Major: Environmental and Water Resources Engineering (EWRE) Concentration: Environmental and Water Resources

# Master of Engineering (ME)

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## General Information

The Department of Civil and Environmental Engineering offers two graduate programs leading to the ME degree:

- Thesis Program
- Non-Thesis Program

The Thesis Program prepares students through course work and provides them with significant research experience in their selected area of concentration. All graduate students must satisfy either the thesis or the non-thesis program requirements. The program will be indicated on the student's transcript.

## Admission Requirements

To be eligible for admission to the graduate program, a student must hold a bachelor's degree in Civil Engineering or a related field. Students with a bachelor's degree in majors other than Civil Engineering must fulfill the prerequisite course requirements as set by the department. Students must also satisfy the requirements of the university and the Maroun Semaan Faculty of Engineering and Architecture for admission to graduate study, as specified in the relevant sections of this catalogue.

Bachelor of Engineering holders from a 5-year equivalent engineering program may obtain a waiver for 9 credits of relevant graduate level courses from their BE degree as long as they maintain a minimum grade of 80 or its equivalent in each of these courses.

Bachelor of Science holders must complete an additional 18 credits of engineering courses prior to enrollment in the master's program and must achieve an average of at least 80 percent in these courses. No credit toward the graduate degree is given for these courses.

A minimum of one calendar year of residence is required for graduation. The student must also satisfy all relevant Maroun Semaan Faculty of Engineering and Architecture (MSFEA) and AUB requirements.

## Major: Civil Engineering (CE)

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### Thesis Program Requirements

In order to fulfill the graduation requirements in the CE Thesis Program, a student must complete a minimum of 24 credit hours of graduate courses and a thesis based on independent research, equivalent to at least 6 credit hours. The required course work is distributed as follows:

- A minimum of four graduate courses (12 credit hours) in the field of concentration
- A maximum of two graduate courses (6 credit hours) in a relevant CEE field
- A maximum of two graduate courses (6 credit hours) of relevant electives in a related field in engineering or science (Math, Physics, Chemistry, Biology, Geology, Economics)
- Comprehensive Exam (CIVE 799T)
- Seminar course (CIVE 600A)

The courses that fall in the elective category must be pre-approved by the department. Up to two senior level civil engineering courses (CIVE 600 series), taken at the undergraduate level, can be counted towards the master's degree.

### Non-Thesis Program Requirements

In order to fulfill the graduation requirements in the Non-Thesis Program, a student must complete a minimum of 33 credit hours of graduate courses. The required course work is distributed as follows:

- A minimum of five graduate courses (15 credit hours) in the field of concentration
- A maximum of three graduate courses (9 credit hours) in a relevant CEE field
- A maximum of three graduate courses (9 credit hours) of relevant electives in a related field in engineering or science (Math, Physics, Chemistry, Biology, Geology, Economics)
- Comprehensive Exam (CIVE 799T)
- Seminar course (CIVE 600A)

The courses that fall in the elective category must be pre-approved by the department. Up to three senior level civil engineering courses (CIVE 600 series), taken at the undergraduate level, can be counted towards the master's degree.

# Major: Environmental and Water Resources Engineering (EWRE)

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## Thesis Program Requirements

In order to fulfill the graduation requirements in the CE Thesis Program, a student must complete a minimum of 24 credit hours of graduate courses and a thesis based on independent research, equivalent to at least 6 credit hours. The required course work is distributed as follows:

- A minimum of two core graduate courses (6 credit hours) in the area of specialty
- A minimum of two graduate elective courses (6 credit hours) in the area of specialty
- A minimum of two graduate courses (6 credit hours) in the minor area
- A maximum of two graduate elective courses (6 credit hours) in a related field in engineering or science (Math, Physics, Chemistry, Biology, Geology, Economics)
- Comprehensive Exam (CIVE 799T)
- Seminar course (CIVE 600B)

The courses that fall in the elective category must be pre-approved by the department. Up to two senior level civil engineering courses (CIVE 600 series), taken at the undergraduate level, can be counted towards the master's degree.

## Non-Thesis Program Requirements

In order to fulfill the graduation requirements in the Non-Thesis Program, a student must complete a minimum of 33 credit hours of graduate courses. The required course work is distributed as follows:

- A minimum of three core graduate courses (9 credit hours) in the area of specialty
- A minimum of three graduate elective courses (9 credit hours) in the area of specialty
- A minimum of three graduate courses (9 credit hours) in the minor area
- A maximum of two graduate elective courses (6 credit hours) in a related field in engineering or science (Math, Physics, Chemistry, Biology, Geology, Economics)
- Comprehensive Exam (CIVE 799T)
- Seminar course (CIVE 600B)

The courses that fall in the elective category must be pre-approved by the department. Up to three senior level civil engineering courses (CIVE 600 series), taken at the undergraduate level, can be counted towards the master's degree.

## Specialization: Environmental Engineering

### Minor: Water Resources Engineering

- Core Courses: CIVE 550, CIVE 551, CIVE 552, CIVE 553, CIVE 555
- Elective Courses: CIVE 645, CIVE 650, CIVE 651, CIVE 652, CIVE 653, CIVE 654, CIVE 655, CIVE 656, CIVE 657, CIVE 751, CIVE 755

## Specialization: Water Resources Engineering

### Minor: Environmental Engineering

- Core Courses: CIVE 541, CIVE 542, CIVE 640, CIVE 641, CIVE 642
- Elective Courses: CIVE 644, CIVE 645, CIVE 647, CIVE 648, CIVE 656, CIVE 740

# Master of Science (MS)

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## Major: Environmental Technology (ET)

The Department of Civil and Environmental Engineering offers a graduate program leading to the degree of Master of Science in Environmental Technology (ET). The program is part of the Interfaculty Graduate Environmental Sciences Program (IGESP) and is open to non-engineering students who hold a degree in basic sciences. For more details, on the IGESP program, refer to the Interdisciplinary Research Centers and Programs section of this catalogue.

In order to fulfill the graduation requirements in the MS Program, a student must complete a minimum of 24 credit hours of graduate courses and a thesis equivalent to 6 credit hours, or 27 credit hours of graduate courses and a project course equivalent to 3 credit hours.

The required course work is distributed as follows:

- A minimum of two core mandatory courses (6 cr.) (ENSC 630, ENSC 640, ENSC 650)
- A minimum of three graduate core courses (9 cr.) in Environmental Engineering
- A minimum of two graduate elective courses (6 cr.) in Environmental Engineering
- Experimental Design and Statistical Methods course (3 cr.) (CIVE 602)
- Comprehensive Exam (ENSC 695)
- Seminar course (CIVE 600B)

# Doctor of Philosophy (PhD)

## General Information

The PhD programs offered by the CEE department train graduate students to address and solve current problems in civil and environmental engineering. PhD students are trained to be future educators and proficient researchers geared to assume leadership roles in their profession.

The objectives of the PhD program are to:

- cultivate expertise in concentration areas of Civil and Environmental Engineering,
- develop research skills necessary for the formulation and solution of challenging problems,
- and acquire teaching expertise through assistance in class lectures and laboratory sessions.

## Admission Requirements

To be eligible for admission to the PhD program, a candidate must:

- hold a master's degree in Civil and Environmental Engineering or a related discipline from AUB or another recognized institution of higher learning (for admission in the regular track), or a bachelor's degree in Civil Engineering or a related discipline (for admission in the accelerated track). A minimum cumulative course average of 85 over 100, or its equivalent, is required for admission.
- submit a complete application including a statement of interest, transcripts of academic records from all institutions attended after high school, a curriculum vitae and three letters of recommendation,
- provide scores for the General Exam part of the Graduate Record Examination (GRE),
- demonstrate proficiency in the English language if English is not the native language (refer to the catalogue section on English Language Proficiency Requirement),
- and complete an interview either in person or by phone (for non-AUB students).

The application to the doctoral program will follow the deadlines set by the Office of Admissions at AUB. Admission decisions for the PhD program are made upon the recommendations of the CEE department and the MSFEA Graduate Studies Committee, with the approval of the AUB Board of Graduate Studies.

## Regular PhD Program Requirements

The regular PhD program requires a minimum of 24 credit hours of course work beyond the master's degree and 24 credit hours of thesis work. The course work consists of

- a minimum of 12 credits in the area of concentration,
- 6 credits in a related area,
- and 6 credits in an area other than the candidate's field of research, which can be taken inside or outside the department.

## Accelerated PhD Program Requirements

The accelerated PhD program requires a minimum of 36 credit hours of course work beyond the bachelor's degree and 42 credit hours of thesis work. The course work consists of

- a minimum of 21 credits in the area of concentration,
- 9 credits in a related area,
- and 6 credits in an area other than the candidate's field of research, which can be taken inside or outside the department.

## Candidacy Requirements

### Qualifying Exam Part I: Comprehensive Exam

All students admitted to the PhD program must successfully complete a written comprehensive examination administered by the department. The purpose of the comprehensive exam is to ascertain the student's knowledge in his/her field of specialization and related areas. The written exam will cover major topics from within the concentration area and related fields. Normally, a student on the regular track will take the comprehensive exam no later than 18 months after enrollment in the PhD program and after completing a minimum of 18 credits of courses. A student on the accelerated track will usually take the comprehensive exam no later than 24 months after enrollment in the PhD program and after completing a minimum of 30 credits of courses. Students who do not pass the comprehensive exam may, upon the recommendation of the department, take it for a second time the following term. Failing the exam a second time will result in the student's discontinuation from the graduate program. See Qualifying Exam Part I: Comprehensive Exam under General University Academic Information section.

### Qualifying Exam Part II: Defense of Thesis Proposal

See Qualifying Exam Part II: PhD Thesis Defense under General University Academic Information section.

## Admission to Candidacy

See Admission to Candidacy under General University Academic Information section.

## Thesis Requirements

Refer to General University Academic Information section.

## Thesis Committee

See PhD Thesis Committee under General University Academic Information section.

## Thesis Defense

See PhD Thesis Defense under General University Academic Information section.

## PhD Publication Requirements

See PhD Publications Requirements under General University Academy Information section.

## Residence Requirements

See Residence Requirements under General University Academy Information section.

## Graduation Requirements

To earn a PhD degree in the Department of Civil and Environmental Engineering, a student must fulfill the following graduation requirements:

- Attain a minimum cumulative average of 85 in 24 credits (regular program) or 36 credits (accelerated program) of course work taken at the PhD level
- Attain a minimum grade of 75 for courses taken at the PhD level
- Pass the PhD thesis defense
- Satisfy the minimum residency requirements
- Have at least two accepted refereed journal papers based on the PhD research
- Satisfy all pertinent AUB regulations

## Sample Study Program

A typical program of study for a PhD student is shown below.

Year	Semester	Course	Credits	Total	Timeline
1	Fall	Major course	3		
		Major course	3		
		Minor course	3	<b>9</b>	
	Spring	Major course	3		
		Major course	3		
		Minor course	3	<b>18</b>	
Summer	Thesis	9	<b>27</b>		
2	Fall	Minor Course	3		
		Minor Course	3	<b>33</b>	Comprehensive Exam
	Spring	Thesis	9	<b>42</b>	
	Summer	Thesis	6	<b>48</b>	
3	Fall	Thesis	0	<b>48</b>	
	Spring	Thesis	0	<b>48</b>	Proposal Defense
4	Fall	Thesis	0	<b>48</b>	
	Spring	Thesis	0	<b>48</b>	Thesis Defense



A typical program of study for an accelerated PhD student is shown below.

Year	Semester	Course	Credits	Total	Timeline
1	Fall	Major course	3		
		Major course	3		
		Minor course	3	<b>9</b>	
	Spring	Major course	3		
		Major course	3		
		Minor course	3	<b>18</b>	
Summer	Thesis	9	<b>27</b>		
2	Fall	Major course	3		
		Major course	3		
		Minor course	3	<b>36</b>	
	Spring	Major course	3		
		Minor course	3		
		Minor course	3	<b>45</b>	
Summer	Thesis	9	<b>54</b>	Comprehensive Exam	
3	Fall	Thesis	9	<b>63</b>	
	Spring	Thesis	9	<b>72</b>	
	Summer	Thesis	6	<b>78</b>	Proposal Defense
4	Fall	Thesis	0	<b>78</b>	
	Spring	Thesis	0	<b>78</b>	Thesis Defense

## PhD in Civil Engineering (CE)

The concentration areas and specialized tracks of the PhD programs in CE are consistent with the fields of expertise and research interests of the faculty members and the existing research and laboratory facilities. The specialty areas are as follows:

### Structural and Materials Engineering

- Advanced design and behavior of concrete, steel structures and fiber-reinforced composites
- Strengthening and rehabilitation of structural systems, and structural health monitoring
- Advanced concrete technology including plain, hot-weathered and high-strength concrete
- Petrographic, chemical, and mechanical properties of sands and aggregates
- Seismic evaluation and assessment, and earthquake engineering design
- Numerical modeling and computer-aided structural engineering

## Construction Engineering and Management

- Pre-project planning and design management for construction projects
- Construction estimating, planning and scheduling
- Construction technologies, methods, equipment and safety
- Construction project delivery, management and contracts
- Construction contract administration and dispute resolution
- IT and BIM applications in construction
- Construction systems analysis and lean applications
- Sustainability issues related to building design and construction
- Construction business environment and risks

## Geotechnical Engineering

- Land reclamation and site improvement
- Geographic Information Systems (GIS) used in decision-making and expert tool applications
- Geo-environmental engineering with reference to waste disposal and site contamination
- Geotechnical earthquake engineering, geo-hazards and risk assessment
- Behavior of soils

## Transportation Systems

- Urban transportation planning and modeling (transport and mobility considerations in urban universities, characterization of uncontrolled traffic conditions and walkability in urban areas, travel demand modeling)
- Public transport (operational planning and market arrangement implications in mass transit systems)
- Transportation and the environment (modeling and estimation of traffic induced emissions)
- Road safety (modeling and simulation of aggressive driver behavior)
- Maritime transport (maritime shipping, optimization of container terminal operations)
- Project evaluation (feasibility assessment and project delivery of transport infrastructure projects)

# PhD in Environmental and Water Resources Engineering (EWRE)

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The PhD program in EWRE focuses on the following courses and research topics:

- Water and wastewater treatment systems
- Solid and industrial waste treatment/management
- Air quality management and air pollution control
- Environmental and water resources management and planning
- Water Quality Modeling
- GIS and IT applications for environmental and water resources management
- Watershed modeling and management
- Hydrologic systems analysis
- Hydraulic systems analysis
- Environmental biotechnology and bioremediation
- Fate and impact of emerging environmental contaminants
- Biofuels and bioenergy

## Course Descriptions

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### Common Courses

- CIVE 501**            **Computer Methods in Civil Engineering**            **3 cr.**  
 A course on the use of computers for analysis, design and decision-making in civil engineering, including programming, numerical, and CAD methods and applications.  
*Prerequisite: EECE 231.*
- CIVE 600A**            **Seminar in Civil Engineering**            **0 cr.**  
 A seminar that consists of current research or applied civil engineering projects presented by faculty members, students or invited speakers.
- CIVE 600B**            **Seminar in Environmental Engineering and Sciences**            **0 cr.**  
 A seminar that consists of current research or applied environmental projects presented by faculty members, students or invited speakers.
- CIVE 601**            **GIS and Geospatial Data Modeling**            **3 cr.**  
 A course that examines the concepts and principles of Geographic Information Systems (GIS). It provides coverage of state-of-the-art GIS methods and tools: spatial and terrain analysis, geostatistical analysis, time series analysis and development of GIS integrated models.
- CIVE 602**            **Experimental Design and Statistical Methods**            **3 cr.**  
 A course that covers the main steps required to efficiently plan, conduct, analyze and interpret results from experimental and observational studies. The course focuses on statistical inference and modeling. Topics covered include ANOVA, t-tests, regression models and non-parametric tests. The course involves working within a statistical modeling environment.

**CIVE 603 Numerical Modeling 3 cr.**  
 A course that deals with ordinary differential equations: initial-, boundary- and characteristic-value problems; partial differential equations: steady state, time dependent and oscillatory problems; techniques: Runge-Kutta, shooting, iterative and finite difference methods. *Prerequisite: MATH 251.*

## Structural Courses

**CIVE 610 Numerical Methods in Structural Analysis 3 cr.**  
 A course that introduces the matrix approach for the modeling and analysis of structural systems; computer modeling/analysis using specialized software (SAP2000); computer implementation and code development; nonlinear analysis of frames. *Prerequisites: CIVE 411 and EECE 231.*

**CIVE 611 Bridges 3 cr.**  
 A course that discusses types of bridges; influence lines; loads and their distribution on bridges; serviceability of bridges; methods of design of bridge deck, superstructure and substructure. *Prerequisite: CIVE 311.*

**CIVE 612 Advanced Steel Design 3 cr.**  
 A course that investigates stability, column strength, beam-columns, composite steel-concrete construction, plate buckling, plate girders, torsion, combined torsion and bending, eccentrically loaded connections, influence of connection stiffness on moment demand and general moment connection. *Prerequisite: CIVE 412.*

**CIVE 613 Prestressed Concrete 3 cr.**  
 A course on material characteristics, prestress losses, working strength design procedures, composite construction, ultimate flexural strength and behavior, shear design and continuous prestressed concrete members. *Prerequisite: CIVE 413.*

**CIVE 614 Special Topics in Concrete 3 cr.**  
 A course that reviews reinforced concrete (R/C) design; torsion in R/C members; wind load on structures; earthquake load and seismic design of structures; design of shear walls; design of corbels, brackets and deep girders; circular and rectangular water tanks; and spherical, conoidal, and ellipsoidal domes. *Prerequisite: CIVE 414.*

**CIVE 615 Strengthening and Rehabilitation of Concrete Structural Systems 3 cr.**  
 A course on assessment of materials and structural deficiency using field test or analytical methods; repair and strengthening materials; strengthening and repair techniques; strengthening of structural members in flexure, shear and axial load; and upgrading of gravity load-designed buildings for earthquake load resistance. *Prerequisites: CIVE 311 and CIVE 413.*

**CIVE 616 Earthquake Engineering 3 cr.**  
 A course that examines the nature of earthquake ground motion, seismic hazard evaluation in engineering practice, response analysis of structures and effect of soil conditions on structural response and behavior under earthquake ground motion and design of structures under earthquake loading. *Prerequisite: CIVE 411.*

**CIVE 710                    The Finite Element Method                    3 cr.**  
 A course that introduces basic elements, interpolation and shape functions, variational formulation methods, Galerkin and weighted residual methods, isoparametric elements, numerical integration, error estimation and modeling issues, and finite elements in structural dynamics. *Prerequisite: CIVE 610.*

**CIVE 711                    Advanced Mechanics of Solids                    3 cr.**  
 A course that covers theories of stress and strain; generalized Hook's law; modes of failure and failure criteria; energy principles and applications; torsion; beams on elastic foundations; introduction to the theory of plates; thin-wall and thick-wall cylinder. *Prerequisite: CIVE 411.*

**CIVE 712                    Structural Dynamics                    3 cr.**  
 A course on analysis of vibration of single degree, multi-degree and infinite degree of freedom systems; free and forced vibration response; analysis of dynamic response by approximate methods; introduction to earthquake engineering. *Prerequisite: CIVE 411.*

**CIVE 713                    Behavior of Reinforced Concrete Members                    3 cr.**  
 A course on building codes; limit state design; mechanical characteristics of concrete and steel reinforcement; creep and shrinkage; flexure: moment-curvature and force-deformation relationships; columns: axial force-moment-curvature relationships; shear: mechanisms of shear resistance and truss analogy; bond and anchorage of reinforcement. *Prerequisite: CIVE 414.*

**CIVE 714                    Seismic Design of Reinforced Concrete Structures                    3 cr.**  
 A course on the seismic behavior and design of reinforced concrete structures; introduction to concepts of seismic design and performance-based earthquake engineering; mechanical behavior of steel reinforcement, concrete and confined concrete under monotonic and cyclic loading; seismic behavior, analysis and design of reinforced concrete elements and systems; design of special structural/shear wall systems; design of special moment resisting frames. *Prerequisites: CIVE 411 and CIVE 414.*

## Construction Engineering and Management Courses

**CIVE 520                    Construction Contract Administration                    3 cr.**  
 The course deals with contract documents, with focus on specifications structure, procedural requirements, specifying methods and the basis for unit rate estimation. It covers the engineer's roles along with contract administration issues. *Prerequisite: CIVE 421.*

**CIVE 522                    Building Construction and Estimating                    3 cr.**  
 A course that exposes students to different building systems (concrete, masonry, steel, waterproofing, mechanical and electrical, etc.) and how to price them by choosing the best materials and methods. The use of drawings and specifications will also be covered. *Prerequisites: CIVE 400 (site work) and CIVE 421.*

**CIVE 524                    Logistics, Technologies and Productivity Concepts                    3 cr.**  
 The course covers construction site layout, team organization, information flow and complexities. Focus is on productivity improvement approaches, data gathering for analysis of construction operations, issues related to process innovation and automation.

- CIVE 525                    Design of Temporary Support Structures                    3 cr.**  
A course that covers design and construction of temporary support structures used in the construction industry, including concrete formwork, scaffolding, caissons, cofferdams and dewatering systems.
- CIVE 620                    Pre-Project Planning and Feasibility Analysis                    3 cr.**  
A course that covers the studies needed to make a go-ahead decision, including assimilation of client needs, surveys of project area and infrastructure conditions, scope validation, team development, project planning and cost estimation, and financial feasibility. *Prerequisite: CIVE 421 or equivalent.*
- CIVE 621                    Design Management for Large Projects                    3 cr.**  
The course covers the characteristics of the design phase, design team selection, and design services agreement formation and negotiation. It focuses on value engineering and management, constructability considerations and project cost management during design.
- CIVE 622                    Advanced Topics in Construction Management (Blended)                    3 cr.**  
A course that focuses on the construction phase of a project's life cycle. Topics include: site organization structure, construction safety, labor management, materials procurement systems, site information management, scheduling, project controls and sustainability. *Prerequisite: CIVE 421 or equivalent.*
- CIVE 623                    Construction Project Management                    3 cr.**  
The course offers an extended overview of project management. It covers integrated planning-estimating-scheduling concept; project time, budget and quality baselines; materials management and subcontracting issues; and integrated project cost-time control. *Prerequisite: CIVE 421 or equivalent.*
- CIVE 624                    Building Information Modeling                    3 cr.**  
A course that covers Building Information Model (BIM) use and benefits in design and construction. It addresses collaborative design, clash detection, level of development (LOD), BIM contracts, automated code checking, simulation, BIM and lean applications, and integrated project delivery.
- CIVE 625                    IT Applications in Construction                    3 cr.**  
A course that covers computing tools impacting the construction industry such as mobile sensing, instrumentation and information systems to support field engineering tasks and computerized systems applications to perform specific functions, such as estimating, scheduling and cost control.
- CIVE 626                    Lean Construction Methods and Applications (Blended)                    3 cr.**  
A course on lean theory, production control, value stream mapping, process improvement, project definition, lean design, integrated project delivery, advanced lean scheduling, risk assessment, budget under uncertainty and project monitoring. *Prerequisite: CIVE 421.*
- CIVE 627                    Construction Systems Analysis and Simulation                    3 cr.**  
A course that covers planning and simulation modeling of construction operations, design of efficient processes, construction productivity and resource use considerations, production system design, construction supply chain management and analysis of construction systems.

**CIVE 628                    Sustainable Building Design and Construction                    3 cr.**  
 A course that covers principles of sustainable design and construction, including life-cycle assessment, economic and environmental impacts, carbon footprint, and green building rating systems such as LEED and BREEAM.

**CIVE 629                    Construction Business Management                    3 cr.**  
 A course that covers the principles of business management of construction companies and projects including financial management, accounting, costs and profits management, cash flows management, evaluation of sources of construction funding and financial decisions analysis. *Prerequisite: CIVE 370.*

**CIVE 720                    Construction Technology for Tall Buildings                    3 cr.**  
 A course on the latest construction practices and processes for tall buildings from foundation to roof. It covers advanced methods, materials, equipment and systems used for the construction of tall buildings, as well as principles of sustainable construction. *Prerequisite: CIVE 422.*

**CIVE 721                    Advanced Scheduling Analysis                    3 cr.**  
 A course that provides advanced techniques in construction scheduling. It examines monitoring, updating and controlling the project schedule. It introduces the methods used in performing forensic scheduling analysis. *Prerequisite: CIVE 423.*

**CIVE 722                    Project Deliverance and Contracts                    3 cr.**  
 The course offers an overview of project delivery organizations, risk considerations and contracts. It covers the elements of construction contracts, with emphasis on contract formation, substantial completion and close-out processes. *Prerequisite: CIVE 421 or equivalent.*

**CIVE 723                    Dispute Resolution on Projects                    3 cr.**  
 The course covers construction contract conditions governing claims and disputes. Focus is on claim evolvement and administration (including issues dealing with time barring, notification and substantiation) and ADR methods and amicable settlement. *Prerequisite: CIVE 520.*

**CIVE 724                    Mediation of Engineering Disputes                    3 cr.**  
 This course focuses on the use of mediation for resolving construction related disputes. Topics include: dispute avoidance in construction, alternative dispute resolution techniques, and the mechanics of mediation and negotiation. *Prerequisite: CIVE 520.*

**CIVE 725                    Construction Decisions Under Uncertainty                    3 cr.**  
 A course that covers construction project and organization decisions for the uncertain future. The course addresses decision theory, competitive bid analysis, probabilistic modeling and simulation, and multiple regression analysis in managing construction. *Prerequisite: STAT 230.*

## Geotechnical Courses

**CIVE 631 Applied Foundation Engineering 3 cr.**  
A course on braced excavations, retaining structures, deep foundations, slope stability and computer applications. *Prerequisite: CIVE 431.*

**CIVE 632 Soil Behavior 3 cr.**  
A course on soil mineralogy, soil formation and composition; influence of geological factors on properties; colloidal phenomena in soils; soil structure; analysis of conduction phenomena (hydraulic, diffusive, thermal and electrical); compressibility, strength and deformation properties. *Prerequisite: CIVE 430.*

**CIVE 633 Soil and Site Improvement 3 cr.**  
A course that covers compaction, admixture stabilization, foundation soil treatment, reinforced soil and composite materials, and material sites reclamation.

**CIVE 634 Shear Strength of Soils 3 cr.**  
A course that covers stresses within a soil mass, tests to measure stress strain properties, stress-strain relationships, shear strength, drained and undrained conditions, constitutive models, and failure criteria applications. *Prerequisite: CIVE 430.*

**CIVE 635 Earth Dams 3 cr.**  
A course that examines hydraulic dams, rolled earth dams, homogenous dams, thin core dams, filters, causes of dam failures, see page control and seismic stability of dams.

**CIVE 636 Geotechnical Earthquake Engineering 3 cr.**  
A course on causative mechanisms and characteristics of earthquakes; evaluation dynamic soil properties local site response; seismic soil-structure interaction; evaluation and mitigation of soil liquefaction; seismic code provisions and additional current topics. *Prerequisite: CIVE 430.*

## Water Resources Courses

**CIVE 541 Engineering Hydrology 3 cr.**  
A course that outlines hydrologic principles, rainfall-runoff analysis, flood routing, frequency analysis and ground water hydrology. *Prerequisites: CIVE 340 and MATH 202.*

**CIVE 542 Urban Hydrology 3 cr.**  
A course that covers design rainfall, infiltration, overland flow, channel flow, storm sewer hydraulics, stormwater detention and simulation models. *Prerequisite: CIVE 440.*

**CIVE 640 Advanced Hydraulics 3 cr.**  
A course that covers closed conduit flow, water distribution systems, transient analysis, open channel flow, flood control, culvert hydraulics and design of various hydraulic structures. *Prerequisite: CIVE 440.*

**CIVE 641 Surface Water Hydrology 3 cr.**  
A course on design storm, rainfall-runoff modeling, flood routing, reservoir routing, simulation models and stochastic hydrology. *Prerequisite: CIVE 541 or equivalent.*



**CIVE 642                    Groundwater Hydrology                    3 cr.**  
 A course that deals with properties of groundwater, Darcy's law, steady groundwater flow, unsteady groundwater flow, well hydraulics, unsaturated flow, sea-water intrusion and numerical modeling. *Prerequisite: CIVE 541.*

**CIVE 644                    Coastal Engineering                    3 cr.**  
 A course on small-amplitude wave theory (linear theory); finite-amplitude wave theory (nonlinear theory); conoidal wave theory; solitary wave theory; wave refraction, diffraction and reflection; wave forces and interaction with man-made structures; and design of maritime structures, e.g., breakwaters. *Prerequisite: CIVE 440.*

**CIVE 645                    Surface Water Quality Modeling and Management                    3 cr.**  
 An introductory course on surface water quality pollution problems in streams, rivers, lakes, reservoirs and estuaries with a focus on both the quantitative modeling aspects of surface water quality and the management and policy aspects of it. Both mechanistic and empirical models for assessing the status of surface water bodies are introduced.

**CIVE 647                    Water Resource Systems: Planning and Management                    3 cr.**  
 A course that introduces principles demonstrating steps in engineering policy planning as it applies to water resources management. Emphasis will be placed on systems and socio-economic analysis, conflict management and concepts in strategic assessment.

**CIVE 648                    Climate Change and Water Resources                    3 cr.**  
 An introductory course on global climate change and its potential impacts on water resources and related sectors. It explores drivers of climate change, greenhouse gases emissions and mitigation efforts, and adaptation options with emphasis on Integrated Water Resources Management.

**CIVE 740                    Transport Phenomena in Surface and Subsurface Waters                    3 cr.**  
 A course on advection, diffusion and dispersion of pollutants; transport in rivers and estuaries; transport in groundwater; numerical modeling; design of wastewater discharge system.

## Environmental Courses

**CIVE 550                    Water Treatment and Laboratory                    3 cr.**  
 A course that examines the quality and principles of municipal and industrial water treatment processes and methods of testing for physical, chemical and biological parameters. *Prerequisite: CIVE 251 or equivalent, or consent of instructor.*

**CIVE 551                    Wastewater Treatment and Laboratory                    3 cr.**  
 A course that examines the quality and principles of municipal wastewater treatment processes and methods of testing for physical, chemical and biological parameters. *Prerequisite: CIVE 252 or equivalent, or consent of instructor.*

**CIVE 552                    Waste Management and Treatment                    3 cr.**  
 A course on engineering principles, practices and techniques for the management of solid wastes: sources, composition, properties, impacts, generation, storage, collection and transport, processing, resource recovery and disposal.

- CIVE 553 Environmental Biotechnology 3 cr.**  
A course that examines current and emerging environmental biotechnologies used for environmental quality evaluation, monitoring and remediation of contaminated environments, and provides students with working knowledge of the science that underpins them. *Prerequisite: CIVE 252 or equivalent, or consent of instructor.*
- CIVE 555 Air Quality Management 3 cr.**  
A course on the principles, practices and techniques for the management of air pollution: Types, sources, properties, impacts, standards, control technologies, atmospheric dispersion, emissions and indoor air quality.
- CIVE 650 Water and Sewage Works Design 3 cr.**  
A course that examines the design of water and wastewater schemes, including design reports and a literature search on the development of conventional treatment processes. *Prerequisite: CIVE 550 or CIVE 551, or consent of instructor.*
- CIVE 651 Processes in Water and Wastewater Treatment 3 cr.**  
A course on sedimentation, filterability, permeability and fluidization, ion exchange, aeration, flotation, membrane filtration and aerobic digestion. Experimental applications of processes. *Prerequisites: CIVE 251 and CIVE 252, or equivalents; or consent of instructor.*
- CIVE 652 Landfill Engineering Design 3 cr.**  
A course on solid waste disposal with emphasis on design development of landfill elements (site selection and characterization, gas extraction and management, leachate collection and management, liners, covers, closure and post-closure monitoring. *Prerequisite: CIVE 552.*
- CIVE 653 Environmental Chemistry and Microbiology 3 cr.**  
A course that deals with organic, inorganic and physical chemistry; chemical equilibrium; reaction kinetics; acidity, alkalinity; composition, morphology and classification of micro-organisms; energy, metabolism and synthesis; growth, decay and kinetics; and biological water quality indicators. *Prerequisites: CIVE 251 and CIVE 252, or equivalents; or consent of instructor.*
- CIVE 654 Environmental Bioremediation 3 cr.**  
A course that discusses the application of biological treatment for the remediation of contaminated environments and highlights current engineering methods/design used to enhance biodegradation.
- CIVE 655 Air Pollution and Control 3 cr.**  
A course that examines processes and design equipment for the control of particulates and gaseous emissions. *Prerequisite: Consent of instructor.*
- CIVE 656 Environmental Impact Assessment 3 cr.**  
A course on procedures of assessing/preparing/reviewing/presenting environmental impacts of developmental projects/facilities: industrial facilities, waste management/disposal, wastewater treatment, transportation, dams and reservoirs, irrigation/drainage schemes, coastal zone developments, natural resource management, etc. *Prerequisite: E4 status or consent of instructor.*

**CIVE 657                    Methods of Environmental Sampling and Analysis                    3 cr.**  
 A course on sampling techniques and instrumental methods in environmental sciences; determination of pollutants in water, air and soil; analytical techniques; adaptation of procedures to specific matrices; case studies. *Prerequisites: CIVE 251 and CIVE 252, or equivalents; or consent of instructor.*

**CIVE 658                    Industrial Waste Management                    3 cr.**  
 A course on engineering principles, practices and techniques for the management of industrial hazardous wastes: sources, generation and properties. Impacts and auditing of industrial facilities. Basic treatment processes and disposal methods. Site remediation. *Prerequisite: E4 status or consent of instructor.*

**CIVE 659                    Environmental and Water Conflict Management                    3 cr.**  
 A course on the development of case studies in environmental and water conflict management taught under a framework of role-play of opponents' perspective and decision-making thereof.

**CIVE 751                    Wastewater Reclamation and Reuse                    3 cr.**  
 A course that examines environmental issues in water reuse, risk assessment, water reclamation technologies, storage of reclaimed water, usage of reclaimed water, and planning of wastewater reclamation and reuse. *Prerequisite: CIVE 551.*

**CIVE 755                    Air Pollution Modeling                    3 cr.**  
 A course that deals with mathematical models, air pollution meteorology, plume rise, dispersion and atmospheric chemistry, meteorological models, as well as Gaussian, statistical and other special application models. *Prerequisite: CIVE 555 or consent of instructor.*

## Transportation Courses

**CIVE 661                    Urban Transportation Planning I                    3 cr.**  
 An introductory course on methods and models used in transportation planning with emphasis on the urban context. Topics include travel patterns in urban areas, data requirements for planning and data collection techniques, transportation/land-use interaction, travel demand and network models, transport supply options and evaluation techniques. *Prerequisite: CIVE 460 or CIVE 461.*

**CIVE 662                    Traffic Engineering                    3 cr.**  
 A course that outlines traffic engineering studies, traffic control of signalized and unsignalized intersections, signal control hardware and maintenance, arterial performance and operations, and network optimization. *Prerequisite: CIVE 460.*

**CIVE 663                    Transportation Systems Analysis                    3 cr.**  
 A course that introduces methods, models and applications of transportation systems analysis focusing on both supply/performance and demand/economics. *Prerequisite: CIVE 460 or CIVE 461.*

**CIVE 664                    Design and Management of Transport Operations                    3 cr.**  
 A course on probabilistic and optimization methods for designing efficient operations in freight carrier, airline, transit and traffic modes. Topics include crew and vehicle

scheduling in freight, airline, transit modes; vehicle routing and facility location problems in carrier systems; runway and air traffic operations; and reliability in transit services. *Prerequisites: CIVE 460 and STAT 230, or equivalents.*

**CIVE 665                      Transportation Economics                      3 cr.**  
A course that investigates the application of economic principles to the evaluation of projects and policies in the transport sector such as transport project benefits, costs and financing, and pricing in the transport sector. *Prerequisite: CIVE 461.*

**CIVE 666                      Public Transportation                      3 cr.**  
A course on public transportation modes and services; single route, network and strategic planning; tasks involved in system operations; management of public transportation organizations; privatization issues. *Prerequisite: CIVE 460 or CIVE 461.*

**CIVE 761                      Urban Transportation Planning II                      3 cr.**  
A course that examines advanced topics in urban transportation planning, transportation systems management techniques, travel demand analysis and discrete choice modeling of travel demand. *Prerequisite: CIVE 661.*

**CIVE 762                      Traffic Flow Theory                      3 cr.**  
A course on characteristics of traffic flow, density and speed; models describing traffic flows; hydrodynamic analogue; and computer simulation models. *Prerequisite: CIVE 460.*

## Materials Courses

**CIVE 670                      Concrete Technology                      3 cr.**  
A course that examines Portland cements; aggregates; pozzolans; proportioning normal concrete mixtures; pumping concrete; consolidating, finishing and curing concrete; durability; testing hardened concrete; high-strength concrete; light and heavy weight concretes; and hot and cold weather concreting.

**CIVE 671                      Pavement Engineering                      3 cr.**  
A course that examines highway and airport pavement design, flexible and rigid pavement types and wheel loads, stresses in flexible and rigid pavements, pavement behavior under moving loads and soil stabilization. The course covers empirical, mechanistic-empirical and mechanistic design methodologies. *Prerequisite: CIVE 461.*

**CIVE 672                      Highway Materials and Construction                      3 cr.**  
A course that covers various materials constituents in highway pavement structures with emphasis on asphalt concrete, aggregate-soil mixtures, geotextiles and bituminous liquids. Materials properties, design, quality control and methods of construction will be described. *Prerequisite: STAT 230.*

**CIVE 673                      Pavement Management Systems                      3 cr.**  
A course that covers the principles of pavement management including types of pavement systems, common distresses and their assessment, pavement evaluation and rating systems, in addition to performance prediction and life cycle analysis. Various field assessment methods in addition to non-destructive and accelerated tests will be discussed and demonstrated. Maintenance and rehabilitation techniques will be compared with emphasis on selection of the most efficient, environment-

friendly and cost-effective approaches. Students will utilize computer applications using GIS, regional and international inventory data and relevant software packages. *Pre or corequisite: CIVE 671 or CIVE 672.*

**CIVE 770                      Viscoelastic Behavior of Construction Materials                      3 cr.**  
A course that covers viscoelastic behavior of construction materials, particularly asphalt concrete and polymer composites. The course deals with basic concepts in material characterization, rheology, time-temperature superposition principles, and linear and nonlinear viscoelastic models.

## Multidisciplinary Courses

**CIVE681                      Evaluation of Cost Alternatives                      3 cr.**  
A course that covers the basic principles of economic evaluations using fundamental concepts of time value of money to compare cost alternatives related to construction, design and real property development.

**CIVE 682                      Infrastructure Systems Management                      3 cr.**  
A course on modeling and optimization methods and their application to inspection, performance prediction and maintenance decision-making for the management of infrastructure systems.

**CIVE 683                      Reliability Based Design of Civil Systems                      3 cr.**  
A course that covers applications of reliability theory in assessing the safety and reliability of civil systems in the presence of uncertainty; decision-making and risk analysis; definition of the probability of failure; modeling uncertainty in resistance and load; load and resistance factor design (LRFD) in structural and geotechnical engineering; basics of design code calibration.

**CIVE 684                      Environmental Geotechnics                      3 cr.**  
A course on geotechnical practice in environmental protection and restoration; influence of physical and chemical processes in soils on the evaluation of contaminant distribution; design of waste containment systems, slurry walls and soil stabilization; the applicability and use of geosynthetics; and technologies for site restoration and cleanup. *Prerequisite: CIVE 430.*

**CIVE 685                      Environmentally Sustainable Renewable Energy Sources                      3 cr.**  
A course that covers basic principles, potentials and limitations of various renewable energy sources and technologies, including solar energy, hydroelectricity, wind energy, bio-energy, fuel cells, batteries and supercapacitors. Sustainability and impact of renewable energy sources on the environment will be discussed. *Prerequisite: CIVE 251 or CHEM 202.*

**CIVE 686                      Environmentally Responsive Buildings                      3 cr.**  
A course that enhances knowledge pertaining to design aspects and application possibilities of climate responsive and environmentally friendly buildings. The impact of using construction building materials throughout the lifecycle of projects will also be discussed. At the end of the course, students will be equipped with the necessary knowledge to make informed decisions regarding green projects in their careers.

## Special Courses

<b>CIVE 690</b>	<b>Special Projects</b>	<b>3 cr.</b>
<b>CIVE 691</b>	<b>Special Topics in Civil and Environmental Engineering</b>	<b>3 cr.</b>
<b>CIVE 692</b>	<b>Advanced Topics in Civil and Environmental Engineering</b>	<b>3 cr.</b>
<b>CIVE 799</b>	<b>ME/MS Thesis</b>	<b>6 cr.</b>
<b>CIVE 980</b>	<b>Qualifying Exam I: Comprehensive Exam</b>	<b>0 cr.</b>
<b>CIVE 981</b>	<b>Qualifying Exam II: Thesis Proposal Defense</b>	<b>0 cr.</b>
<b>CIVE 982</b>	<b>PhD Thesis</b>	<b>3 cr.</b>
<b>CIVE 983</b>	<b>PhD Thesis</b>	<b>6 cr.</b>
<b>CIVE 984</b>	<b>PhD Thesis</b>	<b>9 cr.</b>
<b>CIVE 985</b>	<b>PhD Thesis</b>	<b>12 cr.</b>
<b>CIVE 986</b>	<b>PhD Thesis</b>	<b>0 cr.</b>
<b>CIVE 987</b>	<b>PhD Thesis Defense</b>	<b>0 cr.</b>