Department of Civil and Environmental Engineering

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Lecturers: Basha, Hisham; El Khatib, Helim; Fawwaz, Youssef; Hatem-Musallem, Manal; Karnib, Ali; Masri, Adnan; Nader, Halim; Nasreddine, Khaldoun; Sadeck, Salah El-Dinn; Semerjian, Lucy
Instructors: Abboud, Antoine; Haroun, Akram; Hasbini, Hayssam; Nehme, Elias; Tawil, Mona

Graduate Programs

Master of Engineering and Master of Science Programs

Programs are offered leading to the ME degree in Civil and Environmental Engineering with the following majors:
- Master of Engineering (ME); major, Civil Engineering (CE)
- Master of Engineering (ME); major, Environmental and Water Resources Engineering (EWRE)

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

The master’s degree programs prepare students through course work and research giving them in-depth knowledge in the various fields of civil and environmental engineering. They provide students with significant research experience, and equip graduates with the necessary tools for professional practice and/or the pursuit of higher education.
Doctor of Philosophy Programs

Two programs are offered leading to the PhD degree in Civil and Environmental Engineering with the following specializations:

- Doctor of Philosophy (PhD); specialization, Civil Engineering; areas of concentration:
  - Structural and Materials Engineering
  - Geotechnical Engineering
  - Transportation Systems

- Doctor of Philosophy (PhD); specialization, Environmental and Water Resources Engineering (EWRE)

Master of Engineering (ME) Major: Civil Engineering (CE)

General Information

The Department of Civil and Environmental Engineering offers two graduate programs leading to the degree of Master of Engineering (ME) major, Civil Engineering (CE): CE Thesis Program and CE Non-Thesis Program. The programs prepare students through course work (and research in the case of the Thesis Program) giving them in-depth knowledge in at least one of the following fields of civil engineering: construction, structures, transportation, and geotechnical engineering. All graduate students must satisfy either the thesis program requirements 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 civil engineering graduate program a student must hold a bachelor’s degree in civil engineering or its equivalent. Engineering graduate students in majors other than civil engineering may be admitted to the program and are required to take prerequisite courses set by the department. Students must also satisfy the requirements of the University and the Faculty of Engineering and Architecture for admission to graduate study, as specified in the relevant sections of this catalogue.

Graduates of universities other than AUB may be required to take undergraduate prerequisite courses to make up for deficiencies they may have. A minimum grade of 70, or its equivalent, is required in each of these courses. No credit, toward the graduate degree, is given for these courses.

Thesis Program Requirements

In order to fulfill graduation requirements in the 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 six credit hours. The required course work for the ME degree with a major in civil engineering (Thesis Program) is distributed as follows:

- A minimum of four courses (12 credit hours) in the field of specialty
- A maximum of two courses (6 credit hours) in a relevant field
- A maximum of two courses (6 credit hours) of free electives
Courses in the last two categories need to be approved by the department.

All students registered in the program must take CIVE 797, Civil Engineering Seminar (0 credit), whenever offered.

A minimum of one calendar year of residence is required for graduation. The student must satisfy all relevant FEA and AUB requirements.

**Non-Thesis Program Requirements**

In order to fulfill graduation requirements in the Non-Thesis Program a student must complete a minimum of 33 credit hours of graduate courses. The required course work for the ME degree with a major in civil engineering (Non-Thesis Program) is distributed as follows:

- A minimum of five courses (15 credit hours) in the field of concentration
- A maximum of three courses (9 credit hours) in a relevant field
- A maximum of three courses (9 credit hours) of free electives

Courses in the last two categories need to be approved by the department.

All students registered in the program must take CIVE 797, Civil Engineering Seminar (0 credit), whenever offered.

A minimum of one calendar year of residence is required for graduation. The student must satisfy all relevant FEA and AUB requirements.

**Master of Engineering (ME)**

**Major: Environmental and Water Resources Engineering (EWRE)**

**General Information**

The Department of Civil and Environmental Engineering offers a graduate program leading to the degree of Master of Engineering (ME): major, Environmental and Water Resources Engineering (EWRE). The program prepares students through course work and research giving them in-depth knowledge in the fields of environmental and water resources engineering.

In order to fulfill graduation requirements, a student must complete a minimum of 24 course credit hours as well as a six credit hour thesis. This may be accomplished on either a full, or a part-time basis. A minimum of one calendar year of residence is required for graduation.

The ME program in Environmental and Water Resources Engineering offers two tracks with course requirements as listed below.

**Track A**
- Specialization in Environmental Engineering
- Minor in Water Resources Engineering

**Track B**
- Specialization in Water Resources Engineering
- Minor in Environmental Engineering
Admission Requirements

• To be eligible for admission to the environmental and water resources engineering graduate program, a student must hold a bachelor’s degree in any approved discipline of engineering and must satisfy the requirements of the University and the Faculty of Engineering and Architecture for admission to graduate study, as specified in the relevant sections of this catalogue.

• All students admitted to the program are required to take, or to have taken, the following courses, or their equivalent, as prerequisites.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 202</td>
<td>Differential Equations</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CIVE 340</td>
<td>Fluid Mechanics and Laboratory</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CIVE 350</td>
<td>Environmental Engineering</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CIVE 441</td>
<td>Engineering Hydrology</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CIVE 450</td>
<td>Water and Wastewater Treatment and Laboratory</td>
<td>3 cr.</td>
</tr>
</tbody>
</table>

• A minimum grade of 70, or its equivalent, is required in each of these courses. Students required to take undergraduate prerequisite courses to make up for deficiencies will receive no credits toward the graduate degree.

• All students registered in the program must take ENSC 690, Seminar in Environmental Sciences (0 credit), whenever it is offered.

Course Requirements

Track A

Course Type
Specialization: Environmental Engineering
Minor: Water Resources Engineering

Core Group A1 9
Electives I Group A2+A 9
Electives II Group B1+B2 6
Thesis CIVE 799 6
Total 30

Track B

Course Type
Specialization: Water Resources Engineering
Minor: Environmental Engineering

Core Group B1 6
Electives I Group B1+B2+AB 12
Electives II Group A1+A2 6
Thesis CIVE 799 6
Total 30

Other relevant graduate courses from any Faculty may be taken as Electives I (up to a maximum of two courses) with the consent of the academic adviser and the approval of the chairperson.
<table>
<thead>
<tr>
<th>Group A1</th>
<th>Core Courses in Environmental Engineering</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIVE 649</td>
<td>Microbial Ecology and Molecular Biology for Engineers</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 651</td>
<td>Environmental Chemistry and Microbiology</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 654</td>
<td>Solid Waste Management I</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 656</td>
<td>Air Pollution and Control I</td>
<td>3</td>
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</table>

<table>
<thead>
<tr>
<th>Group A2</th>
<th>Electives in Environmental Engineering</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIVE 650</td>
<td>Methods of Environmental Sampling and Analysis</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 652</td>
<td>Environmental Management and Decision Making</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 653</td>
<td>Water and Sewage Works Design</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 655</td>
<td>Solid Waste Management II</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 657</td>
<td>Air Pollution and Control II</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 658</td>
<td>Industrial/Hazardous Waste Management</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 659</td>
<td>Environmental Impact Assessment</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 750</td>
<td>Wastewater Reclamation and Reuse</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 751</td>
<td>Air Pollution Modeling</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 752</td>
<td>Environmental Case Studies and Conflict Resolution</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 753</td>
<td>Processes in Water and Wastewater Treatment</td>
<td>3</td>
</tr>
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<table>
<thead>
<tr>
<th>Group B1</th>
<th>Core Courses in Water Resources Engineering</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>CIVE 640</td>
<td>Hydraulic Structures</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 641</td>
<td>Surface Water Hydrology</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 642</td>
<td>Ground Water Hydrology</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 644</td>
<td>Coastal Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 646</td>
<td>Water Resource Systems: Planning and Management</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 647</td>
<td>GIS for Water Resources and Environmental Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 648</td>
<td>Climate Change and Water Resources</td>
<td>3</td>
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<table>
<thead>
<tr>
<th>Group B2</th>
<th>Electives in Water Resources Engineering</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CIVE 643</td>
<td>Hydraulics of Open Channels</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 645</td>
<td>Transport Phenomena in Surface and Subsurface Waters</td>
<td>3</td>
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<table>
<thead>
<tr>
<th>Group AB</th>
<th>Common Requirements/Electives in Environmental and Water Resources Engineering</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CIVE 796</td>
<td>Special Projects</td>
<td>3</td>
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<tr>
<td>ENSC 690</td>
<td>Seminar in Environmental Sciences</td>
<td>0</td>
</tr>
<tr>
<td>CIVE 798</td>
<td>Special Topics</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 799</td>
<td>MS Thesis</td>
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<tr>
<td>CIVE 670</td>
<td>Computer Methods in Civil Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CIVE 671</td>
<td>Numerical Modeling</td>
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<tr>
<td>ENMG 623</td>
<td>Stochastic Models and Applications</td>
<td>3</td>
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</table>
Master of Science (MS)  
**Major: Environmental Technology (ET)**

The Department of Civil and Environmental Engineering offers a graduate program leading to the degree of Master of Science (MS): major, Environmental Technology (ET). The program, which is part of the Interfaculty Graduate Environmental Sciences Program (IGESP), is open to non-engineering students who hold a degree in basic sciences.

For more details on the Environmental Technology program refer to the Interdisciplinary Research Centers and Programs section of this catalogue.

Doctor of Philosophy (PhD)  
**Specializations: Civil Engineering (CE); Environmental and Water Resources Engineering (EWRE)**

**General Information**

Through the PhD programs offered by the CEE department, graduate students are trained to address and solve current challenges in civil and environmental engineering, and to develop theory, methodology, and adequate experimental skills to investigate emerging issues in this domain. In addition, PhD students are trained to be future educators, to participate in industrial research, and to work on interdisciplinary teams. The PhD programs provide training that equips graduate students with the maturity and ability to assume academic and professional leadership roles in various fields related to civil and environmental engineering. These programs address issues and provide solutions which directly contribute to societal progress and development in this part of the world. The objectives of the PhD program are to:

- cultivate expertise in specialized concentration areas of civil and environmental engineering;
- develop research skills which include the formulation and study of original ideas as well as development of theory, methodology, and experimental skills;
- promote involvement in inter-disciplinary teams and activities and develop skills pertinent to group and collaborative efforts; and
- acquire teaching expertise through offering class lectures and assisting in courses and labs.

**Admission Requirements**

Applicants to the PhD program and the accelerated track are expected to have demonstrated distinct academic ability. To be eligible for admission to the program, a candidate

- for the regular track must hold a master’s degree in civil engineering or a related discipline from AUB or another recognized institution of higher learning with a minimum cumulative average of 85 over 100 or its equivalent.
• holding a BS in civil engineering or a related discipline may apply to the accelerated program. These students will be required to take additional courses as recommended by the department on a case by case basis.

• provide scores for the General Exam part of the Graduate Record Examination (GRE).

• students from non-English-speaking countries must show proficiency in the English language (refer to catalogue section on English Language Proficiency Requirement).

• submit a complete application including a statement of interest, transcripts of academic record from all institutions attended after high school, a curriculum vita, and three letters of recommendation, 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 decision for the PhD program is made upon the recommendations of the CEE department and the FEA Graduate Studies Committee, with the approval of the AUB Board of Graduate Studies.

Program Requirements

Course 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 dissertation work. The course work consists of a minimum of 12 credits in the area of concentration within a major, six credits in a related area, and six credits in an area other than the candidate's field of research, which can be taken inside or outside the department.

The accelerated PhD program requires a minimum of 36 credit hours of course work beyond the bachelor's degree and 42 credit hours of dissertation work. The course work consists of a minimum of 21 credits in the area of concentration within a major, nine credits in a related area, and six credits in an area other than the candidate's field of research, which can be taken inside or outside the department. Courses selected must be approved by the graduate student’s adviser. It is expected that the student will be involved in setting a plan of course work with the help of the dissertation adviser that is consistent with the area of research.

Candidacy Requirements

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. A student on the regular track must take the comprehensive exam not later than 12 months after enrollment in the PhD program. Normally, a student on the accelerated track will take the comprehensive exam 18 months after enrollment in the PhD program and after completing at least 21 credits of course work with a minimum of 12 credits in the area of concentration. Students who do not pass the comprehensive exam may, upon the recommendation of the department, take it for a second time after an interval of at least three months. Failure on the second attempt will result in the student's discontinuation from the graduate program.
Qualifying Exam

All students must successfully complete a qualifying examination, which is to be taken at least two semesters prior to the final defense of the PhD dissertation. The qualifying exam, administered by the dissertation committee is an oral exam in which the student presents his/her research proposal. This proposal should include the projected research methodology and anticipated outcomes, as well as the preliminary results. The objective of the oral exam is to determine whether the candidate's proposal and methodology are adequate for a PhD dissertation. The candidate must show positive preliminary results and considerable promise of original research. It is the responsibility of the student to inform and update the dissertation committee members about his/her research progress, especially during the period between the comprehensive and qualifying exams. Students who do not pass the qualifying exam are allowed to take it for a second time after an interval of three months. Failure on the second attempt will result in the student's discontinuation from the graduate program.

Admission to Candidacy

Students enrolled in the program must be admitted to candidacy at least two semesters before obtaining their PhD degree. To be eligible for candidacy, students must

- pass the qualifying and comprehensive examinations, and
- complete at least 24 credits of course work on the regular track and 36 credits of course work on the accelerated track with a minimum cumulative grade average of 85.

Dissertation Requirements

In partial fulfillment of the requirements for the degree of doctor of philosophy, a student must submit a dissertation (equivalent to 24 credit hours on the regular track and 42 on the accelerated track) that is expected to make a significant and original contribution to his/her field of research. The research work is to be carried out under the supervision of a full-time faculty member from the Civil and Environmental Engineering department.

Dissertation Committee

The dissertation work will be supervised by a committee of at least five members. One of the committee members should be from outside the department/program and one from outside the university. The thesis adviser and at least three of the committee members must be of professorial rank. All members of the committee must hold a doctoral degree in a relevant field. The chair of the committee must be a full professor who is not the PhD thesis adviser. The PhD dissertation committee must be approved by the department, the Faculty graduate studies committee, and by the AUB Board of Graduate Studies.

The doctoral dissertation committee approves the thesis topic, research plan, conducts the comprehensive and qualifying exams, and the thesis defense.

The PhD thesis topic, examining committee, and admission to candidacy require the approval of the AUB Board of Graduate Studies (BGS).

The thesis proposal and the selection of the dissertation committee should be approved by the AUB BGS at least two semesters before the student defends his/her thesis.
Dissertation Defense

All PhD candidates must defend their dissertation in public. The candidate will be examined by the dissertation defense committee chaired by one of the members of the dissertation committee other than the dissertation adviser. A grade of pass or fail will be reported for the PhD dissertation. If a grade of fail is reported, the student may resubmit the dissertation and defend it after a period of at least four months.

Residence Requirements

To satisfy the minimum residence requirements for the PhD degree, all students must register and be in residence for at least three years beyond the completion of the master’s degree. To satisfy the minimum residency requirements for the PhD degree in the accelerated PhD program, all students must register for at least eight semesters beyond the completion of the bachelor’s degree. The requirements for the degree of doctor of philosophy must be completed within a period of six years after joining the PhD program. Extension beyond the six-year period will require the approval of the AUB Board of Graduate Studies.

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 grade of 80 courses taken at the PhD level;
- 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;
- Pass the PhD dissertation defense;
- Satisfy the minimum residence requirements;
- Present evidence of a paper submittal to a leading international journal, based on the PhD research;
- Have at least one accepted refereed conference paper, 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.

<table>
<thead>
<tr>
<th>Year</th>
<th>Semester</th>
<th>Course</th>
<th>Credits</th>
<th>Total</th>
<th>Timeline</th>
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<tbody>
<tr>
<td>1</td>
<td>Fall</td>
<td>Major course</td>
<td>3</td>
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<td></td>
<td></td>
<td>Major course</td>
<td>3</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minor course</td>
<td>3</td>
<td>9</td>
<td>Thesis Adviser Selection</td>
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<td>Spring</td>
<td>Major course</td>
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<td>9</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Major course</td>
<td>3</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

Comprehensive Exam
PhD in Civil Engineering (CE)

The concentration areas and specialized tracks of the PhD programs in CE and EWRE are consistent with the fields of expertise and research interests of the faculty members, and the existing teaching, research, and laboratory facilities, and relevant to local and regional needs.

The PhD program in CE will be offered in the following areas of concentration:

**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

**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**
- Intelligent Transportation Systems (ITS) - traveler information systems and behavior
- Public and urban transport planning and operations
- Transport operations management
- Transport infrastructure planning and management
- Air quality linkages and modeling
Construction Engineering

- Lean construction and productivity improvement in construction
- Building information modeling and knowledge management
- Applications of innovative sensing approaches and information technology to construction
- Construction processes and methods
- Life cycle cost analysis and value engineering for construction projects
- Sustainable construction
- Infrastructure health monitoring
- Procurement and supply chain management in construction

PhD in Environmental and Water Resources Engineering (EWRE)

The PhD program in EWRE provides courses and research opportunities along the following specialized tracks:

- Water and wastewater treatment systems
- Solid and industrial waste management
- Air pollution control and air quality management
- Environmental and water resources management and planning
- Water resource optimization and conflict management
- GIS and IT applications in water resources
- Risk assessment, mass emergency and disaster, with particular emphasis on dam safety
- Hydrologic systems analysis and watershed modeling and management
- Hydraulic systems analysis

Course Descriptions

Construction Sequence

CIVE 680  Construction Systems Analysis  3 cr.
This course addresses some principles and practices of modern construction engineering and management. It introduces lean project delivery in the AEC industry with a focus on work structuring and supply chain management. Topics include scheduling, productivity, simulation, uncertainty, variation; materials management; logistics; e-commerce; building information modeling (BIM); and integrated product and process design. Students use process simulation to assess performance of different system configurations applying the concepts learned in class on a real project. Prerequisites: CIVE 580 and working knowledge of Microsoft Excel, statistics, and probability theory.

CIVE 681  Infrastructure Construction and Rehabilitation  3 cr.
This is a course on urban requirements and engineering technologies and procedures for construction of infrastructure facilities including: roads and pavements, bridges, water and sanitary networks, electric power lines, and telephone/communication lines; as well as their applications to urban and rural areas. The course content also includes the study of quality (QA/QC), environment, and safety standards and their integration and management in construction projects.
CIVE 682  Construction Business Management 3 cr.
A course that covers the principles of business management of construction companies - theory as well as international and regional practice; an overview of construction business operations including strategic planning, organizational structure, accounting, financing, risk analysis, and quality; and the principles and sources of construction funding for contracting firms and projects.

CIVE 683  IT Applications in Construction 3 cr.
A course that covers computing tools impacting the construction industry and the analysis techniques used to determine company automation requirements; mobile computing and information systems to support field engineering tasks; computerized systems applications to perform specific functions, such as estimating, scheduling, cost control; emerging sensing and instrumentation technologies to solve construction problems and case studies.

CIVE 684  Building Information Modeling 3 cr.
A course that covers Building Information Model (BIM) use and benefits in the industry by different disciplines- integrated management of building data during its life cycle, three-dimensional, real-time, dynamic building modeling techniques to increase productivity in building design and construction; examination of BIM which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components required for estimation, bidding and scheduling into the model.

CIVE 685  Design and Analysis of Construction Operations 3 cr.
A course that covers planning and simulation modeling of construction operations, design of efficient processes, productivity and resource use considerations, site layout design and analysis, preplanning for construction operations, use of quantitative methods and queuing theory, and the effects of new technologies on construction operations.

CIVE 686  Lean Construction Methods and Applications (Blended) 3 cr.
In this course, students will learn about the Toyota production system, the last planner system, value stream mapping, process improvement and other lean topics. Students will also learn fundamental project management concepts and techniques to define, plan, and execute construction projects. The focus will be on actions that can be taken to meet and sometimes exceed expectations for project time, cost, and quality. The importance of communication and risk management throughout all project stages will be emphasized. Students will also be exposed to software applications that aid project management. Students will be challenged as individuals and as members of a team. Prerequisites: CIVE 580 and working knowledge of Microsoft Excel, statistics, and probability theory.

CIVE 690  Construction Technology for Tall Buildings 3 cr.
This is a course that introduces 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. It examines site investigation, excavation and foundations, basement construction, structural systems for the superstructure, site and material handling, wall and floor construction, cladding, and roof construction. Prerequisites: CIVE 582, and CIVE 584.

CIVE 691  Construction Decisions under Uncertainty 3 cr.
This is a course that covers construction project and organization decisions for the uncertain future. The selection of construction method, equipment, contract, markup, and financing alternatives having the highest expected values; uses decision theory, competitive bid analysis, probabilistic modeling and simulation, and multiple regression analysis in managing construction.
CIVE 692  Construction Safety  
A course that covers basic safety and loss control concepts, practices, and skills to improve construction job site safety; OSHA regulations, accidents, ergonomics, documentation, safety policies and procedures; safe work environments; crisis management; and other safety related topics.

CIVE 693  Design of Temporary Support Structures  
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 694  Legal Aspects of Construction  
This is a course that covers legal problems and liability issues in the area of construction contracts, torts, and insurance.

CIVE 695  Sustainable Design and Construction  
This is a course that covers principles of sustainable design and construction, including life-cycle cost analysis, evaluation of economic and environmental impacts, state-of-the-art technology.

CIVE 696  Evaluation of Cost Alternatives  
This 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.

Structural Sequence

CIVE 610  Advanced Structural Analysis  
A course that offers a review of matrix algebra; basic principles of structural analysis: stiffness, flexibility, and energy methods; direct stiffness method for plane and space trusses and frames; linear and non-linear problems; special problems; and computer programming and applications. Prerequisite: CIVE 410.

CIVE 620  Plain Concrete  
This is 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 621  Special Topics in Concrete  
This is 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. Prerequisites: CIVE 410 and CIVE 421.

CIVE 622  Prestressed Concrete  
A course on materials characteristics; pre-stress losses; working strength design procedures; composite construction; ultimate flexural strength and behavior; continuous pre-stressed concrete members. Prerequisites: CIVE 420 and CIVE 421.

CIVE 623  Bridges  
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. Prerequisites: CIVE 410 and CIVE 421.
CIVE 624  Steel Design  3 cr.
A course that examines loads on structures; philosophies of design: LRFD versus ASD; behavior, analysis, and design (according to AISC) of tension members, bolted connections, welded connections, compression members, and beams. **Prerequisite: CIVE 410.**

CIVE 625  Strengthening and Rehabilitation of Concrete Structural Systems  3 cr.
This is 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 410 and CIVE 421.**

CIVE 626  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 the design of structures under earthquake loading.

CIVE 632  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; limit states and limit state functions; approximate and exact methods for assessing reliability; load and resistance factor design (LRFD) in structural and geotechnical engineering; basics of design code calibration; reliability assessments of existing structures, updating reliability with load tests.

CIVE 710  The Finite Element Method  3 cr.
A course on matrix algebra; energy theorems; analysis of discrete member systems; interpolation functions; numerical integration; plane stress and plane strain problems; axisymmetric problems; problems in three dimensions; plate bending. **Prerequisite: CIVE 610.**

CIVE 711  Advanced Mechanics of Solids  3 cr.
A course that covers theories of stress and strain; stress-strain relations, generalized Hook’s law; modes of failure, 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 310.**

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.

CIVE 720  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 421.**

CIVE 722  Advanced Steel Design  3 cr.
A course that investigates stability, column strength, beam-columns, composite steel-concrete construction, plate buckling, plate girders, torsion, and combined torsion and bending. **Prerequisite: CIVE 624.**
CIVE 723  Introduction to Offshore Structures  3 cr.
A course on types of offshore structures, components comprising fixed offshore structures, components comprising jack-ups, components comprising Floating Production Storage and Offloading Units (FPSOs), loading on offshore structures, design and analysis of fixed offshore structures, design and analysis of Mobile Jack-up structures, and design and analysis of Floating Production Storage and Offloading (FPSOs) structures.

Geotechnical Sequence

CIVE 630  Applied Foundation Engineering  3 cr.
A course on braced excavations; retaining structures; deep foundations; slope stability; and computer applications. Prerequisite: CIVE 530.

CIVE 631  Environmental Geotechnics  3 cr.
A course on geotechnical practice in environmental protection and restoration; methods of soil and site characterization for sifting of waste repositories and site restoration; influence of physical and chemical processes in soils on the evaluation of contaminant distribution; design of waste containment systems including landfills, slurry walls, and soil stabilization; the applicability and use of geosynthetics; and technologies for site restoration and cleanup. Prerequisite: CIVE 431.

CIVE 633  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 431.

CIVE 634  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 635  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 conditions, undrained, constitutive models, and failure criteria applications. Prerequisite: CIVE 431.

CIVE 731  Earth Dams  3 cr.
A course that examines hydraulic dams, rolled earth dams, homogenous dams, thin core dams, filters, causes of dam failures, seepage control, and seismic stability of dams.

CIVE 732  Geotechnical Earthquake Engineering  3 cr.
A course on causative mechanisms of earthquake, earthquake magnitudes, ground motion; influence of soil conditions on site response; seismic site response analysis; evaluation and modeling of dynamic soil properties; analysis of seismic soil-structure interaction; evaluation and mitigation of soil liquefaction and its consequences; seismic code provisions and practice; seismic earth pressures, seismic slope stability and deformation analysis, seismic safety of dams and embankments, seismic performance of pile foundations, and additional current topics. Prerequisite: CIVE 431.
Materials and Pavement

CIVE 620  Plain Concrete  3 cr.
(See course description listed in Structural Sequence)

CIVE 660  Pavement Engineering  3 cr.
A course examining highway and airport pavement design; flexible and rigid pavement types and wheel loads; stresses in flexible and rigid pavements; pavement behavior under moving loads; soil stabilization. Prerequisite: CIVE 461.

CIVE 667  Highway Materials and Construction  3 cr.
The course covers various materials constituents in highway pavement structures with emphasis on asphalt concrete, aggregate-soil mixtures, geotextiles, and bituminous liquids. Material properties, design, quality control, and methods of construction will be described. Forensic studies, distress surveys, non-destructive and accelerated pavement testing are also discussed. Prerequisite: STAT 230.

CIVE 763  Viscoelastic Behavior of Construction Materials  3 cr.
The objective of the course is to introduce graduate students to viscoelastic behavior of construction materials, particularly asphalt concrete and polymer composites. The course covers basic concepts in material characterization, rheology, time-temperature superposition principles, in addition to linear and non-linear viscoelastic models. Laboratory tests needed for model development and numerical methods necessary for performance prediction are described and conducted. The course is of interest to graduate students in the areas of structures, materials, geotechnical and pavement engineering.

Transportation Sequence

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. Prerequisite: CIVE 461.

CIVE 662  Traffic Engineering  3 cr.
A course outlining traffic engineering studies; traffic control of signalized and unsignalized intersections; signal control hardware and maintenance; arterial performance and operations; and network optimization. Prerequisite: CIVE 461.

CIVE 663  Transportation Systems Analysis  3 cr.
A course on transportation and traffic problems in modern society. Among the topics covered are travel forecasting problems and methods; theoretical techniques for traffic flow description and management; highway, railway, and runway capacity and performance characteristics; economic considerations; and cost functions.

CIVE 664  Design and Management of Transport Operations  3 cr.
A course that covers the application of quantitative techniques from operations research and probabilistic analysis to transportation problems. Applications covered include: pickup and delivery systems, emergency urban services, facility location, and network problems. Prerequisite: STAT 230 or equivalent.
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.

CIVE 666  Transport Operations  3 cr.
A course that introduces 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, and transit modes; vehicle routing problems in carrier systems; runway and air traffic operations; operations control in transit services; and fundamental relations and models of traffic flow. Prerequisite: CIVE 461.

CIVE 760  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; privatization issues. Pre- or co-requisite: CIVE 661.

CIVE 761  Urban Transportation Planning II  3 cr.
A course examining 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 461 or equivalent.

Environmental and Water Resources Sequence

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

CIVE 641  Surface Water Hydrology  3 cr.
A course on design storm, rainfall-runoff modeling, overland flow, flood routing, reservoir routing, simulation models, and stochastic hydrology. Prerequisite: CIVE 441 or equivalent.

CIVE 642  Groundwater Hydrology  3 cr.
This is 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 441.

CIVE 643  Hydraulics of Open Channels  3 cr.
A course that examines gradually varied flow theory and analysis, spatially varied flow, and numerical modeling of unsteady flow in open-channels. Prerequisite: CIVE 440.

CIVE 644  Coastal Engineering  3 cr.
A course on small-amplitude wave theory (linear theory); finite-amplitude wave theory (nonlinear theory); cnoidal 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  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.

CIVE 646  Water Resource Systems: Planning and Management  3 cr.
A course that introduces the concepts and principles of water resources planning and management. It demonstrates the logical steps in engineering planning as it applies to water resources management. The course provides coverage of mature and state of the art technologies and tools applied in the water resources industry. Emphasis will be placed on systems analysis, GIS and economic and financial analysis, environmental impact assessment techniques.

CIVE 647  GIS for Water Resources and Environmental Engineering  3 cr.
A course that introduces the concepts and principles of Geographic Information Systems (GIS) from the perspective of water resources and environmental engineering. It provides coverage of state-of-the-art GIS methods and tools specifically targeting water resources and environmental applications including: spatial and terrain analysis, geostatistical analysis, watershed delineation and identification of river networks, representation of groundwater and aquifer systems, time series analysis and development of GIS integrated water and environmental models. The course will be based on the recently released ESRI ArcGIS 9.3 and the Arc Hydro data model developed by the Consortium for GIS in Water Resources (CGWR).

CIVE 648  Climate Change and Water Resources  3 cr.
The course introduces students to the global issue of climate change and its potential impact on water resources and implications to their management particularly in the semi-arid MENA region. It explores the drivers of climate change, green house gases mitigation efforts, and adaptation options in the water resources sector with special emphasis on the Integrated Water Resources Management (IWRM) and adaptive management approach.

CIVE 649  Microbial Ecology and Molecular Biology for Engineers  3 cr.
A course that introduces students (undergraduate and graduate) from different engineering disciplines to the concepts and tools in microbial ecology and how to apply these concepts and tools to understand microbial communities underpinning environmental biotechnology processes. Prerequisites: CHEM 202, BIOL 210, or equivalent.

CIVE 650  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.

CIVE 651  Environmental Chemistry and Microbiology  3 cr.
A course that deals with organic, inorganic, and physical chemistry; chemical equilibrium; reaction kinetics; acidity and alkalinity; composition, morphology, and classification of microorganisms; energy, metabolism, and synthesis; growth, decay, and kinetics; biological water quality indicators. Prerequisites: CHEM 202, BIOL 210, or equivalent.

CIVE 652  Environmental Biotechnology and Bioremediation Applications  3 cr.
This course examines current and emergent environmental biotechnologies used for environmental quality evaluation, monitoring, and remediation of contaminated environments, and provides the student with a working knowledge of the science that underpins them. The fundamentals of environmental microbiology are presented; these provide a foundation for subsequent discussions of biotreatment of problem environmental pollutants, and engineering strategies for bioremediation.
CIVE 653  Water and Sewage Works Design  3 cr.
A course that examines the design of water and wastewater schemes, including design reports
and literature search on the development of conventional treatment processes. Prerequisite:
CIVE 450.

CIVE 654  Solid Waste Management I  3 cr.
A course on the nature and effects of solid wastes including hazardous wastes; engineering
management principles, practices, and techniques for management of solid wastes
administration; solid waste generation, storage, collection and transport, processing, resource
recovery, and disposal; and a trip to a local facility.

CIVE 655  Solid Waste Management II  3 cr.
A course on the design of solid waste disposal schemes, including design reports and a literature
search on the development of conventional treatment and disposal processes. Prerequisite:
CIVE 654 or consent of instructor.

CIVE 656  Air Pollution and Control I  3 cr.
An introductory course on air pollutants, sources, and effects; emission estimates, regulations,
and monitoring techniques; particulate matter characterization; meteorology and atmospheric
dispersion; and air pollution control processes. Prerequisite: CHEM 202 or equivalent.

CIVE 657  Air Pollution and Control II  3 cr.
A course that examines process analysis, operational limitations, cost and performance, and
evaluation of control process and equipment; case studies, field visits, and inspection of
industrial installations. Prerequisite: CIVE 656 or consent of instructor.

CIVE 658  Industrial/Hazardous Waste Management  3 cr.
A course that deals with sources, quantity, and quality of industrial wastes; basic industrial
waste treatment processes; major industries, types of waste, and existing treatment practices;
disposal and fate of industrial wastes. Prerequisites: CIVE 450 and CIVE 651, or consent of
instructor.

CIVE 659  Environmental Impact Assessment  3 cr.
A course that outlines theories and procedures of assessing environmental impact; analysis
of the impact of development on various measures of environmental quality; and benefit-cost
considerations in environmental impact assessment. Prerequisites: CIVE 450, CIVE 654, and
CIVE 656; or consent of instructor.

CIVE 750  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. Prerequisites: CIVE 450 and CIVE 450.

CIVE 751  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 656 or consent of instructor.

CIVE 752  Environmental Case Studies and Conflict Resolution  3 cr.
A course on case studies in environmental management: pesticide application, air pollution,
solid waste land filling, wastewater treatment facilities, oil exploration, ocean dumping, deep
well injection, reservoirs, and water resources. Prerequisites: CIVE 450, CIVE 654, and CIVE 656;
or consent of instructor.
CIVE 753  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. Prerequisite: CIVE 450 or consent of instructor.

Common Courses

CIVE 670  Computer Methods in Civil Engineering  3 cr.
A course on the use of the computer for analysis, design, and decision making in civil engineering, including programming, numerical, and CAD methods and applications. Prerequisites: EECE 230 and CIVE 370.

CIVE 671  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, finite difference, and finite element methods.

CIVE 672  Introduction to Geographic Information Systems  3 cr.
An introductory course on Geographic Information Systems (GIS) and their applications in the planning and engineering fields, alternatives in computer-based graphics, data concepts and tools, network data management and planning applications, and implementation issues. This course can be taken as an elective for credit in all graduate engineering programs.

CIVE 673  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.

Special Courses and Thesis

CIVE 796  Special Projects  3 cr.

CIVE 797  Civil Engineering Seminar  0 cr.
A seminar that consists of current research or applied projects presented by faculty members, students, or invited speakers.

ENSC 690  Seminar in Environmental Sciences  0 cr.
A seminar that consists of current research or applied projects presented by faculty members, students, or invited speakers.

CIVE 798  Special Topics  3 cr.

CIVE 799  Thesis  6 cr.

CIVE 799T  Comprehensive Exam  0 cr.

CIVE 898  Advanced Topics in Civil and Environmental Engineering  3 cr.

CIVE 900  PhD Comprehensive Exam  0 cr.

CIVE 990  PhD Dissertation  0 cr.
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