Civil and Environmental Engineering

Website (http://www.civ.neu.edu)

Jerome F. Hajjar, PhD, PE
CDM Smith Professor and Chair
400 Snell Engineering Center
617.373.2444
617.373.4419 (fax)

Overview
With a strategic focus in urban engineering and through a range of teaching and research strengths, anchored by several multidisciplinary, multi-institutional centers and programs, our academic programs are designed to prepare professionals to address the global, complex, and ever-evolving engineering challenges of our time by building on current department strengths and expanding into vital areas. We give our future master's and PhD graduates the opportunity to make real-world impact on and long-lasting contributions to the well-being and development of society.

Mission of the Department
Advancing innovative civil and environmental solutions for society and creating globally oriented engineering leaders by integrating experiential education and use-inspired interdisciplinary research.

Academic Programs
Within our graduate programs, students work alongside world-class faculty on advanced research and courses, developing a solid base for their careers. Three overarching themes are emphasized in our programs: environmental health, civil infrastructure security, and sustainable resource engineering. These themes are aligned with the department's premier strengths in simulation (both computational and experimental), smart sensing, data and network science, and urban informatics and are all reflected in the courses offered in our graduate programs.

MASTER OF SCIENCE DEGREE
The department offers four MS degree programs in the following areas: civil engineering (students can choose one out of six concentrations); environmental engineering; engineering and public policy; and sustainable building systems. Options for a master's thesis or report in place of coursework are available. All civil and environmental engineering master's programs are available on a full-time or part-time basis. For a full list of the department's academic program offerings, please refer to the Programs (p. 1) tab.

DOCTOR OF PHILOSOPHY (PhD) DEGREE
The department offers the following PhD degrees: PhD in Civil and Environmental Engineering and Interdisciplinary PhD. The doctoral program is designed to be flexible with respect to subject area and may be adapted to any subject area in civil and environmental engineering, including interdisciplinary options within the department or across departments or colleges.

The PhD is awarded to students who demonstrate high academic achievement and research competence in the selected field. Students must pursue the PhD program on a basis consistent with the residence requirements for the degree (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-environmental-engineering-phd/ #text).

Graduate Certificate Options
Students enrolled in a master's degree have the opportunity to also pursue one of the many engineering graduate certificate options in addition to or in combination with the MS degree. Students should consult their faculty advisor regarding these options (http://catalog.northeastern.edu/graduate/engineering/graduate-certificate-programs/).

GORDON INSTITUTE OF ENGINEERING LEADERSHIP OPTION
Students have the opportunity to pursue the Gordon Engineering Leadership Program (http://catalog.northeastern.edu/graduate/engineering/multidisciplinary/engineering-leadership-graduate-certificate/) in combination with the MS degree.

Programs
Doctor of Philosophy (PhD)
• Civil and Environmental Engineering (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-environmental-engineering-phd/)

Master of Science (MS)
• Engineering and Public Policy (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/engineering-public-policy-ms/)

Master of Science in Civil Engineering (MSCivE)
• Civil Engineering with Concentration in Construction Management (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-construction-management-msciv/)
• Civil Engineering with Concentration in Data and System (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-data-systems-msciv/)
• Civil Engineering with Concentration in Geotechnical/Geoenvironmental Engineering (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-geotechnical-geoenvironmental-msciv/)
• Civil Engineering with Concentration in Structures (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-structures-msciv/)
• Civil Engineering with Concentration in Transportation (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-transportation-msciv/)
• Civil Engineering with Concentration in Water, Environmental, and Coastal Systems (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-water-environmental-coastal-systems-msciv/)

Master of Science in Environmental Engineering (MSEnvE)
• Environmental Engineering (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/environmental-engineering-msenv/)

Academic Programs
• water-environmental-coastal-systems-msciv/
Master of Science in Sustainable Building Systems (MSSBS)

- Sustainable Building Systems (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/sustainable-building-systems-mssbs/)

Retired Programs

- Civil Engineering

Please see successor program: Civil and Environmental Engineering, PhD (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-environmental-engineering-phd/)

Courses

Civil and Environmental Engineering Courses

Search CIVE, SBSY Courses using FocusSearch (http://catalog.northeastern.edu/class-search/?subject=CIVE%2CSBSY)

CIVE 5150. Climate and Atmospheric Change. (4 Hours)

Offers an in-depth view of the processes that drive change in Earth’s climate system. Examines the modern climate system and how and why climate changes through time. Introduces the tools used to explore past climates and changes, and explores the long-term and short-term controls on the climate system. Also introduces the application of climate models to develop future climate projections. Offers students an opportunity to obtain hands-on experience analyzing and interpreting climate data and model output.

Prerequisite(s): ENVR 1200 with a minimum grade of D- or ENVR 2200 with a minimum grade of D- or graduate program admission

CIVE 5221. Construction Project Control and Organization. (2 Hours)

Overviews the organization of construction firms at the general corporate level and the project level. Covers cost, schedule, budget, and financial control of projects. Also examines the flow of information between parties to the project.

Prerequisite(s): CIVE 4575 with a minimum grade of D- or CIVE 7220 with a minimum grade of C-

CIVE 5231. Alternative Project Delivery Systems in Construction. (2 Hours)

Offers a comprehensive overview of alternative construction project delivery systems in the public and private sectors; project life cycle including project development, schedule, cost and risk management, quality assurance/quality control, project management, and project closeout; innovative financing strategies including contractor financing, franchises, and super turnkey. Focuses on the analysis of design/bid/build execution compared to design/build and construction management systems of delivery. Examines international projects, contracts, and partnering options—for example JVs and alliances—as vehicles to ensure the meeting of project objectives. Uses case studies to identify and practice the management skills required for successful D/B project execution including effective communication, negotiations, and team building.

Prerequisite(s): CIVE 4575 with a minimum grade of D- or CIVE 7220 with a minimum grade of C-

CIVE 5250. Organic Pollutants in the Environment. (4 Hours)

Introduces principles that govern the fate and transport of organic chemicals released to the environment. Topics include chemical structure and thermodynamic properties and how they predict physical processes that control the distribution of contaminants between the atmosphere, fresh and marine surface waters, groundwater, soils, sediments, and biota. Introduces models and methods for predicting fate and transport of organic contaminants within and between environmental media, including molecular diffusion, transport across boundaries, and box models. Explores concepts linking environmental chemistry with ecotoxicology, including bioaccumulation, food web models, and risk assessment. Uses case studies and real-world scenarios to illustrate concepts.

Prerequisite(s): CHEM 1151 with a minimum grade of D- or CHEM 1211 with a minimum grade of D- or graduate program admission

CIVE 5260. Environmental Fluid Mechanics. (4 Hours)

Focuses on fundamentals of fluid mechanics, but with application to the natural and built environment based on transport and dispersion phenomena. Reviews theory necessary for an understanding of environmental fluid flows and methods of observation, including acoustic Doppler current profiles, profiling towers, and modeling, including large eddy simulation (LES).

CIVE 5261. Dynamic Modeling for Environmental Investment and Policymaking. (4 Hours)

Introduces the theory, methods, and tools of dynamic modeling for policy and investment decision making, emphasizing environmental issues. Makes use of state-of-the-art computing methods to translate theory and concepts into executable models and offers extensive hands-on modeling experience. Topics include management of discrete flows (e.g., models of traffic systems); discounting, intertemporal optimization (e.g., models of resource extraction); dynamic games (e.g., models for adaptive management); and treatment of risk, uncertainty, novelty, and complexity (e.g., for investment and policymaking).

CIVE 5271. Solid and Hazardous Waste Management. (4 Hours)

Introduce various aspects of integrated solid waste management system and hazardous waste management practices. Includes both engineering principles as well as socioeconomic and regulatory issues surrounding solid and hazardous waste management. Provides sufficient background to enable the student to understand, evaluate, and critique the design of and the decisions in various waste management alternatives.

CIVE 5275. Life Cycle Assessment of Materials, Products, and Infrastructure. (4 Hours)

Covers the conceptual and mathematical basis of life cycle assessment (LCA), including engineering models of industrial energy use and emissions and environmental science models of fate and transport, exposure, and toxicology. LCA is a widely used systems-modeling method for quantifying the emissions and environmental/health implications of a product over its life cycle, from manufacturing to use to disposal. This guides design, technology decisions, and policy on topics ranging from consumer products to green buildings to large-scale energy technologies. Presents Monte Carlo simulation, structural path analysis, and model sensitivity analysis for the industrial network structure that underlies LCA modeling. Offers students an opportunity to receive hands-on training for open-source LCA software packages and then carry out independent group projects for real clients in industry and government.
CIVE 5280. Remote Sensing of the Environment. (4 Hours)
Introduces remote sensing techniques, including obtaining, visualizing, and analyzing satellite data. Examines physical processes, methods, and data products used in satellite remote sensing of the Earth’s environment. Topics include active and passive remote sensing methods based on fundamentals of electromagnetic radiation, concepts used to develop data products from the remotely sensed measurements, and a suite of satellite data products to investigate current and past conditions of the Earth’s terrestrial and ocean surfaces. Uses geographic information systems (GIS) and student-developed programs to view and interpret satellite data. Knowledge of GIS, R, and Python is preferred.

CIVE 5281. Coastal Dynamics and Design. (4 Hours)
Introduces the basic theory of the forcing and response of the built and natural coastal environment, including hurricanes and extratropical storms, wind waves, astronomical tides, storm surges, currents, fluid-structure interactions, sediment transport, and morphological changes. Seeks to provide an overview of the physical processes and the functional design of coastal works, including anthropogenic and natural and nature-based features. Uses examples and case studies to illustrate the theory and the interdependence of water motion and coastal morphology. Emphasizes the challenges of extreme events and natural hazards in the coastal environment. Requires prior completion of one semester of fluid mechanics or equivalent.

Prerequisite(s): CIVE 2331 with a minimum grade of D- or EEMB 3120 with a minimum grade of D- or graduate program admission

CIVE 5300. Environmental Sampling and Analysis. (2 Hours)
Introduces the theory, application, methodology, and instrumentation used in planning, sampling, and analyzing the environmental contaminants in air, water, and soils. Emphasizes instrument selection and quality control, including documentation, calibration, data analysis and interpretation, and sample management.

Prerequisite(s): CHEM 1151 with a minimum grade of D- or CHEM 1161 with a minimum grade of D- or CHEM 1211 with a minimum grade of D- or graduate program admission
Corequisite(s): CIVE 5301

CIVE 5301. Lab for CIVE 5300. (2 Hours)
Accompanies CIVE 5300. Covers topics from the course through various experiments. Includes a team project.

Corequisite(s): CIVE 5300

CIVE 5363. Climate Science, Engineering Adaptation, and Policy. (4 Hours)
Offers an evidence-based glimpse of what has been called a clear and present danger to mankind. Analyzes case studies from the magic of the butterfly effect in chaos theory to the deep challenges in physics, biogeochemistry, and data sciences. Covers topics from experimental design to satellite-based remote sensing, all the way to the design and operations of next-generation hydraulic infrastructures, transportation systems, smart grids, and communication networks, including the impacts on coastal or inland cities, the resilience to weather hazards, and the sustainability of water-energy-food resources. Includes policy issues and risk-informed trade-offs in renewable energy, environmental regulations, and emissions control. Graduate students are required to complete a mandatory class project.

CIVE 5373. Transportation Systems: Analysis and Planning. (4 Hours)
Discusses urban transportation planning and engineering for modes other than highway. Covers travel demand forecasting for both the short and long term including impact analysis methods, simple elasticity models, and the four-step model system of trip generation, trip distribution, modal split, and network assignment. Introduces transit service analysis and design. Other topics include capacity, service, and engineering design basics for different travel modes, such as bus, airport, rail, and bicycle. Considers the environmental impact, economic evaluation, and financial impact of different modes of transportation.

CIVE 5376. Traffic Engineering and Sustainable Urban Street Design. (4 Hours)
Covers street and intersection design for meeting societal needs related to traffic capacity, level of service, safety, walkability, bikeability, and the quality of public space. Intersection analysis and design topics include traffic flow theory and measurement; capacity, queuing and delay for both vehicles and pedestrians; and signal timing plan design, including design for pedestrian crossings. Street design topics include street functions; speed control; street and intersection layout; bicycling facilities, including bike lanes and separated bike paths; and pedestrian facilities, including sidewalks and crossings. Offers students an opportunity to practice with standard design manuals and intersection analysis software.

CIVE 5520. Structural Systems. (4 Hours)
Covers the design of structural systems. Includes the major aspects of structural behavior and design (loads, load paths, structural system concepts, analysis, member and connection design, and structural detailing). Discusses typical structural building materials along with a brief introduction to less conventional materials. Emphasizes wood and masonry design. Also presents structural principles behind some innovative structural systems. Utilizes current professional practice with a focus on approximate hand methods of structural analysis. Requires one semester of undergraduate structural analysis.

Prerequisite(s): CIVE 2320 with a minimum grade of D- or graduate program admission

CIVE 5522. Structural Systems Modeling. (4 Hours)

Prerequisite(s): CIVE 2320 with a minimum grade of D-; MATH 2341 with a minimum grade of D-

CIVE 5524. Vibration-Based Structural Health Monitoring. (4 Hours)
Explores the theory and implementation of modern techniques for monitoring the health of structural systems using vibration signals. Includes an introduction to system identification, finite element model updating, novelty-based change detection, and techniques for the localization and quantification of damage induced by extreme events or progressive deterioration.

Prerequisite(s): (CIVE 2320 with a minimum grade of D-; MATH 2341 with a minimum grade of D-) or graduate program admission

CIVE 5525. Prestressed Concrete Design. (4 Hours)
Introduces analysis and flexural design of prestressed concrete members, allowable stress in concrete and steel, pre- and posttensioned concrete beams, strength evaluation, and prestressed concrete bridge design. Requires one semester of undergraduate concrete design or one semester of undergraduate structural analysis.
CIVE 5536. Hydrologic and Hydraulic Design. (4 Hours)
Introduces principles of engineering hydrology. Covers the hydrologic cycle, rainfall and flood frequency analysis, rainfall intensity-duration-frequency relationships, rainfall-runoff processes, hydrologic flood routing, and culvert/channel hydraulics. Utilizes these concepts in design applications of civil infrastructure such as stormwater detention basins, drainage pipes, culverts, etc. Uses hydrologic and hydraulic modeling software such as HEC-HMS and HEC-RAS. Includes project component.

Prerequisite(s): (CIVE 2331 with a minimum grade of D-; (ENGL 1111 with a minimum grade of C or ENGW 1111 with a minimum grade of C or ENGL 1102 with a minimum grade of C or ENGW 1102 with a minimum grade of C) or graduate program admission

Attribute(s): NUpath Writing Intensive

CIVE 5699. Special Topics in Civil Engineering. (4 Hours)
Offered when the need for a special topic is evident to faculty and students. Topics are initiated by appropriate faculty members and discipline committee and approved by the department. May be repeated up to two times for up to 12 total credits.

CIVE 5978. Independent Study. (1-4 Hours)
Offers theoretical or experimental work under individual faculty supervision. May be repeated without limit.

CIVE 5984. Research. (1-4 Hours)
Offers an opportunity to conduct research under faculty supervision. May be repeated without limit.

CIVE 6566. Sustainable Urban Transportation: Netherlands. (4 Hours)
Examines how Dutch communities and their transportation systems are planned and designed to promote ABC (all-but-car) transportation, traffic safety, and livability. Topics include design of urban bicycling infrastructure for the mainstream population; planning and service design for high-quality public transportation; urban planning in support of transit, bicycle, and foot transportation, including both suburban development and urban redevelopment; and Vision Zero/Systematic Safety policy and design for traffic safety and its application to urban areas. Taught in study-abroad format in the Netherlands.

CIVE 6777. Climate Hazards and Resilient Cities Abroad. (4 Hours)
Combines the science, engineering, economic, social, and policy aspects of how cities can prepare themselves for climate change and natural hazards. Focuses on the science of unprecedented changes in weather caused by global warming and natural climate variability. Introduces the physical-science basis of climate, computer models and statistical tools, and remote sensor data. Introduces the concept of urban resilience, focusing on preventing natural hazards from turning into catastrophic disasters in densely populated regions. Examines resilience, including governance, emergency response, infrastructural, informational, social, and policy aspects. Encourages students to consider the science, engineering, and policy challenges in transforming vulnerable urban and coastal regions to climate-resilient cities and to examine how societies can learn from each other by comparing Boston with the country visited. Taught abroad.

CIVE 6778. Climate Adaptation and Policy Abroad. (4 Hours)
Explores how the country visited plans to adapt to climate change and natural hazards and how it chooses to participate in international climate and emissions negotiations. Focuses on how an emerging economy adjusts to the reality of climate change/extremes and how the will of citizens may drive decisions and policy. Incorporates topics from climate change, environmental sciences, civil and chemical engineering, remote sensing, social sciences, electrical engineering, computer science, and the management sciences. Encourages students to think about possible policy lessons for the United States. Culminates with a mock climate change war game, simulating an event in which international negotiators meet to formulate treaties on climate change adaptation and mitigation. Taught abroad.

CIVE 6962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.

CIVE 7100. Time Series and Geospatial Data Sciences. (4 Hours)
Offers an interdisciplinary course covering the fundamentals of time series and spatial statistics with applications in engineering, science, and business. Introduces analysis and forecasting methods for time series, spatial, and spatiotemporal data. Discusses classical time or frequency domain methods, as well as recent techniques motivated from computer science, physics, statistics, or engineering. Case studies relate to ongoing research and to real-world examples. A demo project is selected by the instructor based on discussion with individual students. A computer-based final project can be tailored to student interests in environmental engineering, sustainability sciences, security threat assessments, social sciences, business, or management science and finance. Requires undergraduate probability and statistics (CIVE 3464 or equivalent); background in programming languages such as MATLAB or R helpful but not required.

CIVE 7110. Critical Infrastructure Resilience. (4 Hours)
Introduces the concept of resilience by exploring engineering concepts and perspectives to offer students an opportunity to develop the ability to be prepared for and adapt to challenging situations and scenarios—e.g., globalization, climate change, security threats, and natural disasters—on critical infrastructures and key resources. Topics include application of tools for infrastructure modeling and risk assessment; identification of natural and man-made hazards; management of disaster risks and communications; resilience design; and future challenges, policy, and novel approaches to advance resilience. Explores application to real-life examples through group projects. Requires one semester of undergraduate statistics.
CIVE 7150. Data-Driven Decision Support for Civil and Environmental Engineering. (4 Hours)

Presents supervised and unsupervised methods for dealing with large data sets and their application to support decision making in various civil and environmental engineering areas. Focuses on predictive models and methods for knowledge mining. Discusses applications from the transportation, urban mobility, and infrastructure maintenance domains. Topics include classification: linear regression, logistic regression, K-NN, and other classifiers; dimensionality reduction; clustering: K-means, hierarchical clustering, Gaussian mixture models, density-based clustering; model validation; and text mining. Demonstrates the applicability and underlying principles of the various methods through case studies with extensive data sets. Applications include classification of pavement distress images; mobility patterns; real-time transportation demand prediction; and text mining from reports. Background in probability and statistics and familiarity with Python/R recommended.

CIVE 7151. Urban Informatics and Processing. (4 Hours)

Offers a comprehensive review of urban informatics in civil and infrastructure engineering research. Discusses the usage of these data and offers students hands-on opportunities to extensively analyze, comprehend, and visualize five types of data sets: construction and infrastructure development; urban mobility and traffic; sensors in built environments; geosocial networks; and social media. Provides extensive data sets for practices. Python is the main platform for analysis and visualization.

CIVE 7155. Dynamics and Control of Infrastructure Systems. (4 Hours)

Introduces the fundamentals of modeling, optimization, and control of dynamic and automated infrastructure systems. The future of infrastructure engineering will be increasingly automated: building automation systems, autonomous vehicles, smart-grids, and responsive pollution controls. Emphasizes linear systems, including continuous and discrete-time systems, but also presents elementary concepts in nonlinear systems. Additional topics include stability, observers, optimal control, system identification, and cyber-physical system architectures. Offers students an opportunity to acquire practical and theoretical knowledge of control technologies and to apply these modern tools to a semester-long project in their area of interest and to develop the analytical, numerical, and conceptual methods necessary for careers in the emerging field of automated infrastructure systems.

Prerequisite(s): MATH 2341 with a minimum grade of D- or graduate program admission

CIVE 7220. Construction Management. (4 Hours)

Presents all aspects of construction management, with emphasis on cost and schedule. Provides conceptual and detailed cost estimates and network-based scheduling techniques (CPM and PERT). Covers project cash flow and finances. Requires one semester of undergraduate probability and statistics.

CIVE 7230. Legal Aspects of Civil Engineering. (4 Hours)

Overviews the U.S. legal system and the theories necessary for the comprehension of business and contractual liabilities. Discusses various types of contracts, forms of business ownership, claims and disputes, and environmental law.
CIVE 7260. Hydrologic Modeling. (4 Hours)
Covers the vertical and lateral fluxes and stores of water within the terrestrial hydrologic cycle such as precipitation (rain and snow); infiltration; runoff; snowmelt; evapotranspiration; streamflow; groundwater recharge/discharge; and surface (snowpack, lakes, rivers) and subsurface (soil moisture and groundwater) storages. Individual simulation models are developed to represent key processes within the hydrologic cycle. Process models are then integrated to approximate the hydrologic cycle of a watershed. Covers model parameterization, calibration, validation, and uncertainty (model parameters and forcings). Knowledge of geographic information systems and programming is recommended.

Prerequisite(s): CIVE 5300 with a minimum grade of C-

CIVE 7261. Surface Water Quality Modeling. (4 Hours)
Offers a quantitative analysis of the fate and transport of contaminants in surface water systems. Water quality models are developed using a mass balance approach to describe the transport, dispersal, and chemical/biological reactions of substances introduced into river and lake systems. Covers water quality standards; model formulation and application; waste load allocation; and water quality parameters such as biochemical oxygen demand, dissolved oxygen, nutrients, and toxic chemicals. Requires one semester of undergraduate hydrologic engineering, hydrology, or equivalent.

Prerequisite(s): CIVE 5281 with a minimum grade of C- or (EEMB 5516 with a minimum grade of C-

CIVE 7272. Air Quality Management. (4 Hours)
Explores engineering theory and practice related to air resources management. Focuses on modeling dispersion and reactions for atmospheric pollutants and on analysis of systems for controlling gaseous and particulate emissions including dry collection, wet collection, absorption, and catalytic processes. Also addresses biological and chemical aspects of air pollution including toxicological issues, physiological effects of aerosols, analysis of organic and inorganic constituents of the atmosphere, and rationale for establishing air quality criteria and standards. Requires one semester of undergraduate chemistry.

Prerequisite(s): CIVE 5281 with a minimum grade of C-

CIVE 7281. Coastal and Nearshore Hydrodynamics. (4 Hours)
Presents the basic principles and theories of coastal and nearshore hydrodynamics as well as related engineering applications, including water waves, wave transformation and breaking, wave-induced nearshore circulation, wave setup, wave run-up, fluid vegetation interaction, wave-current interaction, storm surges, tide and wind-driven circulation, and tidal inlet hydraulics. Previous study of graduate-level mathematics is strongly recommended.

Prerequisite(s): CIVE 5281 with a minimum grade of C-

CIVE 7302. Advanced Foundation Engineering. (4 Hours)
Focuses on bearing-capacity and settlement analysis of conventional shallow foundations and combined footings; mat design; lateral earth pressure theory and application to retaining wall design, braced excavations, sheet pile wall design, and slurry trench walls; bearing-capacity design and analysis for deep foundations; and laterally loaded piles, friction piles, and pile-driven analysis. Requires one semester of undergraduate soil mechanics.

CIVE 7311. Soil and Foundation Dynamics. (4 Hours)
Considers dynamic loads, blast vibrations and monitoring, dynamic response of single-mass, multi-degree-of-freedom systems, design of machine foundations, dynamic soil properties, ground response analysis, liquefaction, and seismic analysis of slopes and dams. Requires one semester of undergraduate statics.

CIVE 7312. Earthquake Engineering. (4 Hours)
Studies plate tectonics, seismology, faults and characteristics, ground motions, seismic hazard analysis, dynamic response of single degree-of-freedom system, response spectrum, site effects, and seismic design considerations for buildings, bridges, and earth-retaining structures. Requires one semester of undergraduate statics.

CIVE 7313. Ground Improvement. (4 Hours)
Addresses how problematic groundwater conditions, low shear strength, high compressibility, and the need for remediation can be resolved through ground improvement, which is the application of innovative technologies and construction techniques designed to improve the engineering properties of the existing soil and rock at a site. Emphasizes specific, well-established, and emerging ground improvement technologies, including their applications, design, construction/implementation, and quality control. Requires one semester of soil mechanics.

CIVE 7330. Advanced Structural Analysis. (4 Hours)
Explores modern methods of structural analysis, matrix formulation of flexibility and stiffness methods, and analysis of structures with material and geometric nonlinearities. Also introduces energy methods. Requires CIVE 5522 or one semester undergraduate matrix structural analysis.

CIVE 7331. Structural Dynamics. (4 Hours)
Examines single and multi degree-of-freedom systems subjected to arbitrary dynamic loads. Topics include convolution and frequency domain solutions, introduction to analytical dynamics, damping models, modal analysis of classically damped systems, and state-space formulation. Requires one semester of undergraduate structural analysis.

CIVE 7340. Seismic Analysis and Design. (4 Hours)
Considers the response of linear systems to coherent and incoherent support motion, nonlinear response, the concept of ductility, inelastic response spectra, soil-structure interaction, random vibration theory, development of seismic codes, and characterizations of earthquakes for design.

Prerequisite(s): CIVE 7331 with a minimum grade of C-
CIVE 7342. System Identification. (4 Hours)
Studies methods for identifying the fundamental characteristics of structures. Includes topics in linear algebra (singular value and QR decomposition, pseudoinversion, and so on); input-output relationships for linear time-invariant systems; frequency response functions; signal processing fundamentals; realization theory; the eigensystem realization algorithm; use of observers in identification; and introduction to out-only system identification. Requires one semester of undergraduate structural analysis.

CIVE 7350. Behavior of Concrete Structures. (4 Hours)
Considers flexural mechanics of reinforced concrete cross sections and members; combined bending, axial, and shear loads; advanced topics in shear, torsion, and connection design; and application of plastic analysis to reinforced concrete frames, their behavior under cyclic loading, and response of structures under seismic actions. Requires one semester of undergraduate concrete design.

CIVE 7351. Behavior of Steel Structures. (4 Hours)
Studies the behavior and design of steel structural systems, including structural stability; advanced topics in mechanics and design of structural steel members, including combined axial, flexure, and shear loads; composite steel/concrete beam and column behavior and design; plate girders; and advanced topics in connection design. Requires one semester of undergraduate steel design.

CIVE 7354. Wind Engineering. (4 Hours)
Covers atmospheric circulation, atmospheric boundary layer winds, bluff-body aerodynamics, introduction to random vibration theory, response of structures to fluctuating wind loads, aeroelastic phenomena, wind-tunnel and full-scale testing, nonsynoptic winds (hurricanes, tornadoes, etc.), wind-load standards, and design applications.

CIVE 7355. Advanced Bridge Design. (4 Hours)
Studies the behavior and design of prestressed concrete bridges. Includes conceptual design, flexural design, shear design, and torsional design of prestressed elements. Analyzes indeterminate prestressed structures and design for prestressed concrete bridges, including material properties, loads, reinforcement, structural analysis, temperature effects, and construction methods. Covers solid slab, T-beam, and box girders. Final projects include complete designs for a simple supported girder bridge and a continuous girder bridge using load factor and resistance design (LFRD) specifications. Requires one semester of undergraduate structural analysis.

CIVE 7357. Advanced Structural Mechanics. (4 Hours)
Covers stress and strain analysis of structural components, including beams and plates subject to bending, shear, tension, and compression, as well as nonsymmetric geometry and loading cases. Considers the derivation and analysis of elastic instabilities of structural components, including the lateral, torsional, and lateral-torsional buckling of beams and the inelastic yielding and concentrated plasticity of beam components. Includes 3D stress and strain analysis for elastic and inelastic continua as related to advanced structural problems. Introduces variational methods. Requires one semester of graduate structural analysis.

CIVE 7380. Performance Models and Simulation of Transportation Networks. (4 Hours)
Reviews concepts and methods for the analysis of the performance of complex transportation systems and approaches for planning, design, monitoring, and management and control of traffic flows over complex transportation networks. Topics include deterministic and probabilistic models, elements of queuing theory, network optimization algorithms, and simulation. Includes applications in traffic flow modeling, capacity analysis of diverse transportation facilities, level of service and estimation of delays, optimal design of transportation network services, and traffic assignment on congested networks.

CIVE 7381. Transportation Demand Forecasting and Model Estimation. (4 Hours)
Studies methods used for model estimation, model building, and interpretation of results. Emphasizes travel demand forecasting, including trip generation, distribution, model choice, and route choice. Topics include aggregate and disaggregate models, including discrete choice (binary and multinomial logit and extensions), model building and statistical testing, aggregation, sampling, and sample design. Demonstrates the applicability and underlying principles of the various models through case studies with focus on practical aspects and interpretation. Bases main methodological approaches on econometric methods, mainly on regression modeling and maximum likelihood estimation. Uses general and specialized software tools for data analysis and model estimation. While the focus is on estimating transportation demand models, the methods are applicable to a broad class of applications in engineering, marketing, etc.

CIVE 7382. Advanced Traffic Control and Simulation. (4 Hours)
Covers analysis and design of traffic signal control, including actuated control, coordinated control, transit signal priority, and signal control schemes for better accommodating pedestrians and bicycles. Includes the study of traffic microsimulation for urban street networks, including modeling techniques and simulation-based evaluation, and intersection performance models. Offers students an opportunity to practice with standard microsimulation software, including coding traffic signal control logic.

CIVE 7385. Public Transportation. (4 Hours)
Studies the analysis, planning, and operational design of urban public transportation systems. Topics include service planning and scheduling; service reliability and operational control; automated systems for location, fare collection, and passenger counting; service performance measurement; rail system operations and design; data collection; ridership estimation; demand forecasting; pricing; and coordinated transit and land-use planning. Introduces supporting mathematical methods in optimization, random processes, and statistical sampling. Requires knowledge of probability theory.

CIVE 7387. Design Aspects of Roadway Safety. (4 Hours)
Concentrates on roadway design features that affect safety, including system users and design elements. Topics include crash causation and countermeasures, statistical procedures for crash analysis, and geometric design improvements for roads and intersections. Analyzes crash data, including both intersecting and nonintersecting locations. Presents concepts, including design, to create a safer transportation system while addressing specific high-crash locations.
CIVE 7388. Special Topics in Civil Engineering. (4 Hours)
Offered when the need for a special topic is evident to faculty and
students. The course is initiated by the appropriate faculty members and
discipline committee and approved by the department. May be repeated
without limit.

CIVE 7392. Special Topics in Environmental Engineering. (4 Hours)
Offered when the need for a special topic is evident to faculty and
students. The course is initiated by the appropriate faculty members and
discipline committee and approved by the department. May be repeated
without limit.

CIVE 7394. Special Topics in Geotechnical Engineering. (4 Hours)
Offered when the need for a special topic is evident to faculty and
students. The course is initiated by the appropriate faculty members and
discipline committee and approved by the department. May be repeated
without limit.

CIVE 7400. Seminar. (0 Hours)
Presents topics of an advanced nature by staff, outside speakers, and
students in the graduate program. This course must be attended every
semester by all full-time graduate students in the Department of Civil
and Environmental Engineering. Environmental engineering students
permitted. May be repeated without limit.

CIVE 7962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions.
May be repeated without limit.

CIVE 7976. Directed Study. (1-4 Hours)
Offers independent work under the direction of members of the
department on a chosen topic. Course content depends on instructor.
May be repeated without limit.

CIVE 7978. Independent Study. (1-4 Hours)
Offers an individual effort in an area selected by student and adviser and
approved by the Department Discipline Committee resulting in a definitive
report. May be repeated without limit.

CIVE 7990. Thesis. (1-8 Hours)
Offers analytical and/or experimental research conducted by
arrangement with and under the supervision of the department. May be
repeated without limit.

CIVE 7996. Thesis Continuation. (0 Hours)
Offers continued thesis work conducted under the supervision of a
departmental faculty.

CIVE 8674. Master’s Report. (2,4 Hours)
Offers an individual effort consisting of laboratory and/or literature
investigation and analysis of advanced design of a project in an area of
civil engineering selected by student and adviser resulting in a definitive
report. Requires a completed report seven years from the start of the
master’s program.

CIVE 8960. Exam Preparation—Doctoral. (0 Hours)
Offers students an opportunity to prepare for the PhD qualifying exam
under faculty supervision. Intended for students who have completed
all required PhD course work and have not yet achieved PhD candidacy;
students who have not completed all required PhD course work are not
allowed to register for this course. May be repeated once.

CIVE 9894. Research. (1-4 Hours)
Offers an opportunity to conduct research under faculty supervision. May
be repeated without limit.

CIVE 9986. Research. (0 Hours)
Offers an opportunity to conduct full-time research under faculty
supervision. May be repeated without limit.

CIVE 9000. PhD Candidacy Achieved. (0 Hours)
Indicates successful completion of program requirements for PhD
candidacy.

CIVE 9994. Research. (1-4 Hours)
Offers an opportunity to conduct research under faculty supervision. May
be repeated without limit.

CIVE 9996. Research. (0 Hours)
Offers an opportunity to conduct full-time research under faculty
supervision. May be repeated without limit.

CIVE 9990. Dissertation Term 1. (0 Hours)
Offers analytical and/or experimental research conducted by
arrangement with and under the supervision of the department. Open to
full-time students only. Requires PhD candidacy in civil engineering or in
interdisciplinary engineering.

Prerequisite(s): CIVE 9000 with a minimum grade of S

CIVE 9991. Dissertation Term 2. (0 Hours)
Offers dissertation supervision by members of the department.

Prerequisite(s): CIVE 9990 with a minimum grade of S

CIVE 9996. Dissertation Continuation. (0 Hours)
Offers continued thesis work conducted under the supervision of a
departmental faculty.

Prerequisite(s): CIVE 9991 with a minimum grade of S or Dissertation
Check with a score of REQ

SBSY 5100. Sustainable Design and Technologies in Construction. (4
Hours)
Covers theory of sustainability and green building procedures;
sustainable design and construction practices; use of appropriate
materials and systems with low environmental impact for creating
energy-efficient buildings; green construction practices, including
reducing pollution, emissions, and construction waste; and U.S. Green
Building Council's LEED rating system. May be helpful to students
preparing for the LEED Green Associate examination.

SBSY 5200. Sustainable Engineering Systems for Buildings. (4 Hours)
Focuses on the design and construction of sustainable mechanical/
electrical/plumbing (MEP) systems in buildings. Covers MEP
documentation, plumbing water supply, HVAC systems, electrical power
supply and distribution, lighting systems, low-voltage electrical systems,
and estimating and planning for these specialty areas. Addresses
sustainable design and construction practices for MEP, including
minimization of energy consumption and carbon footprint. Requires one
semester of building physics, environmental systems, or equivalent.
SBSY 5250. Building Performance Simulation. (4 Hours)
Studies principles of building performance simulations and the application of these tools to improve the design and operation of buildings. Covers the basic principles of simulation and uses a spectrum of available tools for early stage modeling, daylight estimation, analysis of comfort, and whole building validation. Introduces interpretation and validation of results and code-mandated protocols.

Prerequisite(s): SBSY 5200 with a minimum grade of C-

SBSY 5300. Information Systems for Integrated Project Delivery. (4 Hours)
Focuses on new software systems for increasing efficiency of project delivery and facilitating design and construction integration through the use of BIM (Building Information Modeling) and related technologies. Exposes students to various software systems, including hands-on cases of BIM use, 4D (construction drawings linked to schedule) modeling, and 5D models (4D + cost). Covers the impact of new technology on project delivery, including owner's perspective, advantages, and disadvantages. Also covers use and background of common industry systems to apply BIM concepts to construction projects.

SBSY 5400. Sustainable Building Systems Seminar. (0 Hours)
Features prominent speakers from the sustainable building design and construction industry to showcase new building technologies, tools, and projects and to discuss national and international trends in the industry. Offers students an opportunity to meet innovators and key players advancing the field of sustainable building systems. May be repeated without limit.

SBSY 6962. Elective. (1-4 Hours)
Offers elective credit for courses taken at other academic institutions. May be repeated without limit.