Having a range of teaching and research strengths, anchored by several multidisciplinary, multi-institutional centers and programs that are core to the activities of the department, our department's strategic focus on urban engineering prepares future master's and PhD graduates for many of the greatest challenges of our time. Also, building on current strengths and expanding into new and vital areas in civil and environmental engineering, three overarching themes are highlighted in our department, including environmental health, civil Infrastructure security, and sustainable resource engineering, all aligned with four premier departmental strengths in simulation (both computational and experimental), smart sensing, data and network science, and urban informatics.

The Department of Civil and Environmental Engineering offers research and educational programs at both MS and PhD levels. We offer graduate programs leading to the degrees of Master of Science in Civil Engineering, Master of Science in Environmental Engineering, Master of Science in Engineering and Public Policy, and Master of Science in Sustainable Building Systems. Our cutting-edge doctoral programs include a PhD in civil engineering and an interdisciplinary PhD. Both programs are flexible and may be adapted to any subject area in civil and environmental engineering, including interdisciplinary options within the department or across departments or colleges.

**Master of Science Degree**

Northeastern's Department of Civil and Environmental Engineering's strategic focus on urban engineering gives our graduates the opportunity to make a real-world impact on and make long-lasting contributions to the well-being and development of society. Within our graduate programs, students work alongside world-class faculty on advanced research and courses, developing a solid base for their careers. All civil and environmental engineering master's programs are available on a full-time or part-time basis. Options for a master's thesis or report in place of course work are available. At the master's level, the following degrees are offered:

1. Master of Science in Civil Engineering with concentration in:
   - Construction management
   - Environmental and water systems
   - Geotechnical/geoenvironmental engineering
   - Structural engineering
   - Transportation

2. Master of Science in Environmental Engineering

3. Master of Science in Engineering and Public Policy with concentration in:
   - Energy and environment
   - Infrastructure resilience

4. Master of Science in Sustainable Building Systems

Students in all master's degree programs must complete a minimum of 32 semester hours of approved course work (exclusive of any preparatory courses) with a minimum GPA of 3.00.

There are detailed course and degree requirements for different degree/concentration areas. Three types of courses fulfill the required semester hours, including required core courses, restricted electives, and other electives. Graduate courses that are not listed may also be considered as other electives; these courses require a petition approved by the concentration advisor via the Graduate School of Engineering petition system. Both full-time and part-time students should meet with a faculty advisor at least once during each semester of study to arrange for an appropriate sequence of courses to satisfy all degree requirements. Links to the individual concentrations may be found under the Programs tab.

**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/leadership) in combination with the MS degree.

**Doctor of Philosophy (PhD) Degree**

The Department of Civil and Environmental Engineering admits applicants to the PhD program either directly after earning a suitable bachelor's degree (bachelor's entry) or after earning a master's degree (advanced entry). Upon acceptance into the program, an applicant is designated as a doctoral student. This designation is changed to doctoral candidate upon successful completion of the doctoral qualifying examinations (both written and oral area exams) and all the required course work.

The doctoral program is designed to be flexible with respect to subject area. Since the PhD is primarily a research degree, the program must be adaptable to changes in research needs. The PhD is awarded to students who demonstrate high academic achievement and research competence in the field of civil engineering. Students must pursue the PhD program on a basis consistent with the residence requirements for the degree that may be found under the Degree Requirements tab.

**Programs**

**Doctor of Philosophy (PhD)**

- Civil Engineering (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-phd)
- Civil Engineering—Advanced Entry (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-phd-advanced)
Master of Science (MS)
- Engineering and Public Policy with Concentration in Energy and Environment (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/engineering-public-policy-energy-environment-ms)
- Engineering and Public Policy with Concentration in Infrastructure Resilience (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/engineering-public-policy-infrastructure-resilience-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-mscive)
- Civil Engineering with Concentration in Environmental and Water Systems (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-environmental-engineering-mscive)
- Civil Engineering with Concentration in Geotechnical/Geoenvironmental Engineering (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-geotechnical-geoenvironmental-mscive)
- Civil Engineering with Concentration in Structural Engineering (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-structural-mscive)
- Civil Engineering with Concentration in Transportation (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/civil-engineering-concentration-transportation-mscive)

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

Master of Science in Sustainable Building Systems (MSSBS)
- Sustainable Building Systems (http://catalog.northeastern.edu/graduate/engineering/civil-environmental/sustainable-building-systems-msbsbs)

Courses
Civil and Environmental Engineering Courses
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.

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.

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. Prereq: (a) Either CHEM 1151 or CHEM 1211 and junior or senior standing or (b) graduate standing.

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 5270. Environmental Protection and Management. 4 Hours.
Examines public and private environmental quality management and resource protection systems. Considers regulatory issues, risk management approaches, local vs. regional impacts, long-term sustainability, and economic/financial issues. Covers selected current topics and a broad range of specific environmental issues.

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.
Reviews engineering models that form the foundation of life cycle assessment (LCA), its computational structure, and relevant international standards. LCA is a widely used systems-modeling method for quantifying the environmental and health implications of a product over its entire life cycle, from manufacturing to use to disposal. This information guides design, technology decisions, and policy on topics ranging from consumer products to green buildings to the large-scale energy technologies. Students receive several hands-on training modules for popular commercial and open-source LCA software packages and have an opportunity to work examples for various products and systems. Students 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 5300. Environmental Engineering Laboratory. 4 Hours.
Offers a laboratory-based course that provides students with hands-on experiences to monitor and evaluate relevant environmental processes. Introduces the theory, application, methodology, and instrumentation used in planning, sampling, and analyzing environmental contaminants in air, water, and soil. Emphasizes instrument selection and quality control, including documentation, calibration, data analysis and interpretation, and sample management. Offers students an opportunity to demonstrate the capability to select measurements strategies and sensing technologies to analyze environmental samples, conduct laboratory experiments, critically analyze experimental data, and present the experimental results.

CIVE 5321. Geoenvironmental Engineering. 4 Hours.
Covers definitions and regulations, soil formation and mineralogy, hydraulic conductivity measurements, reactive contaminant transport through fine-grained soils, landfill and liners design, and seepage barriers and cutoff walls. Introduces site characterization and remediation.

CIVE 5373. Transportation Planning and Engineering. 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. 4 Hours.
Explores traffic flow theory and measurement, capacity and level of service analysis for intersections and urban arterials, intersection layout design, intersection signal plan design for both isolated intersections and arterials, parking analysis and design, and congestion mitigation and traffic management. Offers students an opportunity to practice with standard software.

CIVE 5522. Structural Analysis 2. 4 Hours.

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 Engineering. 4 Hours.
Introduces principles of engineering hydrology. Covers the hydrologic cycle; rainfall-runoff relationships; hydrologic flood routing; and ground water hydraulics. Applies these concepts to issues such as water supply and storm water management. Includes project component.

CIVE 5698. Special Topics in Civil Engineering (Nontechnical Elective). 2-4 Hours.
Offered when the need for a special topic is evident to faculty and students. Initiated by the appropriate faculty members and discipline committee and approved by the department. May not be used as a technical elective in a degree program. May be repeated up to five times for up to 12 total credits.

CIVE 5699. Special Topics in Civil Engineering. 2,4 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 five times for up to 12 total credits.

CIVE 5976. 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 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/extrme 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 6960. Exam Preparation—Master's. 0 Hours.
Offers the student the opportunity to prepare for the master's qualifying exam under faculty supervision.

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

CIVE 6964. Co-op Work Experience. 0 Hours.
Provides eligible students with an opportunity for work experience. May be repeated without limit.

CIVE 6965. Co-op Work Experience Abroad. 0 Hours.
Provides eligible students with an opportunity for work experience abroad. May be repeated without limit.

CIVE 6966. Practicum. 1-4 Hours.
Provides eligible students with an opportunity for practical experience. May be repeated without limit.

CIVE 7100. Applied Time Series and Spatial Statistics. 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 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 7240. Construction Equipment and Modeling. 4 Hours.
Focuses on the selection and application of earthmoving equipment. Topics include equipment production systems and cost analysis, simulation modeling of equipment operations, statistical aspects of computer simulation, and risk analysis fundamentals. Requires one semester of construction management or one semester of undergraduate soil mechanics.

CIVE 7250. Environmental Chemistry. 4 Hours.
Examines applications of chemistry to environmental engineering. Covers properties of water and pollutants, acid-base reactions, pH, alkalinity, equilibrium chemistry, chemical kinetics, chemical thermodynamics, coordination chemistry, precipitation-dissolution reactions, surface chemistry, adsorption-desorption, redox reactions, and organic chemistry as it relates to the environment. Includes relevant laboratory exercises such as colorimetry, gravimetric, and electrochemical methods; atomic absorption spectrophotometry; and ion and gas chromatography. Requires one semester of undergraduate chemistry.

CIVE 7251. Environmental Biological Processes. 4 Hours.
Examines microbiology with emphasis on biological processes in environmental engineering applications. Topics include cell structure, morphology, cell nutrition and growth, energy transfer and utilization, aerobic and anaerobic microbial metabolism, biological wastewater process theory and modeling, biological nutrients removal, and disinfection of relevant microorganisms. Includes relevant laboratory exercises of treatment parameters used to monitor the biological processes, such as BOD, TOC, COD, gravimetric methods, and dissolved oxygen. Also covers enzyme kinetics and evaluation of kinetic coefficients for biotreatment. Requires one semester of undergraduate chemistry or one semester of undergraduate biology.
CIVE 7252. Water Engineering, Resources, and Energy Recovery. 4 Hours.
Covers theory and design principles of major water and wastewater treatment processes. Focuses on the emerging issues in water sustainability and advances in fundamental science and technology in integrating scientific principles, engineered processes, and systems analyses to address diverse challenges related to society’s growing water needs and their nexus with energy and the environment. Designed to stimulate multidisciplinary thinking and research among traditional areas of civil and environmental engineering, biology, chemistry, modeling, data science, and others. Special projects are designed to have students working in multidisciplinary teams to develop sustainable solutions to meet the present and future water and resources needs of the society. Given current conditions, innovative approaches and creative energy solutions for self-sustaining wastewater treatment facilities are needed. Requires one semester of undergraduate chemistry or one semester of undergraduate biology.

CIVE 7255. Environmental Physical/Chemical Processes. 4 Hours.
Examines the processes of physical and chemical phenomena related to water quality and water treatment within environmental engineering. Presents the use of fundamental theory, mathematical description, and applied knowledge of these processes and how they are used to characterize water quality in natural systems (lakes, rivers) and to predict performance in engineered systems (water treatment systems). Uses a mass balance and reaction kinetics approach to derive analysis and design equations for water treatment unit operations. Covers physical and chemical processes, including reaction kinetics, flow regimes, dissolved solute removal, particulate removal, phase transfer processes, and redox processes. Includes laboratory demonstrations. Basic knowledge of water quality, environmental chemistry, and differential equations preferred.

CIVE 7260. Hydrologic Modeling. 4 Hours.
Covers evaluation of surface and ground water as an integrated resource using hydrologic principles. Topics include the hydrologic cycle (precipitation, interception and surface storage, infiltration, evapotranspiration, lakes and stream flow, and ground water discharge to oceans), hydrologic measurements and monitoring, surface water hydrology (rainfall/runoff modeling, hydrographs, hydrograph routing, and snow hydrology), and ground water hydrology (basic ground water hydrodynamics, porous media properties, aquifers, regional flow, and basin development and yield). Additional topics include hydrologic design, stochastic hydrology, and simulation modeling. Requires knowledge of differential equations and undergraduate probability and statistics.

CIVE 7261. Surface Water Quality Modeling. 4 Hours.
Examines mechanisms through which environmental water quality becomes degraded, control strategies for mitigating degradation, and resource management strategies for preventing degradation. Topics include contaminant sources, eutrophication processes, environmental transport and transformation processes, water quality measurements and monitoring, contaminant fate and transport modeling in lakes, rivers, estuaries, and ground water, water quality control methods and strategies, and water resource protection regulations and strategies.

CIVE 7263. Groundwater Quality Modeling. 4 Hours.
Examines methods and models used to evaluate flow and contaminant transport in ground water, focusing on practical applications. Topics in ground water flow include one-dimensional flow, well hydraulics, aquifer parameter tests, unsaturated zone flow, seepage from canals and ditches, seepage through earth structures, and an introduction to aquifer modeling. Topics in ground water quality include chemical transport and transformation processes, chemical fate and transport modeling in ground water, and ground water quality measurement and monitoring. Studies solution methods that focus on analytical solutions and flow nets, with an introduction to numerical methods. Also discusses ground water quality control and resource protection methods, strategies, and regulations.

CIVE 7272. Air Quality Management. 4 Hours.
Examines 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.

CIVE 7301. Advanced Soil Mechanics. 4 Hours.
Studies characterization of soils, soil mineralogy and chemistry, stresses within a soil mass, basic porous media flow principles, effective stress principle, compaction, drained and undrained stress-strain-strength concepts, and consolidation theory and its application. Requires one semester of undergraduate soil mechanics.

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 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 space-state 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.

CIVE 7341. Structural Reliability. 4 Hours.
Examines applications of probability theory and random variables for determining the reliability of structures. Includes the following topics: formulation of reliability for structural components and systems; first-order second-moment method, first- and second-order reliability methods, and simulation methods; analysis of model uncertainty and Bayesian parameter estimation technique; load and resistance models and bases for probabilistic structural codes; and time-dependent reliability methods. Assumes no prior knowledge of probability theory.

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 7343. Experimental Modal Analysis. 4 Hours.
Covers the fundamentals of signals, filters, and system identification in the time and frequency domain as applied to structural engineering. Offers students an opportunity to carry out projects in the laboratory to obtain practical experience in modal identification, model updating, and damage diagnosis. 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 (LRFD) 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. Transportation Performance and Simulation Models. 4 Hours.
Reviews concepts and methods for analyzing the performance of complex transportation systems as well as methodologies for planning, designing, monitoring, and managing and controlling traffic flows over complex transportation networks. Topics include deterministic and probabilistic models, elements of queuing theory, network optimization algorithms, and simulation. Applications include traffic flow modeling, traffic assignment, analysis of diverse transportation facilities, level of service and estimation of delays, optimal design of transportation network services, and traffic assignment.

CIVE 7381. Transportation Demand Models. 4 Hours.
Examines methods and models used to predict urban travel demand. Introduces supporting statistical methods including linear regression, maximum likelihood estimation, and statistical tests. Also studies the effect of variable demand on project evaluation. Requires one semester of undergraduate probability and statistics.

CIVE 7382. Advanced Traffic Control and Simulation. 4 Hours.
Covers principles and logic of traffic signal control, including actuated control, coordinated control, transit signal priority, and signal control schemes for better accommodating pedestrians and bicycles. Topics include traffic microsimulation principles for urban street networks, intersection and network performance modeling and measurement, and design and programming of traffic signal control using traffic microsimulation.

CIVE 7385. Public Transportation. 4 Hours.
Studies the analysis, planning, and operational design of urban public transportation systems. Topics include service design and scheduling, such as route and system-level design and optimization, passenger flow modeling, rail operations, and bus operational control including automatic vehicle location and priority at signalized intersections. Also covers passenger sampling, ridership estimation, demand forecasting, data collection design, and service quality monitoring, with an emphasis on intelligent systems. Discusses policy issues including pricing, subsidy, and priority. Introduces supporting mathematical methods in optimization 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. 2,4 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 7390. Special Topics in Construction Management Engineering. 2,4 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. 2,4 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. 2,4 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 7396. Special Topics in Structural Engineering. 2,4 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 7398. Special Topics in Transportation Engineering. 2,4 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 are 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 7994. Thesis Continuation—Part Time. 0 Hours. 
Continues thesis work conducted under the supervision of a departmental faculty member. 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 8964. Co-op Work Experience. 0 Hours. 
Provides eligible students with an opportunity for work experience. May be repeated without limit.

CIVE 8966. Practicum. 1-4 Hours. 
Provides eligible students with an opportunity for practical experience. May be repeated without limit.

CIVE 8982. Readings. 1-4 Hours. 
Offers selected readings under the supervision of a faculty member. May be repeated without limit.

CIVE 8984. Research. 1-4 Hours. 
Offers an opportunity to conduct research under faculty supervision. May be repeated without limit.

CIVE 8986. 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 9984. 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 9990. Dissertation. 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. May be repeated once.

CIVE 9996. Dissertation Continuation. 0 Hours. 
Continues thesis work conducted under the supervision of a departmental faculty. Requires prior completion of CIVE 9990 twice and PhD candidacy in civil engineering or in interdisciplinary engineering. May be repeated without limit.
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 basic design and construction of 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. Also addresses sustainable design and construction practices for MEP, including minimization of energy consumption and carbon footprint.

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.