# CIVIL AND ENVIRONMENTAL ENGINEERING

mccormick.northwestern.edu/civil-environmental

The Department of Civil and Environmental Engineering offers two degree programs for undergraduate students, one in civil engineering and another in environmental engineering, as well as minors in environmental engineering and in architectural engineering and design.

Civil and environmental engineers play central roles in defining sustainable development approaches to the interactions of humans with earth systems. The curricula of these programs place strong emphasis on design, communication, teamwork, and the development of a systems perspective on the complex problems of today and tomorrow.

## Civil Engineering

Civil Engineering is an international profession that provides solutions for pressing societal challenges for both the natural and built environment. Civilian infrastructure systems provide safe and efficient transportation systems for people, food, and manufactured goods; safe and energy efficient residential and commercial buildings; support the ecological and human health by protecting the quality of water, air, and land; and support the energy sector with power plants and their support structures.

Civil Engineering bridges science and society, and thus plays a leading role in planning, designing, building, and ensuring a sustainable future. The American Society of Civil Engineers (ASCE) defines **sustainability** as *a set of economic, environmental and social conditions in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely, without degrading the quantity, quality or the availability of natural resources and ecosystems*. The civil engineering profession recognizes the reality of limited natural resources, the desire for sustainable practice (including life-cycle analysis and sustainable design techniques), and the need for social equity in the consumption of resources.

Civil Engineers are the stewardess of our natural resources and the built environment that support commerce, recreation, health, and other necessities of modern social economies. They design, construct, and manage these systems as well as the taller, longer, lighter, and more elegant structures at the end nodes, such as airports, sky scrapers, bridges, etc. everywhere on the planet and even in space. Each system has unique characteristics that challenge civil engineers to combine engineering knowledge with initiative and creativity to meet project objectives, protect the well-being of society and our finite natural resources, and meet budget constraints.

In addition to the applications of mathematics, physical, natural, and engineering sciences, Civil Engineers must incorporate excellent communication and people-skills, social, economic, managerial sciences, and collaborate with architects, public officials, owners, contractors, material suppliers and the public during various phases of a project. Their work may extend to materials science to develop new building materials; using advanced sensors and communication devices to monitor performance of bridges, tunnels, buildings in real time, over long distances, and under extreme conditions. Civil engineers have designed infrastructures that stretched the limit of materials, performance, and human desire while preserving our natural resources.

The most unique aspects of civil engineering are: the close interaction with the citizens of a community, influence of political policy, and the ability to execute sustainable designs and constructions that have tremendous impact to the social, economic, and welfare of every member in the world.

At Northwestern, the Civil Engineering curriculum is designed to satisfy students' diverse interests and professional goals. Students develop study plans suited to their unique interests, including options such as the Architectural Engineering and Design Minor and the Environmental Engineering Minor within our Department, and the Kellogg School of Management Certificate program for undergraduates, to address the social, physical, and financial challenges of constructing and managing the nation's infrastructure.

While Civil engineering graduates typically work in engineering consulting firms, city and county public works, state departments of transportation, construction companies, various branches of federal government, and engineering material product industries, some of our graduates work in the aerospace industry, Wall Street, medicine, laws, politics, and policy development. A majority of Northwestern graduates receive at least one advanced degree. About half of these received advanced degrees are in other professional fields such as aerospace, business administration, medicine, and law. Others may work in research and development, and teaching.

Our recent graduates hold jobs in a wide spectrum of areas such as infrastructure engineering consulting (buildings, bridges, railroads, power plants, environmental treatment plants, etc.), construction, project management, architecture, energy, and finance. Their positions include project engineers, project managers, field engineers, and designers. Some graduates join the business sector as business analysts, technical consultants, and derivative traders. A sample of their employers include Amazon, Boeing, Accenture, ARCADIS, Mass Electric Construction, General Dynamics' Electric Boat Division, National Forest Service, SOM, WSP, Thornton Tomsasetti, Jacobs, and MWRD. Others go directly to graduate school. Most mid-career civil engineers hold supervisory or administrative positions such as project engineers.

## Environmental Engineering

*Is the water safe to drink? Is the air dangerous to breathe? Should we eat the fish we catch or the crops we grow? Do our living and work spaces pose special threats to our health?* Environmental Engineers are the technical professionals who identify and design solutions for environmental problems. They provide answers to the above and other questions about the potentially harmful interrelationships between human civilization and the environment. Environmental engineers apply scientific and technological knowledge to eliminate or reduce environmental problems. They seek to shield the environment from the harmful effects of human activity, protect human populations from adverse environmental events such as floods and disease, and restore environmental quality for ecological and human well-being. Traditionally, environmental engineering includes:

a. The identification and measurement of potentially harmful physical, chemical, and biological agents in the environment,
b. The transport and fate of these agents,
c. The effects of these agents on people and the environment, and
d. The design and operation of engineered systems for the maintenance and improvement of the quality of our environment.

Historically, it was the sanitary and civil engineers who made cities livable for large populations. However, the role of environmental engineering has been expanding in the past few decades. Increasingly, environmental engineers are being called upon to expand the focus of their efforts to address the challenges associated with alternative energy, sustainability, climate change, ecological restoration and emerging public health threats.

Northwestern has developed an interdisciplinary approach to the education of environmental engineers. The four-year curriculum provides the students with a sound fundamental knowledge of environmental engineering principles and an opportunity to integrate other aspects such as basic science, social science, humanities, and public policy to their knowledge. Environmental Engineers stand at the threshold between natural environmental systems and human societies!

Graduates in environmental engineering will have many career opportunities in a spectrum of business sectors and government agencies. These include engineering consulting firms that offer challenging employment in environmental planning, design, and management. The manufacturing and chemical industries, utilities, the pollution control industry, and others need engineers for the development and management of research and environmental control programs. Engineers in governmental agencies are responsible for planning and assessment of control strategies and measures to assure a clean and healthful environment. Universities and research organizations afford additional avenues of career development.

Our recent graduates hold positions as engineering designers, business analytics, and staff engineers of regulatory agency. A sample of their employers include AECOM, ARCADIS, Black & Veatch, EPA, Jacobs, RAMBOLL, Tetra Tech, WSP, and many energy start-ups. Many of our graduates continue their education in schools of engineering, law, medicine, public health, and management.

# Programs of Study

- Civil Engineering Degree (https://catalogs.northwestern.edu/undergraduate/engineering-applied-science/civil-environmental-engineering/civil-engineering-degree/)
- Environmental Engineering Degree (https://catalogs.northwestern.edu/undergraduate/engineering-applied-science/civil-environmental-engineering/environmental-engineering-degree/)
- Architectural Engineering and Design Minor (https://catalogs.northwestern.edu/undergraduate/engineering-applied-science/civil-environmental-engineering/architectural-engineering-design-minor/)
- Environmental Engineering Minor (https://catalogs.northwestern.edu/undergraduate/engineering-applied-science/civil-environmental-engineering/environmental-engineering-minor/)

**CIV_ENV 101-0 Introduction to Civil and Environmental Engineering (0 Unit)** In this seminar course we discuss the grand challenges facing society in the coming decades, and how Civil and Environmental Engineers are meeting these challenges. Seminars will focus on key CE and EE topics, the CE & EE curricula at NU, and the career paths of recent CE & EE graduates.

**CIV_ENV 195-0 Introductory Course in Civil and Environmental Engineering (0-1 Unit)** Introductory-level special topics courses in civil and environmental engineering. 195 is similar to CIV_ENV 395-0 but intended for first and second-year students.

**CIV_ENV 201-0 Engineering Possibilities: Decision Science in the Age of Smart Technologies (1 Unit)** Define challenges facing cities, and learn how to critically evaluate different solutions, ranging from traditional to innovative. Foster critical thinking about problem definitions along with the definition of metrics that represent desirable (and undesirable) outcomes in urban systems.

**CIV_ENV 202-0 Biological and Ecological Principles (1 Unit)** Fundamentals of biology - including cell biology, genetics, and biochemistry - and ecology - including biological interactions, microbial ecology - and biogeochemical cycling as they apply to natural and engineered systems. Bioinformatics tools necessary for analyzing biological and ecological data. Prerequisites: MATH 220-2; CHEM 131-0, CHEM 151-0, or CHEM 171-0.

**CIV_ENV 203-0 Earth in the Anthropocene (1 Unit)** Fundamentals of Earth system science and their connections to the need for humans to develop food, water, energy and infrastructure systems that has led to transformation of the Earth's surface and of its atmosphere. Prerequisite: MATH 220-2; CHEM 131-0, CHEM 151-0, or CHEM 171-0 is highly recommended. *Natural Sciences Distro Area*

**CIV_ENV 205-0 Economics and Finance for Engineers (1 Unit)** Principles of corporate finance; financial decisions of firms; value; risk and return; investment and capital budgeting decisions under certainty and uncertainty; performance evaluation. May not be taken for credit with or after KELLG_FE 310-0. Prerequisite: MATH 220-1; basic understanding of probability and economics recommended.

**CIV_ENV 216-0 Mechanics of Materials I (1 Unit)** Analytical and experimental study of stresses and deformations and their application to the design of machine and structural elements subjected to static, dynamic, and repeated loads. Prerequisite: GEN_ENG 205-2 or GEN_ENG 206-2.

**CIV_ENV 220-0 Structural Art (1 Unit)** Learn how to interpret and understand the built environment through an examination of the history of structural engineering as a creative art, with particular emphasis on technical, visual, and social analysis and critique of bridges, buildings, and designers.

**CIV_ENV 221-0 Theory of Structures I (1 Unit)** Deflections of structures, energy concepts, idealization of structures, truss analysis, column stability, and influence lines. Introduction to indeterminate truss and frame analyses, slope-deflection analysis, and moment distribution. Portal method. Prerequisite: CIV_ENV 216-0.

**CIV_ENV 250-0 Earth Surface Engineering (1 Unit)** Fundamental properties and behavior of soils as engineering materials. Origin of soils through the properties of soil components to the strength, permeability, and deformation of soil masses. Prerequisite: MECH_ENG 241-0.

**CIV_ENV 260-0 Environmental Systems and Processes (1 Unit)** Basic engineering principles required for the design, operation, analysis, and modeling of both natural and engineered systems and their application to major issues facing human and environmental health of ecosystems. Corequisite: MATH 220-2; CHEM 131-0, CHEM 151-0, or CHEM 171-0 highly recommended.

**CIV_ENV 280-1 Architectural Engineering & Design Seminar I (0 Unit)** First course in the AED seminar series. Students will learn from practicing architects and engineers, and will also conduct independent studies culminating in their own seminars to the class.

**CIV_ENV 280-2 Architectural Engineering & Design Seminar II (0 Unit)** Second course in the AED seminar series. Students will learn from

practicing architects and engineers, and will also conduct independent studies culminating in their own seminars to the class.

**CIV_ENV 280-3 Architectural Engineering & Design Seminar III (0 Unit)** Third course in the AED seminar series. Students will learn from practicing architects and engineers, and will also conduct independent studies culminating in their own seminars to the class.

**CIV_ENV 295-0 Introductory topics in Civil and Environmental Engineering (1 Unit)** Intermediate-level study of topics suggested by students or faculty members and approved by the department.

**CIV_ENV 301-1 Professional Development Seminar I (0.34 Unit)** Case study in engineering ethics, with discussion of topics in professional development and lifelong learning. Prerequisite: junior engineering standing.

**CIV_ENV 301-2 Professional Development Seminar II (0 Unit)**
Preparation for the Fundamentals of Engineering (FE) exam. Prerequisite: senior engineering standing.

**CIV_ENV 302-0 Engineering Law (1 Unit)**
The American legal system from an engineer's perspective. Socratic-method analysis of statutory and case law. Contract, patent, corporation, antitrust, property, and environmental law. Torts, product liability, and arbitration.
Prerequisite: junior engineering standing.

**CIV_ENV 303-0 Environmental Law and Policy (1 Unit)**
An introduction to important aspects of environmental law and policy. Covers a wide range of environmental topics, with a focus on major federal environmental statutes.
Prerequisite: junior or senior standing.

**CIV_ENV 304-0 Civil and Environmental Engineering Systems Analysis (1 Unit)**
Quantitative techniques to develop descriptive and prescriptive models that support efficient planning and management of civil and environmental engineering systems.
Prerequisite: MATH 220-2 or equivalent.

**CIV_ENV 306-0 Uncertainty Analysis (1 Unit)**
Probability, statistics, and decision theory. Discrete and continuous random variables, marginal and conditional distributions, moments, statistical model selection and significance tests, hypothesis testing, and elementary Bayesian decision theory. Application to problems in soil mechanics, water resources, transportation, and structures.

**CIV_ENV 308-0 Environmental Justice (1 Unit)**
This course will examine evidence that there is not equal environmental protection in this country and analyze why this inequality exists. Course participants will review evidence of environmental injustice, with attention to perspectives of grassroots organizations, the U.S. EPA, and businesses. The course will explore why civil and human rights have become important aspects of environmental protection activities worldwide.

**CIV_ENV 309-0 Climate and Energy - Law and Policy (1 Unit)**
This course is a survey of the major laws that regulate the acquisition of energy resources, the conversion of energy resources into usable energy, the energy transmission and transportation infrastructure and the climate change implications of these activities.

**CIV_ENV 314-0 Organic Geochemistry (1 Unit)**
The sources and fates of organic matter in the natural environment; global cycling of organic carbon; applications to the study of modern and ancient environments. Taught with EARTH 314-0; may not receive credit for both courses.
Prerequisites: 1 course in earth and planetary sciences or environmental sciences; 1 course in chemistry.

**CIV_ENV 317-0 Biogeochemistry (1 Unit)**
Cycling of biogenic elements (C, N, S, Fe, Mn) in surficial environments. Emphasis on microbial processes and isotopic signatures.
Prerequisites: 1 quarter of chemistry; 1 quarter of geoscience, environmental sciences, or biological sciences.

**CIV_ENV 320-0 Structural Analysis--Dynamics (1 Unit)**
Single and multiple degree-of-freedom systems subjected to periodic, seismic, and general loadings. Time-history analysis of linear and nonlinear systems. Design methods for earthquakes.
Prerequisite: CIV_ENV 221-0.

**CIV_ENV 321-0 Concrete Properties (1 Unit)**
Concrete as a composite material; relationship between constitutive laws and microstructure; failure theories; fracture; fatigue; strain rate effects; destructive and nondestructive testing; creep and shrinkage; chemistry of cement hydration; admixtures; aggregates; proportioning; new materials.

**CIV_ENV 323-0 Structural Steel Design (1 Unit)**
Rational basis of structural design. Design approach for structural-steel components of a building system.
Prerequisites: CIV_ENV 216-0; CIV_ENV 221-0 or equivalent.

**CIV_ENV 325-0 Reinforced Concrete (1 Unit)**
Fundamentals of reinforced concrete theory and design. Analysis and design of beams, slabs, and columns. Concurrent familiarization with current building codes, specifications, and practices.
Prerequisite: CIV_ENV 221-0.

**CIV_ENV 326-0 Engineering Forensics (1 Unit)** Introduction to failure analysis and forensic engineering to describe how these investigative procedures contribute to regulations, engineering design, safety principles, and the economic aspects of structure engineering.
Prerequisite: CIV_ENV 221-0.

**CIV_ENV 327-0 Finite Element Methods in Mechanics (1 Unit)**
Development of finite elements from variational principles and application to static stress analysis. Introduction to techniques for transient and generalized field problems. Computer implementation of finite element techniques. Taught with MECH_ENG 327-0; may not receive credit for both courses.

**CIV_ENV 328-0 Computational Forensics and Failure Analysis (1 Unit)**
The course will cover the use of the scientific method for accident investigation, hypothesis development, and the use of the finite element method to analyze the root cause of a failure. Practical application problems for both civil and mechanical structures will be analyzed using commercial finite element codes (Abaqus, Hypermesh, LS-Dyna)
Prerequiste: CIV_ENV 327-0 or MECH_ENG 327-0.

**CIV_ENV 330-0 Engineering Project Management (1 Unit)**
Techniques for coordinating decisions and actions of various parties in the design and construction of civil and environmental engineering projects. Delivery systems; preconstruction services; project planning; cost control and value engineering; bidding.
Prerequisite: instructor consent.

**CIV_ENV 332-10 Building Construction Estimating (1 Unit)**
Estimation of cost at different stages of design; conceptual estimating and quantity takeoff of various elements, such as materials, labor, and equipment.
Prerequisites: CIV_ENV 330-0; consent of instructor.

**CIV_ENV 336-10 Project Scheduling (1 Unit)**
Project planning, scheduling, and control using CPM arrow and precedence networks; resource allocation and resource leveling; earned

value analysis; linear scheduling; PERT, CPM in dispute resolution and litigation, computer scheduling.
Prerequisite: CIV_ENV 330-0.

**CIV_ENV 340-0 Hydraulics and Hydrology (1 Unit)**
Civil and environmental engineering applications of fluid mechanics. Turbulent flow in pipes and rivers, pipe and river networks, and open channels.
Prerequisite: MECH_ENG 241-0.

**CIV_ENV 346-0 Ecohydrology (1 Unit)**
Interactions between water and ecosystems in freshwater, terrestrial, and urban environments. Feedbacks between ecological and hydrological processes. Engineering of ecosystems such as constructed wetlands, green roofs, and other green infrastructure for resilient and sustainable water management.
Prerequisites: Students must have taken MECH_ENG 241, CIV_ENV 260, and CIV_ENV 361-1 or graduate standing.

**CIV_ENV 352-0 Foundation Engineering (1 Unit)**
Application of soil mechanics to analysis and design of foundations and embankments. Settlement of structures, bearing capacities of shallow and deep foundations, earth pressures on retaining structures, and slope stability.
Prerequisite: CIV_ENV 250-0.

**CIV_ENV 353-0 Energy Geostructures & Geosystems (1 Unit)**
This course focuses on energy geostructures and geosystems: novel earth-contact technologies that provide renewable energy supply and structural support to any built environment. The course comprises theoretical and practical sessions. The theoretical sessions expand on the analysis and design of such technologies from energy, geotechnical and structural perspectives. The practical sessions simulate an actual design project of energy geostructures.

**CIV_ENV 357-0 Terramechanics (1 Unit)**
Problems defined by the interaction between machines and terrain—or by organisms and terrain—are ubiquitous on Earth, and they are beginning to play important roles elsewhere as we explore, exploit, and perhaps eventually occupy the moon and other planets. While aspects of these problems are understood, much remains to be learned in the field of terramechanics.

**CIV_ENV 361-1 Environmental Microbiology (1 Unit)**
Basic principles and practical applications of microbiology to environmental issues, such as microbial contamination, degradation of organic contaminants, production of alternative fuels, and global climate change.

**CIV_ENV 361-2 Public & Environmental Health (1 Unit)**
Current problems in public and environmental health, such as the worldwide burden of major infectious diseases, emergence of new pathogens, and environmental reservoirs of infectious organisms.
Prerequisite: CIV_ENV 361-1 or consent of instructor.

**CIV_ENV 364-0 Sustainable Water Systems (1 Unit)**
An overview of the engineered water cycle focusing the fundamental principles as well as the design and assessment methods for physical, chemical and biological treatment unit processes for drinking water treatment, used water treatment and reuse, and emerging issues such as the energy-food-water nexus.
Prerequisites: CIV_ENV 260-0, MECH_ENG 241-0.

**CIV_ENV 365-0 Environmental Laboratory (1 Unit)**
Chemical and microbiological aspects of environmental engineering and science are explored through an integrated laboratory course.
Prerequisite: CIV_ENV 367-0.

**CIV_ENV 366-0 Dynamics in Chemical Transport and Reaction (1 Unit)**
Application of environmental engineering fundamentals to evaluate, model, and develop engineering solutions for different environmental contamination scenarios. Prerequisite: CIV_ENV 260 or instructor consent.

**CIV_ENV 367-0 Chemical Processes in Aquatic Systems (1 Unit)**
Chemical principles for understanding and predicting the chemical composition and evolution of natural waters using an equilibrium approach. Applications to environmental issues such as metal speciation and toxicity, ocean acidification, carbon storage.
Prerequisite: BMD_ENG 250-0 or CHEM_ENG 211-0.

**CIV_ENV 368-0 Sustainability: The City (1 Unit)**
Exploration of the issues that motivate the design and engineering of sustainable resource use and development.

**CIV_ENV 370-0 Emerging Organic Contaminants (1 Unit)**
Fundamental molecular processes that govern the fate and transformation of emerging organic contaminants in natural and engineered environmental systems.
Prerequisite: CHEM 210-1 or consent of instructor.

**CIV_ENV 371-0 Introduction to Transportation Planning and Analysis (1 Unit)**
Analysis and design of solutions to transportation problems; introduction to selected operations research and statistical analysis techniques; use of case studies in urban transportation, intercity passenger transport, and freight movements.
Prerequisite: junior standing or consent of instructor.

**CIV_ENV 376-0 Transportation System Operations (1 Unit)**
Traffic-flow theory; vehicle and human factors, capacity analysis, intersection performance and control; management and control of arterial streets and networks; neighborhood traffic restraint, urban transit operations. Operations concepts and theories applied to actual problems through laboratory practice.
Prerequisite: basic understanding of calculus and statistics; knowledge of MATLAB desirable but not required.

**CIV_ENV 377-0 Choice Modelling in Engineering (1 Unit)**
"This course focuses on the theory and practice of survey design, data and analysis. In this course students will learn the theories and scientific debates around the design, ad- ministration and analysis of various types of behavioral data-collection methods."

**CIV_ENV 382-1 Capstone Design I (0.5 Unit)** Culminating team-based design experience in civil and environmental engineering, with an overview of the function, design, and operations of modern infrastructure systems. Part 1 of 2-course sequence. Prerequisite: senior standing in civil or environmental engineering or consent of instructor.

**CIV_ENV 382-2 Capstone Design II (0.5 Unit)** Culminating team-based design experience in civil and environmental engineering, with an overview of the function, design, and operations of modern infrastructure systems. Part 2 of 2-course sequence. Prerequisite: CIV_ENV 382-1.

**CIV_ENV 385-1 Architectural Engineering and Design 1: Fundamentals (1 Unit)**
Architectural engineering and design studios: architectural history, case studies in design, construction and management of buildings, and drawing and model building. Fundamental studio: basic architectural and structural design of a simple building project.
Prerequisite: junior standing in engineering or consent of instructor.

**CIV_ENV 385-2 Architectural Engineering & Design 2: Intermediate (1 Unit)**

Architectural engineering and design studios: architectural history, case studies in design, construction and management of buildings, and drawing and model building. Intermediate studio: architectural and structural design of a building project with multiple requirements.
Prerequisites: CIV_ENV 385-1 and junior standing in engineering; or consent of instructor.

**CIV_ENV 385-3 Architectural Engineering & Design 3: Advanced Studio (1 Unit)**
Architectural engineering and design studios: architectural history, case studies in design, construction and management of buildings, and drawing and model building. Advanced studio: architectural and structural design of a large, complex building project.
Prerequisites: CIV_ENV 385-2 and junior standing in engineering; or consent of instructor.

**CIV_ENV 386-0 High Performance Architectural Design (1 Unit)**
Elements of high performance building design and to explore the various matrics used to analyze the relationship between the structure and function of various design alternatives.

**CIV_ENV 387-0 Design of Sustainable Urban Developments (1 Unit)**
Design high performing neighborhoods, districts and communities that incorporate principles of density, diversity and flexibility around the "operating system of nature". Prerequisites: CIV_ENV 386-0, senior standing, consent of instructor; recommend CIV_ENV 385-1, CIV_ENV 385-2, and CIV_ENV 385-3.

**CIV_ENV 388-1 Building Science I: Fundamentals for Sustainable Buildings (1 Unit)** The course is the first of a two-part series focusing on Building Science. This course aims to provide the fundamental knowledge of the physics related to buildings, focusing on heat and mass transfer, moisture, and the energy consumed in buildings to guarantee the comfort of their occupants.

**CIV_ENV 388-2 Building Science II: Application for Sustainable Buildings (1 Unit)**
This course enriches and applies the concepts learned in CIV_ENV 388-1. The course comprises both theoretical and practical sessions. Theoretical sessions introduce the environmental factors affecting occupants' comfort inside buildings. Practical sessions focus on the design of a virtual project, with calculations related to energy consumption and visual and thermal parameters with the help of computer software.

**CIV_ENV 395-0 Special Topics in Civil and Environmental Engrg (1 Unit)**
Topics suggested by students or faculty and approved by the department.

**CIV_ENV 398-1 Community-based Design 1 (1 Unit)**
Yearlong participation in two-or three-person team projects involving research, analysis, and/or design in the solution of environmental problems affecting primarily lower-income communities. Grade assigned only on completion of both units.
Prerequisite: consent of instructor.

**CIV_ENV 398-2 Community-based Design 2 (1 Unit)**
Yearlong participation in two-or three-person team projects involving research, analysis, and/or design in the solution of environmental problems affecting primarily lower-income communities. Grade assigned only on completion of both units.
Prerequisite: consent of instructor.

**CIV_ENV 399-0 Projects (1 Unit)** Special studies under faculty direction. Credit to be arranged.

**CIV_ENV 410-0 Theory of Plates and Shells (1 Unit)**
Derivation of governing equations for plates, cylindrical shells and spherical shells, analytical and numerical methods for the solutions of elastic and inelastic problems, and civil engineering applications.

**CIV_ENV 413-0 Experimental Solid Mechanics (1 Unit)**
Experimental techniques in measuring stress and strain. Strain gauge, photoelastic, brittle coating, and Moire techniques studies and applied with selected laboratory experiments. CIV_ENV 413-0 and MECH_ENG 413-0 are co-listed.

**CIV_ENV 414-1 Mechanics of Composite Materials 1 (1 Unit)**
Introduction to basic concepts: fabrication of composite materials, micromechanics, macro-mechanics of unidirectional lamina, failure theories, mechanics of multidirectional laminate, lamination theory, hydrothermal effects, inter-laminar stresses, stress concentrations, structural design and optimization, and nondestructive evaluation. CIV_ENV 414-1 and MECH_ENG 414-1 are co-listed.

**CIV_ENV 414-2 Mechanics of Composite Materials II (1 Unit)**
Introduction to basic concepts: fabrication of composite materials, micromechanics, macro-mechanics of unidirectional lamina, failure theories, mechanics of multidirectional laminate, lamination theory, hydrothermal effects, inter-laminar stresses, stress concentrations, structural design and optimization, and nondestructive evaluation. CIV_ENV 414-2 and MECH_ENG 414-2 are co-listed.

**CIV_ENV 415-0 Theory of Elasticity (1 Unit)**
Notions of stress and strain. Basic equations of the linear theory of elastic media. Stress function and displacement potentials. Applications to specific classes of problems such as plane strain, contact stresses, and axisymmetric problems. Stress concentration. Singular states of stress. Dislocations and residual stresses.

**CIV_ENV 416-0 Computational Nanodynamics (1 Unit)**
The objective of this course is to learn how to use theoretical and computational modeling tools to simulate dynamic solid mechanics phenomena at small scales. Topics covered include elementary concepts in dynamics, statistical mechanics, molecular interactions, coarse-graining strategies, and application of the molecular dynamics methodology to elasticity, diffusion, self-assembly, vibrations, fragmentation and fracture problems of relevance to nanoscale, biological and biomolecular systems.

**CIV_ENV 417-1 Mechanics of Continua 1 (1 Unit)**
Introduction to mechanics of continuous media. Cartesian tensors; kinematics of deformable media; stress; balance laws; constitutive relations for selected solids and fluids.

**CIV_ENV 419-0 Elastic Wave Propagation in Periodic Solids (1 Unit)**
Introduction of elastodynamic wave equations in anisotropic solids, plane longitudinal, transverse, and surface waves, harmonic waves and pulses, energy considerations, reflection, transmission, and mode conversion, scattering and diffraction problems, reciprocity relations, piezoelectric materials, and band engineering using periodic solids and metamaterials.
Prerequisites: CIV_ENV 415-0, MECH_ENG 363-0 or MECH_ENG 390-0, or equivalent.

**CIV_ENV 421-0 Prestressed Concrete Design (1 Unit)**
Principles of prestressed concrete. Prestressing systems, end anchorage, and loss of prestress. Analysis and design of sections for flexure, shear, bond, bearing, and deflection. Continuous beams, slab, tension, and compression members. Circular prestressing.

**CIV_ENV 422-0 Inelastic Analysis of Structures (1 Unit)**
Inelastic analysis of frames, plates, and shells. Plastic behavior and limit analysis theorems. Static and kinematic methods for calculating collapse loads. Yield surfaces for plates and shells, plastic potential flow law,

and load capacity. Viscoelastic behavior and rheologic models. Creep of concrete and its effects in structures.

**CIV_ENV 423-0 Matrix Analysis of Structures (1 Unit)**
Use of matrix methods for analysis of articulated structural systems, geometric matrices, stability, analysis of geometrically nonlinear systems, introduction to the finite element method.

**CIV_ENV 424-0 Stability of Structures (1 Unit)**
Buckling of perfect and imperfect columns, mathematical treatment of various types of stability problems and stability criteria, dynamic and static instability, and energy methods. Buckling of frames, trusses, and beams. Snap-through, elastic-plastic columns, creep buckling, and basic approach to buckling of two- and three-dimensional bodies.

**CIV_ENV 425-0 Behavior of Reinforced Concrete (1 Unit)**
Nonlinear behavior of reinforced concrete structural members. assumptions underlying serviceability criteria, ductility for earthquake design, etc.

**CIV_ENV 426-1 Advanced Finite Element Methods 1 (1 Unit)**
Methods for treating material and geometric nonlinearities by finite elements; transient analysis: explicit and implicit time integration, partitioned methods, and stability; hybrid and mixed elements; finite elements for plates and shells; convergence, efficiency, and computer implementation. Co-listed with MECH_ENG 426-1.

**CIV_ENV 426-2 Advanced Finite Element Methods 2 (1 Unit)**
This course will cover the fundamentals of non-standard finite element formulations such as Moving Least Squares (MLS), Element Free Galerkin (EFG), Reproducing Kernel Particle Method (RKPM), Material Point Method (MPM), Aribitrary Lagrangian Eulerian (ALE) Formulations, and the eXtendended Finite Element Method (XFEM). The course will also provide an in-depth investigation of advanced application of finite element analysis and interfacing user-developed material models with commercial finite element codes (Abaqus/LS-DYNA). Theory and implementation of computational plasticity, nonlinear elasticity, pressure-sensitive plasticity, and damage-based plasticity will be discussed. Material classes to be discussed are those commonly found in manufacturing, geomechanical, and biological applications such as ductile metals, soil, and tissue. Co-listed with MECH_ENG 426-2.

**CIV_ENV 428-1 Structural Design I (1 Unit)**
First course in the structural design studio. Students will learn fundamental topics of structural mechanics, materials, and engineering, and then apply them to a realistic design project, coordinated by practicing structural engineers.

**CIV_ENV 428-2 Structural Design II (1 Unit)**
Second course in the structural design studio. Students will learn fundamental topics of structural mechanics, materials, and engineering, and then apply them to a realistic design project, coordinated by practicing structural engineers.

**CIV_ENV 428-3 Structural Design III (1 Unit)**
Third course in the structural design studio. Students will learn fundamental topics of structural mechanics, materials, and engineering, and then apply them to a realistic design project, coordinated by practicing structural engineers.

**CIV_ENV 430-0 Quasibrittle Fracture and Scaling (1 Unit)**
Fracture mechanics fundamentals. Concrete, composites, ice, rocks, soils, ceramics. Cohesive crack model. Crack band model. Damage. Localization. Nonlocality. Size effect laws. Statistical aspects. Discrete micro-modeling. Fracture stability. Environmental effects, loading rate and fatigue.

**CIV_ENV 435-10 Cost Engineering and Control (1 Unit)**
Application of cost engineering for construction companies and projects; accounting methods; estimating process and bid preparation; labor cost; earned value analysis; accounting for equipment; cost-control concepts; cash flow management, changes and extras; claims.
Prerequisites: PROJ_MGT 403-0 and PROJ_MGT 405-0.

**CIV_ENV 440-0 Environmental Transport Processes (1 Unit)**
Processes controlling transport and fate of dissolved and suspended substances in natural and engineered environmental systems. Mass balances, hydrodynamic transport, phase and mass transfers; the fate of reactive species in complex environmental systems..

**CIV_ENV 442-0 Environmental Biotechnology for Resource Recovery (1 Unit)**
Theory and practice of microbiological processes used for pollution control and resource recovery: kinetics of suspended-growth and fixed-film processes, activated sludge, biofilm processes, nitrogen and phosphorus removal, methanogenesis.
Prerequisites: CIV_ENV 440-0, CIV_ENV 361-1.

**CIV_ENV 443-0 Microbial Ecology for Resource Recovery (1 Unit)**
This course provides students with an overview of microbial ecology-that is, the study of interactions between microorganisms and the environment-and how complex microbial communities are linked function and stability of both engineered and natural systems.

**CIV_ENV 447-0 Molecular Microbiology (1 Unit)**
An in-depth look at current molecular methods used to study environmental microbiology. Fundamentals of molecular microbiology, creative and critical analysis of literature through proposal writing and reviewing. Topics focus on polymerase chain reaction and derivatives; DNA sequencing; proteomics & proteogenomics, and metabolomics.

**CIV_ENV 448-0 Computational Chemodynamics (1 Unit)**
An in-depth understanding of the processes that govern the fate of chemicals in the environment by developing computational tools used to quantify the concentrations of contaminants and nutrients. Numerical methods focus on solving: multiphase equilibrium problems, box models, reaction networks and kinetics, the interplay between transport and reaction, partitioning, and trophic relationships.

**CIV_ENV 449-0 Environmental Particles and Surface Chemistry (1 Unit)**
Environmental particles facilitate the cycling of important elements in the environment. This course presents fundamental concepts and applications of chemical kinetics, chemical equilibrium, and molecular spectroscopy to characterize their surface properties.

**CIV_ENV 450-1 Soil Mechanics 1 (1 Unit)**
First Quarter: Shear strength of soils. Theory of consolidation. Problems of rate-independent and rate-dependent settlement. Second Quarter: Foundation engineering. Bearing capacity of shallow and deep foundations. Deformation of foundations. Effects of construction on performance. Case studies. Third Quarter: Earth and earth-supported structures. Earth pressures on walls. Design of retaining structures and supported excavations. Effects of construction on performance. Stability of slopes. Design of earth dams and embankments. Case studies.

**CIV_ENV 450-2 Soil Mechanics 2 (1 Unit)**
First Quarter: Shear strength of soils. Theory of consolidation. Problems of rate-independent and rate-dependent settlement. Second Quarter: Foundation engineering. Bearing capacity of shallow and deep foundations. Deformation of foundations. Effects of construction on performance. Case studies. Third Quarter: Earth and earth-supported structures. Earth pressures on walls. Design of retaining structures and supported excavations. Effects of construction on performance. Stability of slopes. Design of earth dams and embankments. Case studies.

**CIV_ENV 450-3 Soil Mechanics 3 (1 Unit)**
First Quarter: Shear strength of soils. Theory of consolidation. Problems of rate-independent and rate-dependent settlement. Second Quarter: Foundation engineering. Bearing capacity of shallow and deep foundations. Deformation of foundations. Effects of construction on performance. Case studies. Third Quarter: Earth and earth-supported structures. Earth pressures on walls. Design of retaining structures and supported excavations. Effects of construction on performance. Stability of slopes. Design of earth dams and embankments. Case studies.

**CIV_ENV 452-0 Unsaturated Soil Mechanics (1 Unit)**
Principles of the hydraulics and mechanics of natural and engineered soils characterized by unsaturated conditions.

**CIV_ENV 454-0 Constitutive Models for Soils (1 Unit)**
Numerical models of effective and total stress-strain response of soils; non-linear pseudo-elastic, elasto-plastic and bounding surface models; parameter identification and applications.
Prerequisites: CIV_ENV 450-1 or permission of instructor.

**CIV_ENV 455-0 Plasticity and Limit Analysis (1 Unit)**
Fundamental theory of and computational tools for plasticity, including the concepts of yielding and plastic flow in materials and, by extension, the concepts of limit (collapse) loads and collapse mechanisms in boundary value problems.

**CIV_ENV 456-0 Computational Geotechnics (1 Unit)**
Fundamentals of the finite element method for geotechnical analysis. This course provides an essential skillset to those entering the practice of geotechnical engineering, and builds a foundation for future study and inquiry to those who are engaged primarily in research.

**CIV_ENV 457-0 Environmental Geotechnics (1 Unit)**
Site characterization, geotechnical aspects of waste containment, and remediation. Geological setting and the heterogeneous nature of soils. Design, testing, and quality control for geosynthetics.

**CIV_ENV 458-0 Soil Dynamics (1 Unit)**
Dynamics of soils and soil-foundation systems; nuclear weapon effects, earthquake response, vibrations of machine foundations, reactions due to impact equipment, industrial noise and blast effects, fatigue concepts, wave propagation and attenuation, blast-resistant construction, and linear and nonlinear systems.

**CIV_ENV 468-0 Metals in the Environment (1 Unit)**
A course on concepts, fundamentals, and tools used for studying the fate of metals in the environment. The emphasis is placed on the processes that control and regulate the chemical speciation of metals in aquatic environments and inform about their interactions with biological species.

**CIV_ENV 471-1 Transportation Systems Analysis 1 (1 Unit)**
Applications of optimization methods to analysis, design, and operation of transportation and logistics networks. Network equilibrium; flow prediction in congested multicommodity networks; vehicle routing and fleet management; dynamic and stochastic transportation network modeling.
Prerequisites: IEMS 310-0 or equivalent background.

**CIV_ENV 471-2 Transportation Systems Analysis 2 (1 Unit)**
Applications of optimization methods to analysis, design, and operation of transportation and logistics networks. Network equilibrium; flow prediction in congested multicommodity networks; vehicle routing and fleet management; dynamic and stochastic transportation network modeling.
Prerequisites: IEMS 310-0 or equivalent background.

**CIV_ENV 472-1 Transportation System Operations and Control 1: Urban Networks (1 Unit)**
Concepts and advanced methodologies for the design of control strategies for transportation systems operations, focusing on urban traffic networks.

**CIV_ENV 472-2 Transportation System Operations and Control 2: Scheduled Modes and Real-Time (1 Unit)**
Concepts and advanced methodologies for the design of service networks, operating plans and control strategies for scheduled transportation modes and real-time services.

**CIV_ENV 474-0 Data Analytics for Urban Systems (1 Unit)**
This course presents concepts as well as computing tools for analyzing large data sets that are collected to improve urban systems with a particular focus on transportation. It covers tools for data exploration, preprocessing, mining, and visualization; up-to-date machine learning algorithms – random forest, xgboost, deep learning algorithms and reinforcement learning.

**CIV_ENV 479-0 Transp Systems Planning & Management (1 Unit)**
Functional and structural description of transportation systems; characteristics of major US transportation modes; transportation analysis, planning, problem-solving, and decision-making methods illustrated through urban, freight, and intercity case studies.

**CIV_ENV 480-1 Travel Demand Analysis & Forecasting 1 (1 Unit)**
Introduction and application of statistical, econometric, and marketing research techniques to study and forecast travel behavior. First Quarter: Introduction to theory, analysis, and model development. Second Quarter: Advanced theory, disaggregate choice models, and prediction methods.

**CIV_ENV 480-2 Advances in Travel Demand Analysis and Forecasting (1 Unit)**
This course addresses developments in the econometric and behavioral aspects of demand analysis and forecasting, supply-demand interaction in transport systems, and dynamics models.

**CIV_ENV 482-0 Evaluation and Decision Making for Infrastructure Systems (1 Unit)**
Theories and methods of evaluation and choice from alternatives for transportation and other infrastructure projects and systems. Economic, quantitative, and judgmental methods for both a priori and before-and-after evaluation. Measurement, modeling, analysis, and presentation problems.
Prerequisites: CIV_ENV 306-0.

**CIV_ENV 483-0 Infrastructure Systems Analysis (1 Unit)**
Quantitative techniques for developing prescriptive models that can be used to support efficient planning and management of civil infrastructure systems.

**CIV_ENV 484-0 Advanced Theories of Traffic Flow (1 Unit)**
This course is concerned with the behavior of vehicular and multimodal traffic as a complex system. It seeks to convey a conceptual understanding of traffic processes through the development of mathematical models of these processes.

**CIV_ENV 495-0 Selected Topics in Civil Engineering (1 Unit)**
Special topics under faculty direction.

**CIV_ENV 497-0 Special Topics in Civil Engineering (0.5 Unit)**
Topics selected from work of current interest in civil or environmental engineering.

**CIV_ENV 499-0 Projects (1-3 Units)**
Special projects under faculty direction. Permission of instructor and department required.

**CIV_ENV 504-0 Structural System Capstone Pre-design Seminar (0 Unit)**

Preliminary discussion and planning of a structural system with realistic constraints to be designed by students in the M.S. program with specialization in structural engineering and geotechnical engineering.

**CIV_ENV 508-0 M.S. Research Paper for non-thesis option (0 Unit)**
Report on topics approved by faculty for M.S. students with non-thesis option.

**CIV_ENV 512-1 Structural Engineering & Mechanics Sem (0 Unit)**
Selected topics in structural engineering and materials and mechanics of materials and solids.

**CIV_ENV 512-2 Structural Engineering & Mechanics Sem (0 Unit)**
Selected topics in structural engineering and materials and mechanics of materials and solids.

**CIV_ENV 512-3 Structural Engineering & Mechanics Sem (0 Unit)**
Selected topics in structural engineering and materials and mechanics of materials and solids.

**CIV_ENV 515-1 Geotechnics Seminar (0 Unit)**
Discussion of classical and current literature in the field.

**CIV_ENV 515-2 Geotechnics Seminar (0 Unit)**
Discussion of classical and current literature in the field.

**CIV_ENV 516-1 Seminar in Environmental Engineering & Science (0 Unit)**
Topics vary. Examples: environmental microbiology; innovation technologies for recycling, recovery, treatment of chemical residuals; environmental policy; public health; water and waste treatment processes; contaminant fate and impact in nature.

**CIV_ENV 516-2 Seminar in Environmental Engineering and Science (0 Unit)**
Topics vary. Examples: environmental microbiology; innovation technologies for recycling, recovery, treatment of chemical residuals; environmental policy; public health; water and waste treatment processes; contaminant fate and impact in nature.

**CIV_ENV 516-3 Seminar in Environmental Engineering and Science (0 Unit)**
Topics vary. Examples: environmental microbiology; innovation technologies for recycling, recovery, treatment of chemical residuals; environmental policy; public health; water and waste treatment processes; contaminant fate and impact in nature.

**CIV_ENV 517-1 Seminar in Transportation Engineering (0 Unit)**
Selected topics in transportation engineering.

**CIV_ENV 517-2 Seminar in Transportation Engineering (0 Unit)**

**CIV_ENV 517-3 Seminar in Transportation Engineering (0 Unit)**
Selected topics in transportation engineering.

**CIV_ENV 590-0 Research (1-4 Units)**
Independent investigation of selected problems pertaining to thesis or dissertation. May be repeated for credit.