Civil Engineering (CIEN)

Chairperson: Daniel Zitomer, Ph.D., P.E.
Civil Engineering Graduate Programs website (http://www.marquette.edu/engineering/civil_environmental/grad.shtml)

Degrees Offered

Master of Science; Doctor of Philosophy

Mission Statement

The mission of the Department of Civil, Construction and Environmental Engineering is to educate students in the Catholic, Jesuit tradition. These students will be competent in their technical fields, appreciate the moral and ethical impact of their professional work, and continue their professional development throughout their careers. They will advance the state of technical and scientific knowledge through research and provide service to civic and professional communities.

Program Descriptions

The master of science and doctor of philosophy degree programs are designed to provide graduate students with both broad fundamental knowledge and up-to-date information on current and emerging technologies. Students may enroll on either a full-time or part-time basis. Doctoral students and research-oriented master's students (e.g., Plan A) engage in research activities under the close supervision of their advisers, gradually learning to become independent researchers. Their projects are often supported by government and industry grants. Courses and research projects make significant use of the department's extensive laboratory and computational facilities. Graduates find employment in industry, government, academia and research laboratories.

Prerequisites for Admission

Applicants should have graduated with, or be about to graduate with, a baccalaureate degree in an appropriate area of study from an accredited institution. In addition, doctoral applicants are required to have earned a master's degree in a related field. (In some instances, exceptional applicants may be considered for entry into the doctoral program without a master's degree.)

Application Requirements

Applicants must submit, directly to the Graduate School:

1. A completed application form and fee online (http://marquette.edu/grad/future_apply.shtml).
2. Copies of all college/university transcripts except those from Marquette.[1]
3. Three letters of recommendation.
4. (For international applicants only) a TOEFL score or other acceptable proof of English proficiency.
5. (For doctoral and all international applicants) GRE scores (General Test only).
6. The GRE is recommended for, and may be requested of, master's applicants with undergraduate grade point averages less than 3.000 out of 4.000.
7. (For doctoral applicants only) a brief statement of purpose.
8. (For doctoral applicants only) submission of any English-language publications authored by the applicant is optional, but strongly recommended; this includes any master's thesis or essay that the applicant may have written.

[1] Upon admission, final official transcripts from all previously attended colleges/universities, with certified English translations if original language is not English, must be submitted to the Graduate School within the first five weeks of the term of admission or a hold preventing registration for future terms will be placed on the student's record.

Research Activities

The Department of Civil, Construction and Environmental Engineering maintains laboratories related to studies in hydraulics, environmental engineering, engineering materials and structural testing, as well as computational facilities. The Water Quality Center, the Transportation Research Center, and the Engineering Materials and Structural Testing Laboratory are associated with the department.

Research interests of the faculty include the following, listed by specialization:

Construction Engineering (CNEN): computer applications in construction, lean construction practices, management of construction processes, modeling of construction projects, virtual design and construction, work-zone capacity and safety;

Environmental and Water Resources Engineering (ENWR): anaerobic biotechnology, wastewater treatment, analytical chemistry, physical/chemical water treatment, fate and impacts of emerging contaminants, antibiotic resistance, pyrolysis, nutrient recovery, environmental microbiology, advanced

oxidation processes, sustainability and life-cycle cost analysis, hydrologic modeling, green stormwater infrastructure, geographic information systems, flood frequency analysis, real-time control of stormwater systems;

Structural Engineering and Structural Mechanics (SESM): retrofit and repair of structures using fiber-reinforced polymers, prestressed concrete, reliability-based performance assessment of civil infrastructure, health monitoring of civil infrastructure, performance-based engineering, ground motion simulation validation, climate change mitigation and adaptation, sustainable and resilient infrastructure, structural mechanics modeling of micro-structures for chemical/biosensing and energy-harvesting applications;

Transportation Engineering and Materials (TEMA): safety impacts of pavement surface textures, effects of grinding on PCC pavements, human factors, traffic accident relations with roadway geometry, effect of heavy vehicles on freeway operations, traffic control device evaluation.

Civil Engineering Master's Requirements

Specializations: Construction Engineering (CNEN), Environmental and Water Resources Engineering (ENWR), Structural Engineering and Structural Mechanics (SESM), Transportation Engineering and Materials (TEMA)

Students may earn a master's degree under either Plan A (thesis) or Plan B (non-thesis). Regardless of the option chosen, at least one-half of the total course work requirement must be taken at the 6000-level. In most cases, master's students are admitted to the program under Plan B but may transfer to Plan A with permission from their adviser. **Note:** Recipients of teaching or research assistantships are strongly encouraged to pursue Plan A (thesis option).

Plan A requires the student to complete 30 credit hours (24 hours of course work, 6 hours of thesis work), submit an approved thesis, and pass a final oral comprehensive examination (thesis defense). The comprehensive exam for Plan A is focused mainly on the student's thesis topic.

Under the Plan B option, students must complete 30 credit hours of course work and pass a final comprehensive examination. The comprehensive exam for Plan B is usually an oral exam, administered by the student's three-person master's committee. The scope of the Plan B comprehensive exam may span the student's entire body of course work.

Both Plans A and B require that at least 18 credit hours be from the Department of Civil, Construction and Environmental Engineering course offerings.

Accelerated Bachelor's-Master's Degree Program

The department offers a five-year combined bachelor's-master's program available to outstanding Marquette University undergraduate students. This program enables students to earn both their bachelor of science and master of science degrees in civil engineering in just five years. Students currently enrolled in the undergraduate program in civil and environmental engineering at Marquette University (with a GPA of 3.500 or above) may apply for admission to the five-year program during their junior year. Students must submit an application to the Graduate School, indicate their interest in the five-year program and meet all other admission criteria as stated in the Application Requirements section.

In addition to completing their undergraduate degree requirements, students will take master's level courses in their senior year. (**Note:** No course is permitted to satisfy both the undergraduate and graduate degree requirements in the accelerated B.S.-M.S. program of the Department of Civil, Construction and Environmental Engineering.) The remaining master's level course work is taken during the student's fifth year. If students pursue Plan A (thesis option), work on the thesis research should begin the summer between the junior and senior years. Students will continue to gain research experience during the summer between the senior and fifth years, continuing throughout the fifth year and culminating in preparation of a written thesis and defense. Students are also permitted to follow Plan B (course work option), which may also be designed so that the combined bachelor's-master's program may be completed in five years.

Civil Engineering Doctoral Requirements

Specializations: Construction Engineering (CNEN), Environmental and Water Resources Engineering (ENWR), Structural Engineering and Structural Mechanics (SESM), Transportation Engineering and Materials (TEMA)

A doctoral student must complete a program of study prepared in consultation with his or her doctoral adviser and outlined on an approved Doctoral Program Planning Form. This form must be submitted within the first year of the student's doctoral studies. The program normally requires a minimum of 45 credit hours of course work beyond the baccalaureate degree plus 12 credit hours of dissertation work. In cases in which the student enters the program with a master's degree in civil engineering or a closely related field, the student may request that the department and the Graduate School allow credits from the master's degree to satisfy up to 21 credit hours of the required course work. Thus, a minimum of 24 credit hours of course work exclusive of the dissertation must be taken at Marquette University while the student is in the doctoral program. The student must also pass a doctoral qualifying examination (DQE) and submit and successfully defend a dissertation.

The DQE normally consists of both written and oral tests and is administered after the student has completed 30 to 36 credit hours of graduate study (inclusive of any approved credit hours from a previous master's degree). Each faculty member on a doctoral candidate's committee may submit questions for the written examination. The doctoral committee, as a whole, gives the oral examination.

The dissertation must represent an original research contribution showing high attainment and clear ability to do independent research. A public defense of the dissertation (the final oral examination) is administered after the student has completed all other formal requirements for the doctoral degree.

Courses

CEEN 5145. Advanced Strength and Applied Stress Analysis. 3 cr. hrs.
Basic concepts of mechanics of deformable bodies. Two- and three-dimensional stress-strain relationships and theories of failure. Unsymmetrical bending analyses. Shear flow and shear center. Torsion of thin-walled sections (tubular and non-tubular). Composite beams. Stress concentration. Energy principles: strain and complementary energy. Castigliano's theorem.

CEEN 5230. Urban Hydrology and Stormwater Management. 3 cr. hrs.
Distribution and properties of waters on the earth. Concept of the hydrologic cycle, and basic principles of meteorology, precipitation, streamflow, evapotranspiration, and groundwater flow. Erosion and urban stormwater pollution. Design of urban flood protection and stormwater pollution abatement systems.

CEEN 5310. Geographical Information Systems in Engineering and Planning. 3 cr. hrs.
Fundamentals of GIS, databases, data management, map projections, representations of spatial attributes, GIS analysis and GIS software systems such as ARC Info, ARC View, Grass. GIS use and expanded capabilities are taught. Case studies including environmental, transportation and economic applications are discussed.

CEEN 5320. Engineering Decisions Under Uncertainty. 3 cr. hrs.
Application of probability and statistics to modeling, analysis and design of civil engineering systems. Topics include: probability theory, decision theory, utility theory and simulation.

CEEN 5340. Urban Planning for Civil Engineers. 3 cr. hrs.
Concepts and principles underlying urban planning and development. Land use, transportation, utility, community facility planning problems, procedures, and techniques. The master plan and implementation devices such as zoning, subdivision control, official mapping, capital budgeting, and urban renewal.

CEEN 5350. Law for Engineers. 3 cr. hrs.
Basic legal principles and awareness of typical legal questions that arise when engineers and law interact. Topics include: American judicial system, law of contracts, forms of association, construction contracts, professional liabilities of engineers and torts.

CEEN 5411. Matrix Structural Analysis. 3 cr. hrs.
Introduction to symbolic and numerical linear algebra computations using commercial software. Modeling axial, bending, and torsion deformations in structural members using polynomials. Application of the principle of virtual work to compute deflections for statically determinate and indeterminate problems. Formulation of the matrix stiffness method via the principle of virtual displacements and the matrix flexibility method via the principle of virtual forces. Application of the matrix stiffness method for solving statically indeterminate structural analysis problems. Use of approximate methods of structural analysis (cantilever and portal methods) for critical evaluation of software-generated solutions. Use of commercial software for structural analysis.

CEEN 5431. Advanced Structural Steel Design. 3 cr. hrs.
Continuation of CEEN 3430. Design of plate girders, composite beam and slab systems, composite columns and composite beam-columns, simple connections, moment connections, hollow structural shape (HSS) connections, bracing systems and single and multi-story steel framed building systems. Emphasis on AISC Specifications.

CEEN 5441. Advanced Reinforced Concrete Design. 3 cr. hrs.
Continuation of CEEN 3440. Presenting advanced concrete design applications to reinforced concrete statically indeterminate systems, two-way slabs and columns. Introduction to the philosophy and concepts of prestressed concrete design. Basic principles and procedures for the design and analysis of prestressed members including calculation of pre-stress loss, flexural analysis and design, shear, bond and anchorage requirements, member deflections and cable layouts. Emphasis on ACI code requirements.

CEEN 5450. Bridge Design. 3 cr. hrs.
Introduction to bridge engineering and construction including: an abbreviated history of bridge construction; bridge types; bridge nomenclature; lessons from failures; design philosophies; and the construction process. Analysis of single- and multi-span bridge superstructures using classical techniques and commercial software. Design of single-span reinforced concrete slab bridges; reinforced concrete bridge decks; and single-span slab-bridges in prestressed concrete.

CEEN 5460. Foundation Engineering. 3 cr. hrs.
Design of earth retention systems, earthen dams, shallow and deep foundation members subjected to vertical and eccentric loadings. The effects of solid origin and deposition are analyzed in relation to bearing and capacity and settlement of structures. Prereq: CEEN 3160.

CEEN 5515. Environmental Chemistry. 3 cr. hrs.
Chemical stoichiometry, equilibrium, and kinetics relating to natural and engineered environmental systems. Basic concepts from organic and inorganic chemistry including oxidation-reduction reactions, acid-base chemistry, the carbonate system, alkalinity and acidity. Equilibrium and kinetic theories of chemical partitioning among gas, liquid and solid phases governing chemical fate and transport in the environment. Coordination chemistry describing metal-ligand interactions, precipitation and bioavailability of materials.

CEEN 5520. Industrial Wastewater Management. 3 cr. hrs.
Review of federal legislation and state regulations with regard to industrial wastewater management practices. Consideration of industrial process modifications and wastewater treatment options with respect to their effect on industrial user fees. Pretreatment standards and discharge permit requirements. Case studies of specific industrial applications.

CEEN 5525. Treatment Plant Design and Operation. 3 cr. hrs.
Review of water and wastewater characteristics, drinking water, receiving water and effluent standards. Basic design methodology and operational features of common physical, chemical and biological processes for the treatment of waters and wastewaters. Introduction to the processing and disposal of sludges and other treatment plant residuals.

CEEN 5530. Hazardous and Industrial Waste Management. 3 cr. hrs.
Overview of hazardous waste management, disposal and soil and ground water remediation. Review of RCRA, CERCLA-SARA, TSCA and Wisconsin's NR 700 and other regulations. Definition of hazardous wastes and characterization of industrial waste stream. Chemical, physical and biological properties of hazardous wastes. Introduction to hazardous waste remediation/treatment methods and technologies. Landfills and the RCRA Land Ban regulations. Site assessments, field investigations and laboratory analytical techniques. Environmental risk assessments, cleanup objectives and waste minimization.

CEEN 5535. Environmental Engineering Microbiology. 3 cr. hrs.
Includes microbiological and biochemical properties of microorganisms important in environmental engineering practice. General fundamentals of environmental microbiology and their application to drinking water treatment and distribution, water pollution control and natural systems.

CEEN 5550. Water Resources Planning and Management. 3 cr. hrs.
Planning and management of water resources. Institutional frameworks for water resources engineering. Comprehensive integration of the engineering economic, social and legal aspects of water resources planning and management. Case studies of water use and environmental resources are studied.

CEEN 5560. Environmental Fate and Transport. 3 cr. hrs.
Introduction to the movement and fate of chemicals in surface and subsurface waters, including physical transport and chemical and biological sources and sinks. Development and solution of continuity equations for coupled water and chemical transport relevant to environmental remediation, storm water control and wastewater treatment.

CEEN 5615. Highway Planning and Design. 3 cr. hrs.
Emphasis on highway planning, alternate highway alignments and alternate evaluation. Geometric design of highways including horizontal and vertical alignment, cross-section design. Projects on detailed design of reverse curves (plan and profile views); intersection design; cross-section and earthwork quantities. Legal aspects of engineering. Use of American Association of State Highway and Transportation Officials design guidelines.

CEEN 5630. Airport Planning and Design. 3 cr. hrs.
Introduction to airport planning and design parameters, aircraft characteristics, payload versus range, runway length requirements, air traffic control, wind analysis, airside capacity and delay, airside separation criteria, terminal analysis and delay, airport access flow and capacity, ramp charts. Economic analysis of facility improvements.

CEEN 5640. Traffic Characteristics and Design. 3 cr. hrs.
Components of the traffic system: vehicle and road user characteristics, geometric design and traffic controls. Intersection types, cross-section design elements and typical dimensions. Basic variables of traffic flow, observed traffic flow values. Freeway operations. Signalized intersections: flow, capacity, level of service. Projects addressing: intersection existing conditions (traffic, geometry, signalization); approach delay; safety performance; capacity; suggestions for improvements. Use of the Highway Capacity Manual and the Highway Capacity Software. Emphasis on technical report-writing and presentation.

CEEN 5650. Pavement Design. 3 cr. hrs.
Study of the behavior and properties of highway pavements with emphasis on hot mix asphalt and jointed Portland cement concrete pavement. Pavement thickness designs are developed using current design methods and incorporating subgrade soil properties, traffic forecasts and pavement performance expectations. Use of spreadsheets and computer programs are required. Prereq: CEEN 3160 and CEEN 3610; or equiv.

CEEN 5660. Pavement Management. 3 cr. hrs.
Study of the performance of pavement systems based on design, traffic and maintenance activities. Methods for evaluating in-service pavements including distress surveys and nondestructive testing are examined. Maintenance strategies are developed and life-cycle cost analysis of these strategies are studied. Prereq: CEEN 3610 or equiv.

CEEN 5670. Advanced Transportation Materials. 3 cr. hrs.
Advanced study of materials used for constructing transportation facilities, with particular emphasis on subgrade soils, bound and unbound aggregates, hot mix asphalt and Portland cement concrete. Laboratory test are conducted and analytical models used for characterizing transportation materials are examined.

CEEN 5715. Sustainable Engineering. 3 cr. hrs.
Provides a framework for the theory and practice of sustainable engineering. Introduces the importance and role of technological, social and sustainable systems in the modern world, which is increasingly characterized by integrated human/natural/built complex adaptive systems at local, regional and global scales. Develops critical problem solving approaches, including life-cycle assessment, global awareness, consciousness of patterns in technological evolution, and strategies for addressing environmental, economic and social equity issues in engineering design.

CEEN 5815. Mechanical and Electrical Systems for Buildings. 3 cr. hrs.
Provides basic knowledge of electrical, plumbing and HVAC systems used in residential, commercial and industrial buildings. Studies the advantages and disadvantages of various systems, and how their design and installation integrates into the management of the building process. Particular attention is given to soliciting and managing mechanical and electrical subcontractors.

CEEN 5820. Construction Operations and Productivity. 3 cr. hrs.
Study of construction operations with emphasis on productivity measurement and enhancement. Application of an integrated approach to planning, analysis and design of construction operations. Application of simulation models and other analytical tools for modeling construction operations. Study of productivity improvement strategies, including lean construction principles.

CEEN 5825. e-Business in the Construction Industry. 3 cr. hrs.
Explores the ways in which information technology and its Internet components help to provide competitive advantage for construction companies. Selection/implementation of Web-based project management tools. An investigation of digital technologies in construction industry. Wire/wireless communication, online plan/bid rooms, mobile computing, and video conferencing.

CEEN 5830. Construction Planning, Scheduling, and Control. 3 cr. hrs.
A study of principles and techniques used to plan, schedule and control costs on building construction projects. Network and linear scheduling models, resource allocation and time-cost analysis. Develops an appreciation of the resources required in a project and their limitations and introduces the techniques for analyzing and improving their use. Develops an understanding of the correlation between project planning and control and cost estimating and scheduling.

CEEN 5840. Construction Cost Analysis and Estimating. 3 cr. hrs.
Study of various cost estimating methods and their applications. Topics include: labor, material, equipment and indirect costs; quantity takeoff; analysis of historical cost data; forecasting and computerized estimating methods.

CEEN 5845. Construction Equipment and Methods. 3 cr. hrs.
Construction equipment and productivity analysis. Design of equipment fleet operations. Design of temporary structures used during construction such as earth retaining structures and concrete formwork systems. Construction equipment safety and safety standards related to earthwork and concrete forming operations.

CEEN 5850. FRP in Civil Engineering Infrastructure. 3 cr. hrs.
Introduces Fiber Reinforced Polymer (FRP) material properties, FRP reinforced concrete, FRP prestressed concrete, FRP repaired and retrofitted structures and pure FRP structures.

CEEN 5931. Topics in Civil Engineering. 1-3 cr. hrs.
Course content announced each term. Prereq: Cons. of instr.

CEEN 6110. Theory of Elasticity. 3 cr. hrs.
Mathematical preliminaries (indicial notation, vectors, Cartesian tensors, coordinate transformations, eigenvalue problems, divergence theorem); kinematic relations (strain-displacement and compatibility); stress tensor and traction vector; differential and virtual work expressions of equilibrium; constitutive relations; stored energy functions; formulation of elastostatics boundary value problems; uniqueness theorems; theorem of minimum potential energy; Saint-Venant's principle; Saint-Venant beam theory; plane stress and plane strain.

CEEN 6120. Introduction to the Finite Element Method. 3 cr. hrs.
Theoretical development of the finite element method (FEM) of analysis, with particular emphasis on problems of solid mechanics; development of element stiffness matrices for axial, beam, plane stress, plane strain, plate, shell, and solid elements; synthesis of global stiffness matrix, solution of the finite element equations; introduction to numerical implementation of FEM and general purpose FEM software.

CEEN 6121. Applied Finite Element Analysis and Modeling. 3 cr. hrs.
Review of linear elastic finite element analysis (FEA) theory in solid/structural mechanics; review of commercial FEA code use (ANSYS®) in linear elastic applications; introduction to advanced theories, including theories of vibration, material nonlinearities, geometric nonlinearities, structural instabilities, and/or time-dependent deformations (creep); use of ANSYS® to simulate complex structural behavior; model development, verification, and improvement. Prereq: CEEN 6120 or equiv.

CEEN 6210. River Engineering. 3 cr. hrs.
Offers a solid background in the basic principles of open-channel hydraulics, gradually-varied flow, rapidly-varied flow, hydrologic and hydraulic flood routing, and river restoration/naturalization. Hand calculations of numerous open-channel flow problems, and application of the HEC-RAS program for backwater analysis and for flood routing in combination with HEC-1. Includes concepts for stream restoration/naturalization.

CEEN 6240. Water Quality Modeling and Management. 3 cr. hrs.
Water and environment. Water quality criteria and standards. Attainability of water quality goals. Oxygen balance and self-purification. River, estuaries, and reservoirs water quality modeling. Toxicity and bioassays. Limnological aspects, waste assimilative capacity. Groundwater protection, river and estuary and groundwater quality management systems.

CEEN 6340. Advanced Hydrology. 3 cr. hrs.
Measurement of hydrologic phenomena including precipitation and streamflow. Applications of statistics to hydrology, floods and droughts. Hydrologic design of water resources development and management projects. State-of-the-art computer models for watershed management and urban hydrology.

CEEN 6350. Modeling in Water Resources Engineering. 3 cr. hrs.
Introduction to hydraulic and hydrologic models with applications to water resources engineering. Continuity equations. Analytical and numerical methods for linear, nonlinear and coupled systems. Model applications include: calibration and validation, parameter estimation and optimization methods. Model systems include: surface and subsurface waters, storm water and combined sewer collection systems and water distribution systems.

CEEN 6410. Numerical Analysis with Structural Application. 3 cr. hrs.
Interpolation polynomials; numerical integration and differentiation; Taylor series, Fourier, cubic spline, and least-squares polynomial approximations; numerical solution of initial-value problems by Prediction-Correction and Runge-Kutta methods; numerical solution of boundary-value problems by finite difference method; numerical solution of integral equations; approximate solution of ordinary differential equations by weighted residuals and Galerkin methods; approximate solution of variational problems by Rayleigh-Ritz method.

CEEN 6420. Nonlinear Structural Analysis. 3 cr. hrs.
Application of the principle of virtual displacements in the formulation of element stiffness equations that include geometric and material nonlinearity. Determination of critical (buckling) loads of structural systems using eigenvalue analysis. Formulation and application of algorithms for nonlinear structural analysis. Application of commercial software in geometrically nonlinear analysis, materially nonlinear analysis, and critical load (buckling) analysis. Prereq: CEEN 5411.

CEEN 6425. Earthquake Engineering. 3 cr. hrs.
Introduction to the mechanics of ground motion (earthquake) and its effects on building and bridge structures. Application of structural dynamics principles in relation to structural analysis for earthquake-generated forces. Response to simulation of single degree of freedom and multi-degree of freedom linear structural systems to earthquake-induced ground accelerations using Newmark response history analysis (RHA), modal response history analysis (mRHA) and response spectrum analysis (RSA). Discussion of philosophies upon which building-code IBC, NEHRP) mandated earthquake analysis and design procedures are based. Prereq: CEEN 3430, CEEN 3440, CEEN 5411, CEEN 6435.

CEEN 6435. Structural Dynamics. 3 cr. hrs.
Formulation of single-degree-of-freedom (SDOF) equation of motion; generalized SDOF systems; free-vibration response; harmonic excitation; periodic loading and Fourier series; impulsive loads; response (shock) spectra; general response by Duhamel and Fourier integrals; non-linear dynamic analysis; Rayleigh's method; formulation of multiple-degree-of-freedom (MDOF) equations of motion; structural property matrices and load vectors; eigenvalue problem for natural frequencies and mode shapes; orthogonality of mode shapes; mode superposition.

CEEN 6460. Engineering Reliability. 3 cr. hrs.
Introduces concepts and applications of engineering reliability. Presents how to formulate a reliability question to solve engineering problems of interest; compute first- and second-order estimates of failure probabilities of engineered systems; compute sensitivities of failure probabilities to assumed parameter values; measure the relative importance of the random variables associated with a system; identify the relative advantages and disadvantages of various analytical reliability methods as well as Monte Carlo simulation; update reliability estimates based on new observational data; and compute system reliability for series and parallel systems. Prereq: Requires basic knowledge of probability and statistics, descriptions of random variables, probability distributions, functions of random variables, estimation of model parameters, model selection and verification, covered by MSCS 6010 or equivalent; EECE 6020, CEEN 4320/5320, MATH 4700/5700, 4710/5710, 4720/5720; linear algebra, systems of equations, matrix operations, transformations; calculus and differential equations, differentiation, integration, ordinary and partial differential equations. Knowledge of basic Matlab programming helpful.

CEEN 6470. Performance-Based Engineering. 3 cr. hrs.
Provides an opportunity to utilize and master the framework of performance-based engineering to aid decision making via useful applications. Presents how to estimate the hazard at the site and system of interest, in order to assess system response, predict damage extent, and evaluate system performance in terms of expected loss. Topics include: analyses of hazard, response, damage and loss; synthesis of recent advancement in research and practice with case studies; emphasis on the impact of earthquakes on buildings, with extension to other hazards and systems. Prereq: Requires basic knowledge of probability and statistics, equivalent to MATH 4700/5700, 4710/5710, 4720/5720, or CEEN 4320. Knowledge of basic Matlab programming helpful.

CEEN 6510. Biochemical Transformations in the Environment. 3 cr. hrs.
Study of biologically catalyzed chemical transformations in natural and engineered environments. Presentation of microbiology, biologically important oxidation-reduction reactions, bioenergetic principles, fermentation kinetics, and toxicity considerations relating to wastewater treatment and remediation of contaminated groundwater and soil. Review of aerobic processes for biochemical oxygen demand reduction and ammonia oxidation, anoxic processes for denitrification and anaerobic processes for reductive dechlorination. Prereq: CEEN 5525.

CEEN 6520. Environmental Laboratory 1 - Analyses. 3 cr. hrs.
Physical, chemical and biological analyses for the characterization of waters, wastewaters, solid wastes, sludges and leachates. Use of modern instrumentation in laboratory analysis. Applicability of analytical results to the environmental field. Prereq: CEEN 3510 and CEEN 5515.

CEEN 6521. Environmental Laboratory 2 - Processes. 3 cr. hrs.
Theoretical principles and laboratory experimentation governing the processes of settling, coagulation, adsorption, flotation, disinfection, oxygen transfer, biological treatment and sludge conditioning, thickening and dewatering. Prereq: CEEN 5525 and CEEN 6520.

CEEN 6530. Hazardous Waste Remediation Technologies. 3 cr. hrs.
Hazardous waste remediation technology selection. Chemical kinetics, equilibria and mass transfer. Aqueous phase treatment and solid/liquid separation processes. Physical, chemical and biological interactions under environmental conditions. Specific technologies will include: physical barriers, bioremediation and soil vapor extraction, soil flushing and chemical extraction, immobilization and chemical and thermal destruction technologies. Multi-media, multi-contaminant treatment approaches. Computer model simulations and case studies. Prereq: CEEN 5515 and CEEN 5525.

CEEN 6540. Physical and Chemical Processes of Environmental Engineering. 3 cr. hrs.
Theory and design of unit operations and processes utilized for the treatment of water and wastewater, including coagulation, flocculation, sedimentation, filtration, adsorption, ion exchange and aeration. Prereq: CEEN 5515 and CEEN 5525.

CEEN 6560. Fate of Micropollutants. 3 cr. hrs.
Presents how to predict what a compound will do in an environment, based on the structure of the molecule. Discusses publications in peer-reviewed literature. Develops skills including critical thinking, public speaking via oral presentations, and technical writing.

CEEN 6610. Advanced Traffic Operations Analysis and Design. 3 cr. hrs.
Traffic stream characteristics-volume, flow rate, speed, density. Facility characteristics-level of service, capacity. Uninterrupted flow facility operations analysis: basic freeway segments, freeway weaving areas, merge and diverge areas, two-lane highways. Interrupted flow facility operations analysis: two-way and all-way stop controlled intersections; roundabouts. Non-highway facility operations analysis: pedestrian paths, bicycle paths and transit routes. Safety performance of highway facilities. Use of the Highway Capacity Manual and the Highway Capacity Software. Existing facility conditions, design upgrades.

CEEN 6620. Urban Facility Design. 3 cr. hrs.
Design controls overview. Access management location, spacing and design. Intersection design elements and traffic control devices. Local street design; Collector street design; Arterial street design. Roadside design-roadside obstacles. Bus and rail transit design for on- and off-street operation.

CEEN 6635. Highway Interchange Design. 3 cr. hrs.
Planning, analysis, design and operational analysis of highway interchanges. Determination and adaptability of interchange types for freeway-to-freeway and service interchanges.

CEEN 6650. Bituminous Materials. 3 cr. hrs.
Study of the behavior and properties of asphalt binders and hot mix asphalt pavement materials. The chemistry and rheological properties of asphalt binders with and without additives as well as the physical properties of aggregates are examined. Hot mix asphalt mix design methods are analyzed and laboratory testing of asphalt binders is conducted.

CEEN 6655. Transportation Soils. 3 cr. hrs.
Advanced study of surficial soils, soils variability, subgrade evaluation procedures, repeated loading behavior or soils and subgrade stability as used for constructing transportation facilities. Prereq: CEEN 3320 and CEEN 3160 or equiv.

CEEN 6660. Advanced Pavement Design. 3 cr. hrs.
Advanced study of behavior and properties of highway and airfield pavements with emphasis on computer analysis of the stress-strain behavior under loading. Distress-specific performance expectations are developed for design pavement structures. Prereq: CEEN 3160 and CEEN 3610; or equiv.

CEEN 6840. Infrastructure Information Modeling. 3 cr. hrs.
Infrastructure project lifecycle information generated during various stages of a project lifecycle. Computer modeling technologies used for managing project information. Relational data models. Relational representation of building information. Designing relational databases for efficient storage and management of infrastructure information. Object-created data models. Object-created analysis and design. Object-oriented representation of building information. Involves a project that accesses and integrates information from several sources such as a BIM model and other project resource databases for problem solving. Homework problems and course project are implemented in C# programming language.

CEEN 6850. Temporary Structures in Construction. 3 cr. hrs.
Investigates the design, safety analysis and economic considerations related to temporary structures used during construction. Topics covered include: construction and environmental loads, temporary earth retaining structures, cofferdams, construction dewatering, construction ramps and platforms, construction formwork, shoring and re-shoring in multistory concrete construction, scaffolding, bracing and guying for stability during construction.

CEEN 6860. GIS Applications in Water Resources Engineering. 3 cr. hrs.
Use of Geographical Information Systems (GIS) concepts and methods to solve water resources problems. GIS fundamentals such as databases, map projections, spatial analysis, and raster analysis. Applications for water resources engineering including terrain analysis, watershed characterization and hydrologic analysis and modeling. Approaches to GIS integration with modeling software and online tools.

CEEN 6865. Biotechnology - Microbial Communities. 3 cr. hrs.
Development of molecular methods with a focus on genomic approaches to characterize microbial community structure. Bioprocesses for waste management including anaerobic digestion, nitrification, denitrification, enhanced biological phosphorus removal, anammox and others. Concepts linking microbial community structure to process function, including functional resistance and resilience.

CEEN 6932. Advanced Topics in Civil Engineering. 1-3 cr. hrs.
Course content announced each term. Topics may include: structural optimization, design of structures for random loads, transportation systems analysis and design, water and wastewater systems analysis and design, and soil-structure interaction.

CEEN 6953. Graduate Seminar in Civil Engineering. 0-3 cr. hrs.
Review of current literature. Group discussion of recent work and current research by students and staff. 0 credit will be SNC/UNC grade assessment; 1-3 credits will be graded.

CEEN 6995. Independent Study in Civil Engineering. 1-3 cr. hrs.
Prereq: Cons. of instr. and cons. of dept. ch.

CEEN 6999. Master's Thesis. 1-6 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.

CEEN 8953. Doctoral Seminar in Civil Engineering. 0-3 cr. hrs.
0 credit will be SNC/UNC grade assessment; 1-3 credits will be graded.

CEEN 8995. Independent Study in Civil Engineering. 1-3 cr. hrs.

CEEN 8999. Doctoral Dissertation. 1-12 cr. hrs.
S/U grade assessment. Prereq: Cons. of dept. ch.

CEEN 9970. Graduate Standing Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9974. Graduate Fellowship: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9975. Graduate Assistant Teaching: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9976. Graduate Assistant Research: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9984. Master's Comprehensive Examination Preparation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9985. Master's Comprehensive Examination Preparation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9986. Master's Comprehensive Examination Preparation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9987. Doctoral Comprehensive Examination Preparation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9988. Doctoral Comprehensive Examination Preparation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9989. Doctoral Comprehensive Examination Preparation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9994. Master's Thesis Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9995. Master's Thesis Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9996. Master's Thesis Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9997. Doctoral Dissertation Continuation: Less than Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9998. Doctoral Dissertation Continuation: Half-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.

CEEN 9999. Doctoral Dissertation Continuation: Full-Time. 0 cr. hrs.
Fee. SNC/UNC grade assessment. Prereq: Cons. of dept. ch.