

# CIVIL AND ENVIRONMENTAL ENGINEERING

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Chairperson: William Shuster

<http://www.engineering.wayne.edu/cee> ([http://](http://www.engineering.wayne.edu/cee/)

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Civil and environmental engineers apply the principles and techniques of engineering to the analysis, design, and integration of complex infrastructure and environmental systems. They have traditionally been leaders in many aspects of urban development, and aid in addressing uniquely urban issues associated with providing critical services to residents. We respond to crises like ageing infrastructure, and how to sustain critical services without undue pressure on the environment at large. The civil and environmental engineer is trained to be a leader in such diverse areas as:

- the design and control of structural systems, including tall buildings, bridges and transportation systems necessary for urban development and redevelopment, demolition, commerce and industry;
- water resources planning and management;
- fate, transport, and remediation of contaminants in water, soil resources;
- design of collection and treatment systems for sanitary sewage and stormwater management;
- integrated waste management;
- drinking water treatment and distribution systems;
- construction engineering and management; and
- the integration and management of public works projects designed to improve equity and availability in municipal services.

In these ways, the responsibilities of the civil and environmental engineer directly involve sustaining the health, safety and welfare of the public.

The Civil and Environmental Engineering Department maintains laboratories for teaching and research with facilities for testing structural components under static and dynamic loads; strain measurement; transportation network sensing and assessment, traffic simulation; environmental microbiological, biogeochemical characterization; air quality sampling and characterization; and hydraulic, hydrologic assessments. The Department and the University maintain excellent computer facilities for data acquisition and analysis.

DATTA, TAPAN K.: Ph.D., Michigan State University; M.S., Wayne State University; B.E., Graduate Diploma, University of Calcutta; Professor

EAMON, CHRISTOPHER D.: Ph.D., M.Arch., M.S., University of Michigan; B.S., University of Wisconsin; Associate Professor

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MILLER, CAROL J.: Ph.D., M.S., B.S., University of Michigan; Professor

REMIAS, STEPHEN M.: Ph.D., M.S., Purdue University; B.S., Michigan State University; Assistant Professor

USMEN, MUMTAZ A.: Ph.D., West Virginia University; M.S.C.E., California State University, Long Beach; B.S.C.E., Robert College; Professor and Chair

WILLIAM D., SHUSTER: Ph.D., Ohio State University; B.S., University of Michigan; Professor and Chair

WU, HWAI-CHUNG: Ph.D., Massachusetts Institute of Technology; M.S. Auburn University; B.S., National Taiwan University; Associate Professor

ZHANG, YONGLI: Ph.D., University of Virginia; M.S., Guangxi University; B.S., Sichuan University; Assistant Professor

- Civil Engineering (B.S.) (<http://bulletins.wayne.edu/undergraduate/college-engineering/civil-environmental-engineering/civil-engineering-bs/>)

## CE 2000 How Cities Work: An Introduction to Civil and Environmental Infrastructure Cr. 3

**Satisfies General Education Requirement:** Social Inquiry

Cities are built on the backbone of infrastructure, particularly civil and environmental infrastructure. These infrastructures provide essential services to residents. This course will make students aware of the tensions that arise out of the social, economic, and environmental demands on sustaining engineered infrastructure in a diverse and pluralistic society. Students will learn how our engineered urban centers operate so they are better prepared for careers in governance and management; understand actuarial and accounting matters in the context of tax revenue and insurance; can perform social work with citizens who are disconnected from vital services, plan for sustainable urban futures; serve as an informed public health or medical professional, and under the role of infrastructure in a dynamic urban geography; and work as an engineer to develop infrastructure that provides equitable returns, among other interests that pertain to the urban experience. Offered Yearly.

## CE 2410 Statics Cr. 3

Basic concepts and principles of statics with applications to Newton's Laws of Motion to engineering problems. Forces, moments, equilibrium, couples, free body diagrams, trusses, frames, fluid statics, friction, area and mass moment of inertia. Offered Every Term.

**Prerequisites:** MAT 2020 with a minimum grade of C-, PHY 2175 with a minimum grade of C-, and BE 1500 with a minimum grade of C-

**Equivalent:** ME 2410

## CE 2420 Elementary Mechanics of Materials Cr. 3

Elastic relationships between external forces acting on deformable bodies and the associated stresses and deformations; structural members subjected to axial load, torsion, and bending; column buckling; combined stresses; repeated loads; unsymmetrical bending. Offered Every Term.

**Prerequisites:** ME 2410 with a minimum grade of C- or CE 2410 with a minimum grade of C-

**Equivalent:** ME 2420

## CE 3010 Introduction to CAD in Civil Engineering Cr. 3

Principles of computer graphics and utilization of computers in the design process. Civil engineering applications of AutoCAD. Offered Every Other Year.

**Prerequisite:** MAT 2020 with a minimum grade of C- and BE 1200 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**CE 3070 Surveying Cr. 3**

Principles of plane surveying; measurement of horizontal and vertical distance, directions and angles, traverses, areas. Offered Intermittently.

**Prerequisite:** PHY 2185 with a minimum grade of C- or PHY 2180 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$20

**CE 3250 Applied Fluid Mechanics Cr. 4**

Application of theoretical fluid mechanics to problems of special interest to civil engineers including pipe flow, open channel flow, forces on submerged bodies, and flow measurement. Laboratory component of course provides experimental verification of theories and computer visualization. Offered Fall.

**Prerequisite:** MAT 2030 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$15

**CE 3450 Civil Engineering Materials Cr. 4**

Structure, composition and engineering properties of aggregates, cement concrete, asphalt, asphalt concrete, and other civil engineering materials. Mix design, testing, and quality control. Material Fee as indicated in the Schedule of Classes. Offered Winter.

**Prerequisite:** BE 2100 with a minimum grade of C- and CE 2420 (may be taken concurrently) with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$35

**CE 4210 Introduction to Environmental Engineering Cr. 3**

Introduction to environmental laws; reaction kinetics; principles of mass balances; plug-flow and completely stirred tank reactors; Stoke's Law; Streeter-Phelps oxygen sag curves; water chemistry; hydrologic cycle; population growth models; elements of soil waste management and air pollution. Offered Winter.

**Prerequisite:** CE 3250 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$10

**CE 4240 Environmental Engineering Design Cr. 3**

Design of engineered environmental systems, including drinking water distribution systems, sanitary and storm water sewer systems, and municipal waste disposal sites. Offered Fall.

**Prerequisite:** CE 4210 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**CE 4400 Structural Analysis Cr. 4**

Basic concepts of structural analysis; reactions, forces, and stresses in trusses and beams; influence lines; elastic deflections; introduction to indeterminate structures; computer applications. Offered Fall.

**Prerequisites:** CE 2410 with a minimum grade of C- and CE 2420 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**CE 4410 Steel Design Cr. 3**

First course in design of steel structures. Introduction to the concepts, requirements, and fundamental skills for steel building structural design. Offered Winter.

**Prerequisites:** CE 4400 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**CE 4420 Reinforced Concrete Design Cr. 3**

First course in design of concrete structures. Design and analysis of reinforced concrete beams, columns, and other structural members; ACI code requirements, cost concerns, safety, industry practices; introduction to prestressed concrete. Offered Fall.

**Prerequisite:** CE 4400 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**CE 4510 Introduction to Geotechnical Engineering Cr. 4**

Composition, engineering properties and behavior of soils. Principles of soil mechanics. Experimental determination of engineering classification, strength and deformation characteristics of natural and artificially placed soils. Offered Fall.

**Prerequisite:** CE 3450 with a minimum grade of C- and CE 3250 (may be taken concurrently) with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$30

**CE 4600 Transportation Engineering Cr. 3**

Transportation functions; transportation systems including highways, railways and airways. Techniques of transportation systems analysis including optimization, network flows and queueing theory. Offered Winter.

**Prerequisite:** BE 3220 with a minimum grade of C- or BE 2100 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$10

**CE 4610 Highway Design Cr. 3**

This course covers the standards recommended by: American Association of State Highway and Transportation Officials (AASHTO); FHWA; and MDOT for designing and evaluation of highways. Its objective is to introduce the students to the concepts, requirements, and fundamental skills for highway design and evaluation. The primary goal of geometric design is to provide for the safety and comfort of road users with due regard to social, economic and environmental constraints. Although there are suggested design standards and controls that must be followed to meet design goals, their application is determined on a case-by-case basis. The objective of this course is to illustrate the practical application of scientific knowledge to the planning and designing of roadway elements. The course uses up-to-date software design tools in accomplishing these goals. Upon completion of the course, the student is expected to be able to design and evaluate highways per AASHTO, MDOT and FHWA standards. Offered Fall.

**Prerequisite:** CE 4600 with a minimum grade of C-

**CE 4640 Transportation Systems Design and Operation Cr. 3**

Provides an overview of various system components of transportation, including the driver, vehicle and roadway. The subject matter will be covered at an intermediate level, appropriate for CEE students already familiar with the basic concepts of transportation engineering who wish to expand their knowledge. There will be a particular emphasis on transportation safety and multimodal roadway operations, as are typical priorities in an urban or suburban setting. Topics include: traffic flow design elements including volume, density and speed; intersection design elements including delay, capacity and crash countermeasures and terminal design elements including inflow, outflow and circulation. Offered Fall.

**Prerequisite:** CE 4600 with a minimum grade of C-

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**CE 4850 Engineering Economy Cr. 3**

Economic analysis of engineering projects. Selection of appropriate financial parameters (e.g., interest rates) and methods of analysis for depreciation, tax considerations, and use of accounting data for comparison among investment options. Offered Fall.

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Computer Science, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Course Material Fees:** \$10

**Equivalent:** IE 4850

**CE 4990 Directed Study Cr. 1-4**

Supervised study and instruction in civil engineering. Written report required. Offered Every Term.

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**Repeatable for 6 Credits**

**CE 4995 Senior Design Project Cr. 3**

**Satisfies General Education Requirement:** Writing Intensive Competency Capstone design experience through civil engineering projects. Satisfies General Education Writing Intensive requirement. Offered Winter.

**Restriction(s):** Enrollment limited to students in the following programs: BS in Biomedical Engineering, BS in Chemical Engineering, BS in Civil Engineering, BS in Electrical Engineering, BS in Industrial Engineering, BS in Mechanical Engineering; enrollment limited to students in the College of Engineering.

**CE 5220 Environmental Chemistry Cr. 3**

Fundamentals of aqueous chemistry for environmental engineers and scientists. Basic chemistry, equilibria, kinetics and thermodynamics; includes acid/base reactions, precipitation/dissolution, oxidation/reduction reactions and partitioning. Offered Every Other Year.

**Course Material Fees:** \$5

**CE 5230 Water Supply and Wastewater Engineering Cr. 3**

Analysis and design of water supply and wastewater treatment systems; water distribution systems; treatment of municipal water supplies, including sedimentation, softening, filtration and disinfection; design of sanitary and storm sewers; primary, secondary and tertiary treatment plant design; sludge handling. Offered Yearly.

**Prerequisite:** CE 4210 with a minimum grade of C-

**Course Material Fees:** \$5

**CE 5240 Air Pollution Engineering Cr. 3**

Designed to introduce students to the fields of air pollution and air quality, this course will provide an overview of the U.S. regulation of air pollution and explain the fundamental principles of the physical and chemical processes of air pollutants associated with natural and anthropogenic emission sources. In particular, we will focus on air pollutants that contribute to the formation of acid rain, smog and haze, as well as the gas- and particle-phase tropospheric chemistry. Engineering methods to control and mitigate air pollution will be also covered. Offered Yearly.

**CE 5350 Introduction to Structural Dynamics Cr. 4**

Dynamic properties of structures, Modeling of dynamic loads. Structural response to dynamic loading. Structural design requirements for dynamic loads. Fundamental techniques of dynamic system analysis. Offered Winter.

**Prerequisite:** ME 3400 with a minimum grade of C- and CE 4400 with a minimum grade of C-

**CE 5370 Finite Element Analysis Fundamentals Cr. 3**

Matrix structural analysis, discretization of continuous structural systems, stress analysis. Commercial finite element software preprocessing for developing finite element models; post-processing for evaluating analysis results. Offered Fall.

**Prerequisites:** CE 4400 with a minimum grade of C-

**CE 5390 Design of Prestressed Concrete Structures Cr. 3**

Focuses on the design of prestressed structures. The principle and methods of prestressing are discussed including approaches for computing prestress losses. The course deals with the estimation of capacity of various structural members such as beams and columns and their response to various structural actions such as flexure, vertical shear, horizontal shear, and combined axial and flexure loads. Performance at service is discussed in terms of stresses, deflections and crack control. Offered Yearly.

**Prerequisite:** CE 4420 with a minimum grade of C-

**CE 5410 Energy, Emissions, Environment (E3) Design Cr. 3**

Provides students the tools to uncover the relation between energy consumption and energy generation and optimize processes to take most advantage of low emitting energy options. Exposes students to design tools and methodologies from a diverse group of sources including US EPA, DOE, EIA, and the latest in emerging research. Offered Fall.

**Equivalent:** AET 5410, STE 5410

**CE 5510 Geotechnical Engineering I Cr. 4**

Site investigation, site improvement, bearing capacity and settlement of shallow foundations, axial capacity and lateral deflection of deep foundations, design of conventional earth retaining walls, and basics of slope stability analyses. Offered Fall.

**Prerequisites:** CE 4510 with a minimum grade of C-

**CE 5520 Geotechnical Engineering II Cr. 3**

Lateral earth pressure theories, design of conventional earth-retaining walls and of reinforced earth walls, anchored sheet-pile walls and cofferdams, fundamentals of soft-ground tunneling, two- and three-dimensional slope stability analyses, and static design of earth dams. Offered Every Other Year.

**Prerequisites:** CE 4510 with a minimum grade of C-

**CE 5610 Advanced Highway Design Cr. 3**

This course covers the standards recommended by: American Association of State Highway and Transportation Officials (AASHTO); FHWA; and MDOT for designing and evaluation of highways. Its objective is to introduce the students to the concepts, requirements, and fundamental skills for highway design and evaluation. The primary goal of geometric design is to provide for the safety and comfort of road users with due regard to social, economic and environmental constraints. Although there are suggested design standards and controls that must be followed to meet design goals, their application is determined on a case-by-case basis. The objective of this course is to illustrate the practical application of scientific knowledge to the planning and designing of roadway elements. The course uses up-to-date software design tools in accomplishing these goals. Upon completion of the course, the student is expected to be able to design and evaluate highways per AASHTO, MDOT and FHWA standards. Offered Fall.

**Prerequisites:** CE 4640 with a minimum grade of C-

**CE 5640 Advanced Transportation Systems Design and Operation Cr. 3**

Provides an overview of various system components of transportation, including the driver, vehicle and roadway. The subject matter will be covered at an intermediate level, appropriate for CEE students already familiar with the basic concepts of transportation engineering who wish to expand their knowledge, and for non-CEE students specifically interested in applications of transportation engineering theory. There will be a particular emphasis on transportation safety and multimodal roadway operations, as are typical priorities in an urban or suburban setting. Traffic flow design elements including volume, density and speed; intersection design elements including delay, capacity and crash countermeasures and terminal design elements including inflow, outflow and circulation. Offered Fall.

**CE 5810 Legal Aspects of Engineering and Construction Cr. 3**

Business of contracting, construction, liabilities of owner, architect, engineer and contractor. Rights in land, boundaries and foundations. Case studies. Offered Fall.

**Course Material Fees:** \$5

**CE 5830 Business of Engineering Cr. 3**

Defining the engineering company, creating the organization, support services, business development, project management, scheduling, budgeting and profitability, operations, financial management and risk management. Offered Every Term.

**Prerequisites:** CE 4850 with a minimum grade of C-

**CE 5995 Special Topics in Civil Engineering I Cr. 1-3**

Topics to be announced in Schedule of Classes. Offered Intermittently.

**Repeatable for 12 Credits**

**CE 6010 Introduction to Construction Engineering and Management Cr. 3**

An introduction to the organization and management of construction projects. Project lifecycle including engineering, procurement and construction phases. Fundamentals of cost estimating, scheduling, quality, safety and risk management, legal and ethical aspects, construction productivity and lean construction, building codes, and building information modeling. Offered Winter.

**Prerequisites:** CE 4850 with a minimum grade of C-

**Course Material Fees:** \$5

**CE 6050 Construction Cost Estimating Cr. 3**

Estimating construction costs of engineering projects including materials, man-hours, equipment and overhead. Emphasis on construction equipment, including productivity and planning. Bidding and bid documents. Offered Every Other Year.

**Prerequisites:** CE 4850 with a minimum grade of C-

**CE 6060 Construction Techniques and Methods Cr. 3**

Construction techniques and methods for excavation, foundations, concrete, wood, steel, masonry, heavy construction, wastewater treatment plants, highways and roads, high rise structures, bridges, and tunneling projects. Offered Every Other Year.

**Prerequisites:** CE 4450 with a minimum grade of C-

**CE 6130 Open Channel Hydraulics Cr. 3**

Theoretical development of equations governing flow in open channels. Application to real-world engineering problems involving water surface profiles, flood studies, and river. Offered Winter.

**Prerequisites:** CE 3250 with a minimum grade of C-

**CE 6150 Hydrologic Analysis and Design Cr. 3**

Principles of surface water hydrology and their application for evaluation of floods and the design of surface runoff control system; watershed characteristics; design storms and SCS methods; unit hydrographs; hydrologic models; application of computer methods. Offered Every Other Year.

**Prerequisite:** CE 6130

**CE 6160 Principles of Atmospheric Chemistry and Applications Cr. 3**

Provides the student with an overview of photochemical reactions that directly impact atmospheric composition and thus pertinent to the management of air quality. Focuses on atmospheric radicals, tropospheric ozone and mechanisms of particulate matter formation; the impact of these constituents associated with air pollutions on air quality and global climate change. Students will be introduced to modeling atmospheric chemistry using simple box models as well as state-of-the-science 3-dimensional global chemical transport models. Offered Yearly.

**CE 6170 River Assessment and Restoration I Cr. 3**

Students will learn field methods to assess stability, condition of rivers and contributing watersheds. Students will learn basic surveying techniques, apply these to the collection, analysis of cross-sectional data and longitudinal profiles. Other field methods include: Wolman pebble count, measurement of plan-form geometry, identification of key geomorphic features (e.g., bankfull elevation, abandoned floodplains, mid-channel and transverse features). Field measurements will be made to calculate Bank Erosion Hazard Index (BEHI), Near-Bank Stress Index. Students will learn how to monitor a river for bank erosion (e.g., bank pins), riverbed aggradation/degradation (e.g., scour chains). Students will learn stream classification, sediment budgeting, methods to quantify sediment yield and transport, and how to analyze data, and identify trends in river hydrology and sediment supply. Offered Every Other Spr/Sum.



**CE 6190 Groundwater Cr. 3**

Historical background, aquifers and aquitards, saturated and unsaturated flow, sources of ground water contamination, artificial recharge of ground water, development of ground water basins and efficient use of ground water resources. Offered Yearly.

**Prerequisites:** CE 3250 with a minimum grade of C-

**CE 6270 Sustainability Assessment and Management Cr. 3**

Sustainability assessment and management for engineering design and development; theoretical, regulatory, and practical implications; Detroit and global applications. Offered Yearly.

**Prerequisites:** CE 4210 with a minimum grade of C-

**Equivalent:** STE 6270

**CE 6330 Advanced Structural Analysis Cr. 3**

Effect of axial loads on stiffness of flexural members. Buckling of trusses and rigid frames. Matrix method of analysis. Complex structures. Computer applications. Offered Fall.

**Prerequisites:** CE 4410 with a minimum grade of C-

**CE 6340 Bridge Design and Evaluation Cr. 3**

Concepts, procedures, methods of design and condition evaluation for modern highway bridges, according to current specifications. Entire system is covered, including superstructure, substructure, and their connections. Offered Every Other Year.

**Prerequisites:** CE 4420 with a minimum grade of C-

**CE 6370 Advanced Reinforced Concrete Design Cr. 3**

Theory and design of two-way slabs, footings, retaining walls, shear walls, and composite beams using ultimate strength design. Precast and prestressed concrete fundamentals. Offered Yearly.

**Prerequisites:** CE 4420 with a minimum grade of C-

**CE 6410 Advanced Steel Design Cr. 3**

Advanced topics of structural steel design: thin walled rolled and built-up members, beam columns, lateral torsional buckling, steel fatigue design, connection details. Steel design project. Offered Every Other Year.

**Prerequisites:** CE 4420 with a minimum grade of C-

**CE 6580 Geoenvironmental Engineering I Cr. 4**

Properties and test methods for natural and synthetic materials used in landfills; analysis of chemical interactions, flow mechanisms, stability and settlement for the design of landfill components. Offered Yearly.

**Prerequisites:** CE 4510 with a minimum grade of C-

**CE 6660 Pavement Asset Management Cr. 3**

Principles and practices of pavement management at the network and project level: serviceability, pavement design models, economic analysis, and priority programming. Offered Yearly.

**Prerequisites:** CE 4640 with a minimum grade of C-

**CE 6880 Building Information Modeling (BIM) Cr. 3**

Lectures, hands-on demonstrations and lab exercises to familiarize students with concepts and tools in Revit Architecture 2010 software; how software integrates 3D and 2D modeling. Includes an overview of the Building Information Modeling (BIM) process; integration of designs from different disciplines (architectural, structural and MEP) in a BIM model; and use of BIM tools (including Revit and Navisworks) to create 2D, 3D, 4D (schedule) and 5D (cost) models for project control purposes, as well as clash detections. Offered Every Other Year.

**Prerequisites:** CE 3010 with a minimum grade of C-

**CE 6910 Pharmaceutical Waste: Environmental Impact and Management Cr. 2-3**

Course designed for advanced professional and graduate students with sufficient chemistry and/or biological sciences background who are interested in the environmental impact, management, and regulation of waste pharmaceuticals as emerging issues. Offered Winter.

**Restriction(s):** Enrollment is limited to Graduate or Professional level students.

**Equivalent:** PSC 6910

**CE 6991 Internship in Industry Cr. 1-4**

Written report describing internship experience. Offered Every Term.

**Repeatable for 4 Credits**