

CIVIL ENGINEERING (C E)

Courses primarily for undergraduates:

C E 105: Introduction to the Civil Engineering Profession

(1-0) Cr. 1. F.S.

Overview of the nature and scope of the civil engineering profession. Exploration of the various specialty areas within civil engineering. Bloom's Taxonomy and creativity. Departmental rules, student services operations, degree requirements, educational objectives, program of study planning, career options, and student organizations.

C E 111: Fundamentals of Surveying I

(2-3) Cr. 3. F.S.

Prereq: C E 160, credit or enrollment in ENGR 170 or C E 170, MATH 165
Introduction to error theory. Fundamentals of observing distances, elevations, and angles. Traversing. Irregular areas. Circular and parabolic curves. Earthwork including mass diagrams. Construction staking. Computer applications and introduction to photogrammetry, geographic information systems and global positioning systems technology.

C E 120: Civil Engineering Learning Community

Cr. R. Repeatable.

Integration of first-year students into the Civil Engineering program. Assignments and activities involving teamwork, academic preparation, study skills, and preparation for entry into the Civil Engineering profession. Completed both individually and in learning teams under the direction of faculty and peer mentors. Offered on a satisfactory-fail basis only.

C E 160: Engineering Problems with Computational Laboratory

(2-2) Cr. 3. F.S.

Prereq: MATH 143 or satisfactory scores on mathematics placement examinations; credit or enrollment in MATH 165
Formulation of engineering problems using spreadsheets and Visual Basic for Application for solution. Presenting results using word processing, tables, and graphs. Introduction to engineering economics and statics. Civil engineering examples.

C E 170: Graphics for Civil Engineering

(0-4) Cr. 2. F.S.

Fundamental graphics. Introduction to computer aided drafting and modeling. Civil engineering applications.

C E 206: Engineering Economic Analysis and Professional Issues in Civil Engineering

(3-0) Cr. 3. F.S.

Prereq: MATH 166, ENGL 250; C E 105; ECON 101 recommended
Engineering/managerial analysis of the economic aspects of project proposals. Alternative sources of funds; time value of money; expenditure of capital funds and methods of evaluating alternative projects. Professionalism, licensure, liability, ethics, leadership, social responsibility, creative and critical thinking, and applications/impacts of regulations in civil engineering.

C E 306: Project Management for Civil Engineers

(2-3) Cr. 3. F.S.

Prereq: ENGL 250, C E 105

Project management, including work breakdown structures, cost estimating, scheduling, and project control. Civil engineering project life cycle, including planning, design, construction, and maintenance processes. Techniques in interpretation of contract documents, plan reading, and in estimating quantities.

C E 326: Principles of Environmental Engineering

(2-2) Cr. 3. F.S.

Prereq: CHEM 177 or CHEM 178, MATH 166, credit or enrollment in E M 378
Introduction to environmental problems, water quality indicators and requirements, potable water quality and quantity objectives, water sources and treatment methods; water pollution control objectives and treatment methods; survey of solid and hazardous waste management and air pollution control.

C E 332: Structural Analysis I

(2-2) Cr. 3. F.S.

Prereq: E M 324

Loads, shear, moment, and deflected shape diagrams for beams and framed structures. Deformation calculations. Approximate methods. Application of consistent deformation methods to continuous beams and frames. Application of displacement or slope deflection methods to continuous beams and frames without sway. Influence lines for determinate and indeterminate structures. Computer applications to analyze beams and frames. Validation of computer results.

C E 333: Structural Steel Design I

(3-1) Cr. 3. F.S.

Prereq: C E 332, E M 327

AISC design methods for structural steel buildings. Design of steel tension members. Design of steel members for flexure. Design of members for compression. Beam-Column member design. Introduction to steel building systems. Steel moment frames and concentrically braced frames. Design of commonly used connections in steel buildings.

C E 334: Reinforced Concrete Design I

(2-2) Cr. 3. F.S.

Prereq: C E 332, E M 327

ACI design methods for structural concrete members. Emphasis on the analysis and design for flexure of singly reinforced and doubly reinforced sections, T-section, one-way slabs, short columns, and isolated footings. Analysis and design for shear, and serviceability. Bond, anchorage, and development of reinforcement.

C E 355: Principles of Transportation Engineering

(3-0) Cr. 3. F.S.

Prereq: C E 111

Introduction to planning, design, and operations of transportation facilities. Road user, vehicle and roadway characteristics. Technological, economic and environmental factors. Asset management, transportation planning, capacity analysis, traffic control, geometric design, traffic safety.

C E 360: Geotechnical Engineering

(2-3) Cr. 3. F.S.

Prereq: E M 324, credit or enrollment in GEOL 201

Introduction to geotechnical engineering and testing. Identification and classification tests, soil water systems, principles of settlement, stresses in soils, and shear strength testing; slope stability, retaining walls, bearing capacity.

C E 372: Engineering Hydrology and Hydraulics

(3-0) Cr. 3. F.S.

Prereq: E M 378, a course in statistics from the approved department list

The hydrologic cycle: precipitation, infiltration, runoff, evapotranspiration, groundwater, and streamflow. Hydrograph analysis, flood routing, frequency analysis and urban hydrology. Applied hydraulics including pipe and channel flow with design applications in culverts, pumping, water distribution, storm and sanitary sewer systems. Design project required.

C E 382: Design of Concretes

(2-3) Cr. 3. F.S.

Prereq: E M 274

Physical and chemical properties of bituminous, portland, and other cements; aggregate properties and blending; mix design and testing of concretes; admixtures, mixing, handling, placing and curing; principles of pavement thickness design.

C E 383: Design of Portland Cement Concrete

(0-2) Cr. 1. F.S.

Prereq: E M 274

For Con E students only. Physical and chemical properties of portland cement and p.c. concrete. Mix design and testing of p.c. concrete. Credit for both C E 382 and C E 383 may not be applied for graduation.

C E 388: Sustainable Engineering and International Development

(Cross-listed with A B E, E E). (2-2) Cr. 3. F.

Prereq: Junior classification in engineering

Multi-disciplinary approach to sustainable engineering and international development, sustainable development, appropriate design and engineering, feasibility analysis, international aid, business development, philosophy and politics of technology, and ethics in engineering. Engineering-based projects from problem formulation through implementation. Interactions with partner community organizations or international partners such as nongovernment organizations (NGOs). Course readings, final project/design report. Meets International Perspectives Requirement.

C E 395: Global Perspectives in Transportation

Cr. 3. Repeatable, maximum of 2 times. SS.

Prereq: CE 355 or equivalent

Background on historical civil engineering design and construction. Impacts of historical, cultural, social, economic, ethical, environmental, and political conditions on the design and construction of various infrastructure projects outside the United States. Global road safety and intermodal operations. Addressing transportation problems in a large metropolitan area. Meets International Perspectives Requirement.

C E 396: Summer Internship

Cr. R. Repeatable. SS.

Prereq: Permission of department and Engineering Career Services

Summer professional work period. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

C E 398: Cooperative Education (Co-op)

Cr. R. Repeatable. F.S.

Prereq: Permission of department and Engineering Career Services

Professional work period. One semester per academic or calendar year. Students must register for this course before commencing work. Offered on a satisfactory-fail basis only.

C E 403: Program and Outcome Assessment

Cr. R. F.S.

Prereq: Verification of undergraduate application for graduation by the end of the first week of class. Permission of instructor for students who are scheduled for summer graduation

Assessment of C E Curriculum and educational objectives. Assessments to be reviewed by the CE Department to incorporate potential improvements. Offered on a satisfactory-fail basis only.

C E 417: Land Surveying

(2-3) Cr. 3. S.

Prereq: C E 111

Legal principles affecting the determination of land boundaries, public domain survey systems. Locating sequential and simultaneous conveyances. Record research, plat preparation, and land description. Study of selected court cases.

C E 420: Environmental Engineering Chemistry

(Dual-listed with C E 520). (Cross-listed with ENSCI). (2-3) Cr. 3. F.

Prereq: C E 326, CHEM 178

Principles of chemical and physical phenomena applicable to the treatment of water and wastewater and natural waters; including chemical equilibria, reaction kinetics, acid-base equilibria, chemical precipitation, redox reactions, and mass transfer principles. Individual laboratory practicals and group projects required.

C E 421: Environmental Biotechnology

(Dual-listed with C E 521). (2-2) Cr. 3. F.

Prereq: C E 326

Fundamentals of biochemical and microbial processes applied to environmental engineering processes, role of microorganisms in wastewater treatment and bioremediation, bioenergetics and kinetics, metabolism of xenobiotic compounds, waterborne pathogens and parasites, and disinfection. Term paper and oral presentation.

C E 424: Air Pollution

(Dual-listed with C E 524). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

C E 424A: Air Pollution: Air quality and effects of pollutants

(Dual-listed with C E 524A). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

C E 424B: Air Pollution: Climate change and causes

(Dual-listed with C E 524B). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

C E 424C: Air Pollution: Transportation Air Quality

(Dual-listed with C E 524C). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

*Prereq: C E 524A; PHYS 221 or CHEM 178; MATH 166 or 3 credits in statistics. Senior classification or above.***C E 424D: Air Pollution: Off-gas treatment technology**

(Dual-listed with C E 524D). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

*Prereq: C E 524A, C E 524B; Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above***C E 424E: Air Pollution: Agricultural sources of pollution**

(Dual-listed with C E 524E). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

C E 428: Water and Wastewater Treatment Plant Design

(2-2) Cr. 3. S.

Prereq: C E 326

Physical, chemical and biological processes for the treatment of water and wastewater including coagulation and flocculation, sedimentation, filtration, adsorption, chemical oxidation/disinfection, fixed film and suspended growth biological processes and sludge management.

C E 440: Bioprocessing and Bioproducts

(Dual-listed with C E 540). (Cross-listed with FS HN). (3-0) Cr. 3. F.

Prereq: C E 326 or equivalent, MATH 160 or MATH 165, CHEM 167 or higher, BIOL 173 or BIOL 211 or higher, senior or graduate classification

Sustainability, cleaner production. Taxonomy, kinetics, metabolism, microbial cultivation, aerobic and anaerobic fermentation. Antibiotics, food supplements, fermented foods, vitamin production. Biofuels, bioenergy and coproducts. Mass/energy balances, process integration, pretreatment, separation. Membrane reactors, bioelectrolysis, microbial fuel cells, nanotechnology, genetic engineering, mutagenesis.

C E 446: Bridge Design

(Dual-listed with C E 546). (2-2) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: C E 333, C E 334

Bridge design in structural steel and reinforced concrete. Application of AASHTO Bridge Design Specifications. Analysis techniques for complex structures. Preliminary designs include investigating alternative structural systems and materials. Final designs include preparation of design calculations and sketches.

C E 448: Building Design

(Dual-listed with C E 548). (2-2) Cr. 3. Alt. S., offered even-numbered years.

Prereq: C E 333, C E 334

Building design in structural steel and reinforced concrete. Investigation of structural behavior. Gravity and lateral load resisting systems. Application of current building codes and design specifications. In-depth analysis of gravity and wind loads on buildings. Review of building designs. Preliminary designs include investigating alternative structural systems. Approximate methods of structural analysis for gravity and lateral loads. Final designs include preparation of design calculations and sketches.

C E 449: Structural Health Monitoring

(Dual-listed with C E 549). (Cross-listed with MAT E). (3-0) Cr. 3.

Prereq: Senior classification in Engineering or permission of instructor

Introductory and advanced topics in structural health monitoring (SHM) of aeronautical, civil, and mechanical systems. Topics include sensors, signal processing in time and frequency domains, data acquisition and transmission systems, design of integrated SHM solutions, nondestructive evaluation techniques, feature extraction methods, and cutting-edge research in the field of SHM. Graduate students will have a supervisory role to assist students in 449 and an additional design project or more in-depth analysis and design.

C E 451: Urban Transportation Planning Models

(Dual-listed with C E 551). (3-0) Cr. 3. F.

Prereq: C E 355, STAT 101 or STAT 105

Urban transportation planning context and process. Project planning and programming. Congestion, mitigation, and air quality issues. Transportation data sources. Travel demand and network modeling. Use of popular travel demand software and applications of geographic information systems.

C E 453: Highway Design

(2-2) Cr. 3. F.S.

Prereq: C E 306, C E 355

Introduction to highway planning and design. Design, construction, and maintenance of highway facilities. Level-of-service, stopping sight distance, highway alignment, earthwork and pavement design. Design project, oral reports and written reports. Computer applications.

C E 460: Foundation Engineering

(3-0) Cr. 3. F.S.

Prereq: C E 360

Fundamentals of foundation engineering. Exploration, sampling, and in-situ tests. Shallow and deep foundations. Settlement and bearing capacity analyses. Stability of excavations and earth retaining structures.

C E 467: Geomaterials Stabilization

(Dual-listed with C E 567). (2-2) Cr. 3. S.

Prereq: C E 360, C E 382 or C E 383

Soil and aggregate physical, chemical and biological stabilization procedures. Stabilization analysis and design. Ground modification and compaction methods. Geosynthetics application and design.

C E 473: Groundwater Hydrology

(Dual-listed with C E 573). (3-0) Cr. 3. F.

Prereq: C E 372

Principles of groundwater flow, hydraulics of wells, superposition, slug and pumping tests, streamlines and flownets, and regional groundwater flow. Contaminant transport. Computer modeling. Design project. Extra assignments required for graduate students.

C E 483: Pavement Analysis and Design

(Dual-listed with C E 583). (3-0) Cr. 3. S.

Prereq: C E 360 and C E 382

Analysis, behavior, performance, and structural design of pavement systems. Topics include climate factors, rehabilitation, life cycle design economics, material and system response, pavement foundations and traffic loadings. Development of models for and analysis of pavement systems. Use of transfer functions relating pavement response to pavement performance. Evaluation and application of current and evolving pavement design practices and procedures. Mechanistic-based pavement design techniques and concepts. Analysis of the effects of maintenance activities on pavement performance and economic evaluation of pavement systems.

C E 484: Advanced Design of Concretes

(Dual-listed with C E 584). (2-3) Cr. 3.

Prereq: C E 382

Asphalt binder characterization, fundamentals of asphalt rheology, asphalt materials behavior under loading and temperature effects. High-strength, lightweight, fiber-reinforced, and self-consolidating portland cement concretes, mix design, properties, advanced performance testing. A term project is required for graduate level only.

C E 485: Civil Engineering Design

(2-2) Cr. 3. F.S.

Prereq: C E 206, C E 306, C E 326, C E 333 or C E 334, C E 355, C E 360, C E 372, C E 382, SP CM 212. Course enrollment limited to final graduating semester.

The civil engineering design process, interacting with the client, identification of the engineering problems, development of a technical proposal, identification of design criteria, cost estimating, planning and scheduling, codes and standards, development of feasible alternatives, selection of best alternative, and oral presentation.

C E 488: Sustainable Horizontal Civil Infrastructure Systems

(Dual-listed with C E 588). (3-0) Cr. 3. F.

Prereq: Junior or higher classification in engineering or science
Sustainable planning, life cycle analysis, appropriate engineering design, and overall rating assessment of horizontal civil infrastructure (i.e., versus 'vertical building') systems, including highway, bridge, airport, rail, and port facilities. Course readings and final project/design report.

C E 489: Pavement Preservation and Rehabilitation

(Dual-listed with C E 589). Cr. 3. F.S.

Prereq: C E 382

Overview of pavement preservation and pavement rehabilitation techniques. Overview and selection of materials used in pavement preservation and rehabilitation strategies. Evaluating suitability of pavement preservation and pavement rehabilitation strategies based on existing structure, pavement distresses and non-condition factors. Use of recycled pavement materials in pavement reconstruction techniques.

C E 490: Independent Study

Cr. 1-3. Repeatable. F.S.SS.

Prereq: Permission of instructor

Independent study in any phase of civil engineering. Pre-enrollment contract required. No more than 6 credits of C E 490 may be counted towards engineering topics electives.

C E 490H: Independent Study: Honors

Cr. 1-3. Repeatable. F.S.SS.

Prereq: Permission of instructor

Independent study in any phase of civil engineering. Pre-enrollment contract required. No more than 6 credits of C E 490H may be counted towards engineering topics electives.

Courses primarily for graduate students, open to qualified undergraduates:**C E 501: Preconstruction Project Engineering and Management**

(3-0) Cr. 3. F.

Prereq: Credit or enrollment in CON E 422 or C E 306 or graduate standing

Application of engineering and management control techniques to construction project development from conceptualization to notice to proceed. Emphasis is on managing complex projects using 5-dimensional project management theory.

C E 502: Construction Project Engineering and Management

(3-0) Cr. 3. S.

Prereq: Credit or enrollment in CON E 422 or C E 594A or permission of instructor

Application of engineering and management control techniques to complex construction projects. Construction project control techniques, stochastic estimating and scheduling, equipment selection and utilization, project administration, construction process simulation, Quality Management, and productivity improvement programs.

C E 503: Construction Finance and Business Management

(3-0) Cr. 3. F.

Prereq: Credit or enrollment in CON E 422 or C E 594A or permission of instructor

Fundamental theories and applied methods for financial management of construction companies. Construction accounting, cash flow analysis, financial planning and management, and risk analysis. Case studies.

C E 505: Design of Construction Systems

(3-0) Cr. 3. S.

Prereq: C E 333, C E 360, CON E 322, CON E 340 or graduate standing

Advanced design of concrete formwork and falsework systems. Design for excavation and marine construction including temporary retaining structures and cofferdams. Aggregate production operations, including blasting, crushing, and conveying systems. Rigging system design.

C E 506: Case Histories in Construction Documents

(3-0) Cr. 3.

Prereq: Graduate standing or permission of instructor

Study of cases involving disputes, claims, and responsibilities encountered by management in construction contract documents. Analysis of methods of resolving differences among the owner, architect, engineer, and construction contractor for a project.

C E 510: Information Technologies for Construction

(3-0) Cr. 3.

Prereq: Graduate standing or permission of instructor

Information technologies including microcomputer based systems, management information systems, automation technologies, computer-aided design, and expert systems and their application in the construction industry. Overview of systems acquisition, communications, and networking.

C E 520: Environmental Engineering Chemistry

(Dual-listed with C E 420). (Cross-listed with ENSCI). (2-3) Cr. 3. F.

Prereq: C E 326, CHEM 178

Principles of chemical and physical phenomena applicable to the treatment of water and wastewater and natural waters; including chemical equilibria, reaction kinetics, acid-base equilibria, chemical precipitation, redox reactions, and mass transfer principles. Individual laboratory practicals and group projects required.

C E 521: Environmental Biotechnology

(Dual-listed with C E 421). (Cross-listed with ENSCI). (2-2) Cr. 3. F.

Prereq: C E 326

Fundamentals of biochemical and microbial processes applied to environmental engineering processes, role of microorganisms in wastewater treatment and bioremediation, bioenergetics and kinetics, metabolism of xenobiotic compounds, waterborne pathogens and parasites, and disinfection. Term paper and oral presentation.

C E 522: Water Pollution Control Processes

(Cross-listed with ENSCI). (2-2) Cr. 3.

Prereq: C E 521

Fundamentals of biochemical processes, aerobic growth in a single CSTR, multiple events in complex systems, and techniques for evaluating kinetic parameters; unit processes of activated sludge system, attached growth systems, stabilization and aerated lagoon systems, biosolids digestion and disposal, nutrient removal, and anaerobic treatment systems.

C E 523: Physical-Chemical Treatment Process

(Cross-listed with ENSCI). (2-2) Cr. 3.

Prereq: C E 520

Material and energy balances. Principles and design of physical-chemical unit processes; including screening, coagulation, flocculation, chemical precipitation, sedimentation, filtration, lime softening and stabilization, oxidation, adsorption, membrane processes, ion exchange and disinfection; recovery of resources from residuals and sludges; laboratory exercises and demonstrations; case studies in mineral processing and secondary industries.

C E 524: Air Pollution

(Dual-listed with C E 424). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

C E 524A: Air Pollution: Air quality and effects of pollutants

(Dual-listed with C E 424A). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

C E 524B: Air Pollution: Climate change and causes

(Dual-listed with C E 424B). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

C E 524C: Air Pollution: Transportation Air Quality

(Dual-listed with C E 424C). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: C E 524A; PHYS 221 or CHEM 178; MATH 166 or 3 credits in statistics. Senior classification or above.

C E 524D: Air Pollution: Off-gas treatment technology

(Dual-listed with C E 424D). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: C E 524A, C E 524B; Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

C E 524E: Air Pollution: Agricultural sources of pollution

(Dual-listed with C E 424E). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.

Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

C E 528: Solid and Hazardous Waste Management

(Cross-listed with ENSCI). (3-0) Cr. 3.

Prereq: C E 326 or background courses in both environmental chemistry and microbiology; junior or higher standing

Evaluation, characterization, assessment, planning and design of solid and hazardous waste management systems, regulatory requirements, material characterization and collection, minimization and recycling, energy and materials recovery, composting, off-gas treatment, incineration, stabilization, and landfill design. Design of treatment and disposal systems, including physical, chemical, and biological treatment, solidification, incineration, secure landfill design, and final disposal site closure plus restoration.

C E 532: Structural Analysis II

(3-0) Cr. 3. F.

Prereq: C E 332

Analysis of indeterminate structural problems by the consistent deformation and generalized direct displacement methods. Direct stiffness method for 2-D frames, grids, 3-D frames. Special topics for the stiffness method.

C E 533: Structural Steel Design II

(3-0) Cr. 3.

Prereq: C E 333

Theoretical background and development of AISC Specification equations. In-depth analysis and design of tension members, columns, beams, beam-columns, and plate girders. Emphasis on Load and Resistance Factor Design. Elastic and inelastic buckling of members and member elements. Investigation of amplification factors for members subject to combined bending and axial load and to combined bending and torsion. Effective Length Method and Direct Analysis Method of design. Approximate Second-Order Analysis. Biaxial bending. Torsion and combined bending and torsion of W-shapes.

C E 534: Reinforced Concrete Design II

(2-2) Cr. 3.

Prereq: C E 334

Advanced topics in reinforced concrete analysis and design. Moment-curvature and load-deflection behavior. Design of reinforced concrete long columns, two-way floor slabs, and isolated and combined footings. Design and behavior considerations for torsion, biaxial bending, and structural joints. Strut-and-tie modeling.

C E 535: Prestressed Concrete Structures

(3-0) Cr. 3.

Prereq: C E 334

Design of prestressed concrete structures, review of hardware, stress calculations, prestress losses, section proportioning, flexural design, shear design, deflections, and statically indeterminate structures.

C E 540: Bioprocessing and Bioproducts

(Dual-listed with C E 440). (Cross-listed with BRT, FS HN). (3-0) Cr. 3. F.

Prereq: C E 326 or equivalent, MATH 160 or MATH 165, CHEM 167 or higher, BIOL 173 or BIOL 211 or higher, senior or graduate classification

Sustainability, cleaner production. Taxonomy, kinetics, metabolism, microbial cultivation, aerobic and anaerobic fermentation. Antibiotics, food supplements, fermented foods, vitamin production. Biofuels, bioenergy and coproducts. Mass/energy balances, process integration, pretreatment, separation. Membrane reactors, bioelectrolysis, microbial fuel cells, nanotechnology, genetic engineering, mutagenesis.

C E 541: Dynamic Analysis of Structures

(3-0) Cr. 3.

Prereq: E M 345 and credit or enrollment in C E 532

Single and multi-degree-of-freedom systems. Free and forced vibrations. Linear and nonlinear response. Modal analysis. Response spectra. Seismic analysis.

C E 542: Structural Analysis by Finite Elements

(3-0) Cr. 3.

Prereq: C E 532

Use of the finite element method for the analysis of complex structural configurations. Plane stress, solid, Axisymmetric and plate elements. Numerical integration. Use of general purpose finite element programs.

C E 545: Seismic Design

(3-0) Cr. 3.

Prereq: C E 333, C E 334

Seismic hazard in the United States. Engineering characteristics of ground motions. Structural damage in past earthquakes. Capacity design philosophy for seismic resistant design. Conceptual design of structures. Capacity design process including design of structural members.

C E 546: Bridge Design

(Dual-listed with C E 446). (2-2) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: C E 333, C E 334

Bridge design in structural steel and reinforced concrete. Application of AASHTO Bridge Design Specifications. Analysis techniques for complex structures. Preliminary designs include investigating alternative structural systems and materials. Final designs include preparation of design calculations and sketches.

C E 547: Analysis and Design of Plate and Slab Structures

(3-0) Cr. 3.

Prereq: C E 334, E M 514, MATH 266

Bending and buckling of thin plate components in structures utilizing classical and energy methods. Analysis of shell roofs by membrane and bending theories.

C E 548: Building Design

(Dual-listed with C E 448). (2-2) Cr. 3. Alt. S., offered even-numbered years.

Prereq: C E 333, C E 334

Building design in structural steel and reinforced concrete. Investigation of structural behavior. Gravity and lateral load resisting systems. Application of current building codes and design specifications. In-depth analysis of gravity and wind loads on buildings. Review of building designs. Preliminary designs include investigating alternative structural systems. Approximate methods of structural analysis for gravity and lateral loads. Final designs include preparation of design calculations and sketches.

C E 549: Structural Health Monitoring

(Dual-listed with C E 449). (Cross-listed with M S E). (3-0) Cr. 3.

Prereq: Senior classification in Engineering or permission of instructor

Introductory and advanced topics in structural health monitoring (SHM) of aeronautical, civil, and mechanical systems. Topics include sensors, signal processing in time and frequency domains, data acquisition and transmission systems, design of integrated SHM solutions, nondestructive evaluation techniques, feature extraction methods, and cutting-edge research in the field of SHM. Graduate students will have a supervisory role to assist students in 449 and an additional design project or more in-depth analysis and design.

C E 551: Urban Transportation Planning Models

(Dual-listed with C E 451). (3-0) Cr. 3. F.

Prereq: C E 355, STAT 101 or STAT 105

Urban transportation planning context and process. Project planning and programming. Congestion, mitigation, and air quality issues. Transportation data sources. Travel demand and network modeling. Use of popular travel demand software and applications of geographic information systems.

C E 552: Traffic Safety, Operations, and Maintenance

(3-0) Cr. 3. Alt. S., offered even-numbered years.

Prereq: C E 355

Engineering aspects of highway traffic safety. Reduction of crash incidence and severity through highway design and traffic control. Accident analysis. Safety in highway design, maintenance, and operation.

C E 553: Traffic Engineering

(3-0) Cr. 3. F.

Prereq: C E 355

Driver, pedestrian, and vehicular characteristics. Traffic characteristics; highway capacity; traffic studies and analyses. Principles of traffic control for improved highway traffic service. Application of appropriate computing software and tools.

C E 556: Transportation Data Analysis

(3-0) Cr. 3.

Prereq: C E 355, a Statistics course at the 300 level or higher

Analysis of transportation data, identification of data sources and limitations. Static and dynamic data elements such as infrastructure characteristics, flow and operations-related data elements. Spatial and temporal extents data for planning, design, operations, and management of transportation systems. Summarizing, analyzing, modeling, and interpreting data. Use of information technologies for highways, transit, and aviation systems.

C E 557: Transportation Systems Analysis

(3-0) Cr. 3. Alt. S., offered odd-numbered years.

Prereq: C E 355, 3 credits in statistics or probability

Travel studies and analysis of data. Transportation systems forecasts and analyses. Statewide, regional, and local transportation system planning. Network level systems planning and operations. Optimization of systems.

C E 558: Transportation Systems Development and Management

(3-0) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: C E 355

Study of designated problems in traffic engineering, transportation planning, and development. Forecasting and evaluation of social, economic, and environmental impacts of proposed solutions; considerations of alternatives. Formulation of recommendations and publication of a report. Presentation of recommendations in the host community.

C E 559: Transportation Infrastructure/Asset Management

(3-0) Cr. 3. Alt. F., offered even-numbered years.

Prereq: C E 355

Engineering management techniques for maintaining and managing infrastructure assets. Systematic approach to management through value engineering, engineering economics, and life cycle cost analysis. Selection and scheduling of maintenance activities. Analysis of network-wide resource needs. Project level analysis.

C E 560: Fundamentals of Soil Mechanics

(3-0) Cr. 3.

Prereq: C E 360

Nature of soil deposits, seepage, settlement and secondary compression, consolidation theories and analysis, failure theories, stress paths, introduction to critical state soil mechanics, constitutive models, soil strength under various drainage conditions, liquefaction of soil, pore pressure parameters, selection of soil parameters.

C E 561: Applied Foundation Engineering

(3-0) Cr. 3.

Prereq: C E 460

Analysis and design of shallow and deep foundations, lateral earth pressure theories and retaining structures, field investigations, in-situ testing, and foundations on problematic soils. Foundation engineering reports.

C E 562: Site Evaluations for Civil Engineering Projects

(2-2) Cr. 3. Alt. F., offered even-numbered years.

Prereq: C E 360

Identification and mapping of engineering soils from aerial photos, maps, and soil surveys. Planning subsurface investigations, geomaterials prospecting, geotechnical hazards, geomorphology, in situ testing and sampling, geophysical site characterization, instrumentation and monitoring, interpretation of engineering parameter values for design.

C E 563: Experimental Methods in Geo-Engineering

(2-2) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: C E 360

Principles of geo-engineering laboratory testing including the conduct, analysis, and interpretation of permeability, consolidation, triaxial, direct and ring shear, and direct simple shear tests. Issues regarding laboratory testing versus field testing and acquisition, transport, storage, and preparation of samples for geotechnical testing. Field and laboratory geotechnical monitoring techniques, including the measurements of deformation, strain, total stress and pore water pressure.

C E 564: Application of Numerical Methods to Geotechnical Design

(3-0) Cr. 3.

Prereq: C E 560

Application of numerical methods to analysis and design of foundations, underground structures, and soil-structure interaction. Application of slope stability software. Layered soils, bearing capacity and settlement for complex geometries, wave equation for piles, and foundation vibrations.

C E 565: Fundamentals of Geomaterials Behavior

(2-3) Cr. 3. S.

Prereq: C E 382

Atoms and molecules, crystal chemistry, clay minerals, structure of solids, phase transformations and phase equilibria. Surfaces and interfacial phenomena, colloid chemistry, mechanical properties. Applications to soils and civil engineering materials. Overview of state-of-the-art instrumental techniques for analysis of the physicochemical properties of soils and civil engineering materials.

C E 567: Geomaterials Stabilization

(Dual-listed with C E 467). (2-2) Cr. 3. S.

Prereq: C E 360, C E 382 or C E 383

Soil and aggregate physical, chemical and biological stabilization procedures. Stabilization analysis and design. Ground modification and compaction methods. Geosynthetics application and design.

C E 568: Dynamics of Soils and Foundations

(3-0) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: C E 360, E M 345

Dynamic soil properties and their measurement. Foundation dynamics and soil-structure interaction. Sources and characteristics of dynamic loads. Vibration of single- and multi-degree-of-freedom systems. Vibration of continuous systems; 1D, 2D, and 3D analyses, wave propagation. Liquefaction concepts and analysis methods. Introduction to geotechnical earthquake engineering.

C E 569: Ground Improvement

(3-0) Cr. 3.

Prereq: C E 360

Classification of ground improvement methods. Dynamic compaction, vibrocompaction, preloading using fill surcharge, vacuum or a combination of both and prefabricated vertical drains, vibro replacement or stone columns, dynamic replacement, sand compaction piles, geotextile confined columns, rigid inclusion, column supported embankment, microbial methods, particulate and chemical grouting, lime and cement columns, jet grouting, and deep cement mixing.

C E 570: Applied Hydraulic Design

(2-2) Cr. 3. Alt. F., offered odd-numbered years.

Prereq: C E 372

Flow characteristics in natural and constructed channels; principles of hydraulic design of culverts, bridge waterway openings, spillways, hydraulic gates and gated structures, pumping stations, and miscellaneous water control structures; pipe networks, mathematical modeling. Design project.

C E 571: Surface Water Hydrology

(Cross-listed with ENSCI). (3-0) Cr. 3. S.

Prereq: C E 372

Analysis of hydrologic data including precipitation, infiltration, evapotranspiration, direct runoff and streamflow; theory and use of frequency analysis; theory of streamflow and reservoir routing; use of deterministic and statistical hydrologic models. Fundamentals of surface water quality modeling, point and non-point sources of contamination.

C E 572: Analysis and Modeling Aquatic Environments

(Cross-listed with ENSCI). (3-0) Cr. 3. Alt. F., offered even-numbered years.

Prereq: C E 372

Principles of surface water flows and mixing. Introduction to hydrologic transport and water quality simulation in natural water systems. Advection, diffusion and dispersion, chemical and biologic kinetics, and water quality dynamics. Applications to temperature, dissolved oxygen, primary productivity, and other water quality problems in rivers, lakes and reservoirs. Deterministic vs. stochastic models.

C E 573: Groundwater Hydrology

(Dual-listed with C E 473). (3-0) Cr. 3. F.

Prereq: C E 372

Principles of groundwater flow, hydraulics of wells, superposition, slug and pumping tests, streamlines and flownets, and regional groundwater flow. Contaminant transport. Computer modeling. Design project. Extra assignments required for graduate students.

C E 576: Environmental Flows

(3-0) Cr. 3.

Prereq: E M 378 or equivalent

Analysis and applications of flows in civil engineering, environmental engineering, and water resources. Primary topics include conservation laws, laminar flow, turbulence, mixing, diffusion, dispersion, water waves, and boundary layers. Associated applications include particle settling, transfer at air-water and water-sediment boundaries, flow and friction in pipes and open channels, contaminant transport, waves in lakes, jets, plumes, and salt wedges.

C E 581: Geotechnical and Materials Engineering Seminar

Cr. R. Repeatable.

Prereq: Graduate classification

(1-0) Students and outside/invited speakers give weekly presentations about the ongoing research work and Geotechnical and Materials Engineering issues. Offered on a satisfactory-fail basis only.

C E 583: Pavement Analysis and Design

(Dual-listed with C E 483). (3-0) Cr. 3. S.

Prereq: C E 360 and C E 382

Analysis, behavior, performance, and structural design of pavement systems. Topics include climate factors, rehabilitation, life cycle design economics, material and system response, pavement foundations and traffic loadings. Development of models for and analysis of pavement systems. Use of transfer functions relating pavement response to pavement performance. Evaluation and application of current and evolving pavement design practices and procedures. Mechanistic-based pavement design techniques and concepts. Analysis of the effects of maintenance activities on pavement performance and economic evaluation of pavement systems.

C E 584: Advanced Design of Concretes

(Dual-listed with C E 484). (2-3) Cr. 3.

Prereq: C E 382

Asphalt binder characterization, fundamentals of asphalt rheology, asphalt materials behavior under loading and temperature effects. High-strength, lightweight, fiber-reinforced, and self-consolidating portland cement concretes, mix design, properties, advanced performance testing. A term project is required for graduate level only.

C E 586: Advanced Asphalt Materials

(2-3) Cr. 3.

Prereq: C E 382

Advanced asphalt concrete (SUPERPAVE) mix designs. Aggregates. Admixtures. Production and construction, quality control and inspection. Nondestructive testing. Pavement thickness design. Materials engineering reports.

C E 587: Advanced Portland Cement Concretes

(2-3) Cr. 3.

Prereq: C E 382 or C E 383

Hydraulic cements, aggregates, admixtures, and concrete mix design; cement hydration and microstructure development; fresh, early-age, and mechanical properties of concrete; concrete distress examination, damage mechanism, and prevention.

C E 588: Sustainable Horizontal Civil Infrastructure Systems

(Dual-listed with C E 488). (3-0) Cr. 3. F.

Prereq: Junior or higher classification in engineering or science

Sustainable planning, life cycle analysis, appropriate engineering design, and overall rating assessment of horizontal civil infrastructure (i.e., versus 'vertical building') systems, including highway, bridge, airport, rail, and port facilities. Course readings and final project/design report.

C E 589: Pavement Preservation and Rehabilitation

(Dual-listed with C E 489). Cr. 3. F.S.

Prereq: C E 382

Overview of pavement preservation and pavement rehabilitation techniques. Overview and selection of materials used in pavement preservation and rehabilitation strategies. Evaluating suitability of pavement preservation and pavement rehabilitation strategies based on existing structure, pavement distresses and non-condition factors. Use of recycled pavement materials in pavement reconstruction techniques.

C E 590: Special Topics

Cr. 1-5. Repeatable. F.S.SS.

Pre-enrollment contract required.

C E 591: Seminar in Environmental Engineering

Cr. R. Repeatable. F.S.

Prereq: Graduate classification

(1-0) Contemporary environmental engineering issues. Outside speakers. Review of ongoing research in environmental engineering. Offered on a satisfactory-fail basis only.

C E 594: Special Topics in Construction Engineering and Management

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Some topics have a set number of credits and some topics have the number of credits vary. Emphasis for a particular offering will be selected from the following topics:

C E 594A: Special Topics Construction Engineering and Mgt.: Planning and Scheduling

Cr. 3. F.

Prereq: C E 306 or graduate standing

Studies in planning and scheduling including scheduling and estimating.

C E 594B: Special Topics Construction Engineering and Mgt.: Computer Applications for Planning and Scheduling

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in computer applications for planning and scheduling.

C E 594C: Special Topics Construction Engineering and Mgt.: Cost Estimating

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in cost estimating.

C E 594D: Special Topics Construction Engineering and Mgt.: Computer Applications for Cost Estimating

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in computer applications for cost estimating.

C E 594E: Special Topics Construction Engineering and Mgt.: Project Controls

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in project controls.

C E 594F: Special Topics Construction Engineering and Mgt.: Computer Applications for Project Controls

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in computer applications for project controls.

C E 594G: Special Topics Construction Engr and Mgt: Integration of Planning, Scheduling and Project Controls

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in integration of planning, scheduling and project controls.

C E 594J: Special Topics Construction Engineering and Mgt.: Trenchless Technologies

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in trenchless technologies.

C E 594K: Special Topics Construction Engineering and Mgt.: Electrical and Mechanical Construction

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in electrical and mechanical construction.

C E 594L: Special Topics Construction Engineering and Mgt.: Advanced Building Construction Topics

Cr. 3. SS.

Prereq: CON E 352 or C E 306 or graduate standing or permission of instructor

Studies in advanced building construction topics including LEED.

C E 594M: Special Topics Construction Engineering and Mgt.: Design Build Construction

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in design build construction.

C E 594N: Special Topics Construction Engineering and Mgt.: Industrial Construction

Cr. 3.

Prereq: Graduate standing or permission of instructor

Studies in industrial construction.

C E 594O: Special Topics Construction Engineering and Mgt.: Highway and Heavy Construction

Cr. 3.

Prereq: CON E 322 or C E 306 or graduate standing

Studies in highway and heavy construction.

C E 594P: Special Topics Construction Engineering and Mgt.: Advanced Technologies

Cr. 3.

Prereq: CON E 352 or graduate standing or permission of instructor

Studies in advanced technologies including building energy modeling.

C E 594Q: Special Topics Construction Engineering and Mgt.: Construction Quality Control

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in construction quality control.

C E 594R: Special Topics Construction Engineering and Mgt.: Risk Management

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in risk management.

C E 594S: Special Topics Construction Engineering and Mgt.: Building Information Modeling

Cr. 1-3. Repeatable.

Prereq: Permission of instructor

Studies in building information modeling.

C E 595: Research Methods in Construction Engineering and Management

(1-0) Cr. 1.

Prereq: Graduate standing or permission of instructor

Assigned readings and reports on research methods to solve construction engineering and management problems such as alternative project delivery methods, asset management, data mining, construction procurement, robotics, project controls, automation, construction visualization, etc. Identification of research methods and priorities, selection and development of research design, and critique of research in construction engineering and management.

C E 595A: Research Methods Seminar in Construction Engineering and Management: Qualitative Methods

(1-0) Cr. 1.

Prereq: Graduate standing or permission of instructor

Assigned readings and reports on research methods to assess and solve qualitative construction engineering and management problems.

C E 595B: Research Methods Seminar in Construction Engineering and Management: Quantitative Methods

(1-0) Cr. 1.

Prereq: Graduate standing or permission of instructor

Assigned readings and reports on research methods to assess and solve quantitative construction engineering and management problems.

C E 595C: Research Methods Seminar in Construction Engineering and Management: Technical Reporting

(1-0) Cr. 1.

Prereq: Graduate standing or permission of instructor

Assigned readings and reports on research methods for planning and preparation of technical reports with construction engineering and management projects.

C E 596: Special Topics in Transportation Engineering

Cr. arr. Repeatable.

Prereq: C E 355

C E 596B: Special Topics in Transportation Engineering: Geographic Information Systems in Transportation

Cr. arr. Repeatable.

Prereq: C E 355

C E 596C: Special Topics in Transportation Engineering: Hazardous Materials Transportation

Cr. arr. Repeatable.

Prereq: C E 355

C E 596D: Special Topics in Transportation Engineering: Transportation and Public Works

Cr. arr. Repeatable.

Prereq: C E 355

C E 596E: Special Topics in Transportation Engineering: Sustainable Transportation

Cr. arr. Repeatable.

Prereq: C E 355

C E 596F: Special Topics in Transportation Engineering: Freight Transportation

Cr. arr. Repeatable.

Prereq: C E 355

C E 599: Creative Component

Cr. 1-3. Repeatable.

Pre-enrollment contract required. Advanced topic for creative component report in lieu of thesis.

Courses for graduate students:

C E 622: Advanced Topics in Environmental Engineering

(2-0) Cr. 2. Repeatable.

Prereq: Permission of environmental engineering graduate faculty

Advanced concepts in environmental engineering. Emphasis on a particular offering will be selected from the following topics:.

C E 622A: Advanced Topics in Environmental Engineering: Water Pollution Control

(2-0) Cr. 2. Repeatable.

Prereq: Permission of environmental engineering graduate faculty

Advanced concepts in environmental engineering. Emphasis on a particular offering will be selected from the following topics:.

C E 622B: Advanced Topics in Environmental Engineering: Water Treatment

(2-0) Cr. 2. Repeatable.

Prereq: Permission of environmental engineering graduate faculty

Advanced concepts in environmental engineering. Emphasis on a particular offering will be selected from the following topics:.

C E 622C: Advanced Topics in Environmental Engineering: Solid and Hazardous Waste

(2-0) Cr. 2. Repeatable.

Prereq: Permission of environmental engineering graduate faculty

Advanced concepts in environmental engineering. Emphasis for a particular offering will be selected from the following topics:.

C E 622D: Advanced Topics in Environmental Engineering: Water Resources

(2-0) Cr. 2. Repeatable.

Prereq: Permission of environmental engineering graduate faculty

Advanced concepts in environmental engineering. Emphasis for a particular offering will be selected from the following topics:.

C E 622E: Advanced Topics in Environmental Engineering: Instrumental Methods for Environmental Analyses

(2-0) Cr. 2. Repeatable.

Prereq: Permission of environmental engineering graduate faculty

Advanced concepts in environmental engineering.

C E 650: Advanced Topics in Transportation Engineering

(3-0) Cr. 3. Repeatable.

Prereq: Permission of Transportation Engineering graduate faculty

C E 650A: Advanced Topics in Transportation Engineering: Highway Design

(3-0) Cr. 3. Repeatable.

Prereq: Permission of Transportation Engineering graduate faculty

C E 650B: Advanced Topics in Transportation Engineering: Traffic Operations

(3-0) Cr. 3. Repeatable.

Prereq: Permission of Transportation Engineering graduate faculty

C E 650C: Advanced Topics in Transportation Engineering: Data Analysis

(3-0) Cr. 3. Repeatable.

Prereq: Permission of Transportation Engineering graduate faculty

Topics in transportation engineering related to data analysis.

C E 690: Advanced Topics

Cr. 1-3. Repeatable. F.S.SS.

Pre-enrollment contract required.

C E 697: Engineering Internship

Cr. R. Repeatable.

Prereq: Permission of coop advisor, graduate classification

One semester and one summer maximum per academic year professional work period. Offered on a satisfactory-fail basis only.

C E 699: Research

Cr. 1-30. Repeatable.

Prereq: Pre-enrollment contract required

Advanced topic for thesis/dissertation.