

Civil Engineering (C E)

Courses primarily for undergraduates:

C E 101. Technical Lecture.

Cr. R. F.S.

(1-0) Discussion of various phases of civil engineering. For transfer students only. Evaluation of transfer credits and discussion of graduation requirements. Offered on a satisfactory-fail basis only.

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, credit or enrollment in C E 105 for C E majors*

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 141, MATH 142 or satisfactory scores on mathematics placement assessments; 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. *Prereq: MATH 165, credit or enrollment in C E 105*

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; 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 298. Cooperative Education.

Cr. R. F.S.SS. *Prereq: Permission of department and Engineering Career Services*

First professional work period in the cooperative education program. Students must register for this course before commencing work. Offered on a satisfactory-fail basis only.

C E 306. Project Management for Civil Engineers.

(2-3) Cr. 3. F.S. *Prereq: C E 206, Credit or enrollment in a technical communication elective from the approved department list*

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. Nonmajor graduate credit.

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 flexibility methods to frames and continuous beams. Application of moment distribution to continuous beams. Application of displacement methods to continuous beams and braced frames. Influence lines for determinate and indeterminate beams using Muller-Breslau principle. Computer applications to analyze beams and frames. Nonmajor graduate credit.

C E 333. Structural Steel Design I.

(2-2) Cr. 3. F.S. *Prereq: C E 332, E M 327*

AISC design methods for structural steel buildings. Load and Resistance Factor Design. Theoretical behavior and applications. Analysis and design of structural steel members subject to tension, compression, flexure, and combined axial force and bending. Analysis and design of bolted and welded connections. Nonmajor graduate credit.

C E 334. Reinforced Concrete Design I.

(2-2) Cr. 3. F.S. *Prereq: C E 332, E M 327*

Analysis and design of beams, one-way slabs, and columns. Preliminary design of building frames using pattern loading and moment coefficients. Nonmajor graduate credit.

C E 350. Introduction to Transportation Planning.

(3-0) Cr. 3. S. *Prereq: 3 credits in statistics, junior classification*

An introductory course for planning urban and regional transportation systems within government. Applications and impacts of legislation, financing, four-step planning process, population trends, land use, societal impacts, public transportation, master plans and traffic impact studies. Organization and coordination of the transportation planning function. Nonmajor graduate credit. Not available for graduation credit for students in civil engineering.

C E 355. Principles of Transportation Engineering.

(3-0) Cr. 3. F.S. *Prereq: C E 111, C E 206, PHYS 221, a course in statistics from the approved departmental list*

Introduction to planning and operations of transportation facilities. Vehicle/operation/infrastructure characteristics. Technological, economic and environmental factors. Travel demand modeling and capacity analysis. Nonmajor graduate credit.

C E 360. Geotechnical Engineering.

(2-3) Cr. 3. F.S. *Prereq: E M 324, credit or enrollment in GEOL 201*

Introduction to soil 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. Nonmajor graduate credit.

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. Nonmajor graduate credit.

C E 382. Design of Concretes.

(2-3) Cr. 3. F.S. *Prereq: Credit or enrollment in C E 360*

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. Nonmajor graduate credit.

C E 383. Design of Portland Cement Concrete.

(0-2) Cr. 1. F.S. *Prereq: Credit or enrollment in C E 360*

For Con E students only. Physical and chemical properties of portland cement and p.c. concrete. Mix design and testing of p.c. concrete.

C E 388. Sustainable Engineering and International Development.

(Cross-listed with A E, E E, M E, MAT E, BSE). (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 396. Summer Internship.

Cr. R. Repeatable. SS. *Prereq:* Permission of department and Engineering Career Services, completion of two terms in residence in civil engineering, employment in civil engineering or related field

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

C E 397. Engineering Internship.

Cr. R. Repeatable. F.S. *Prereq:* Permission of department and Engineering Career Services

One semester maximum per academic year 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.

Cr. R. F.S.SS. *Prereq:* C E 298, permission of department and Engineering Career Services

Second professional work period in the cooperative education program. 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 411. Bioprocessing and Bioproducts.

(Dual-listed with C E 511). (Cross-listed with A E, BIOE, BSE). (3-0) Cr. 3. F. *Prereq:* A E 216, 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 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. Nonmajor graduate credit.

C E 420. Environmental Engineering Chemistry.

(Dual-listed with C E 520). (2-3) Cr. 3. F. *Prereq:* C E 326, CHEM 177 and CHEM 178, MATH 166

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, parasites, and disinfection.

C E 424. Air Pollution.

(Dual-listed with C E 524). (Cross-listed with ENSCI, A E). (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 ENSCI, A E). (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 ENSCI, A E). (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 constraints.

(Dual-listed with C E 524C). (Cross-listed with ENSCI, A E). (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 424D. Air Pollution: Off-gas treatment technology.

(Dual-listed with C E 524D). (Cross-listed with ENSCI, A E). (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 424E. Air Pollution: Agricultural sources of pollution.

(Dual-listed with C E 524E). (Cross-listed with ENSCI, A E). (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 436. Masonry and Timber Design.

(Dual-listed with C E 536). (2-2) Cr. 3. Alt. F., offered 2013. *Prereq:* C E 334

Behavior and design of clay and concrete masonry beams, columns, walls, and structural systems. Behavior and design of timber and laminated timber beams, columns, connections, and structural systems. Nonmajor graduate credit.

C E 446. Bridge Design.

(Dual-listed with C E 546). (2-2) Cr. 3. Alt. S., offered 2015. *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. Nonmajor graduate credit.

C E 448. Building Design.

(Dual-listed with C E 548). (2-2) Cr. 3. Alt. S., offered 2014. *Prereq:* C E 333, C E 334

Building design in structural steel and reinforced concrete. Investigation of structural behavior of frameworks. Gravity and lateral load resisting systems. Application of current building codes and design specifications. Review of building designs. Preliminary designs include investigating alternative structural systems. Final designs include preparation of design calculations and sketches. Nonmajor graduate credit.

C E 451. Urban Transportation Planning Models.

(Dual-listed with C E 551). (2-2) Cr. 3. F. *Prereq:* C E 350 or C E 355

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. Nonmajor graduate credit.

C E 453. Highway Design.

(2-2) Cr. 3. F.S. *Prereq:* C E 306, C E 355, C E 372, C E 382

Introduction to traffic engineering and highway planning. Design, construction, and maintenance of highway facilities; earthwork, drainage structures; pavements. Preparation of environmental impact statement. A complete design project is required. Oral and written reports. Computer applications. Nonmajor graduate credit.

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. Nonmajor graduate credit.

C E 467. Geomaterials Stabilization.(Dual-listed with C E 567). (2-2) Cr. 3. F. *Prereq: C E 360*

Soil and aggregate physical and chemical stabilization procedures. Soil stabilization analysis and design. Ground modification methods. Geosynthetics application and design. Nonmajor graduate credit.

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, super-position, slug and pumping tests, streamlines and flownets, and regional groundwater flow. Contaminant transport. Computer modeling. Nonmajor graduate credit.

C E 483. Pavement Analysis and Design.(Dual-listed with C E 583). (3-0) Cr. 3. *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. Nonmajor graduate credit.

C E 484. Advanced Design of Concretes.(Dual-listed with C E 584). (2-2) Cr. 3. F. *Prereq: C E 382*

Asphalt binder characterization, fundamentals of asphalt rheology, asphalt materials behavior under loading and temperature effects. Portland cement concrete admixtures, cements and admixture compatibility, environmental effects on concrete performance, advanced performance testing. Nonmajor graduate credit.

C E 485. Civil Engineering Design.(2-2) Cr. 3. F.S. *Prereq: C E 306, C E 326, C E 333 or C E 334, C E 355, SP CM 212*

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 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.

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.

C E 498. Cooperative Education.Cr. R. Repeatable. F.S.SS. *Prereq: C E 398, permission of department and Engineering Career Services*

Third and subsequent professional work periods in the cooperative education program. Students must register for this course before commencing work. Offered on a satisfactory-fail basis only.

Courses primarily for graduate students, open to qualified undergraduates:

C E 501. Preconstruction Project Engineering and Management.(3-0) Cr. 3. *Prereq: CON E 221 and CON E 421*

Application of engineering and management control techniques to construction project development from conceptualization to notice to proceed. Determinants of construction project success, conceptual estimating, design and engineering planning for automated construction techniques, constructability review procedures, planning for safety, value engineering.

C E 502. Construction Project Engineering and Management.(3-0) Cr. 3. *Prereq: CON E 221 and CON E 421*

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

C E 503. Construction Management Functions and Processes.(3-0) Cr. 3. *Prereq: CON E 421*

Analysis of critical construction management skills. Analysis of organizational systems related to construction management. Case studies. Analysis of theories of motivation, planning, leadership, organizational change, etc., as they relate to field construction operations.

C E 505. Design of Construction Systems.(3-0) Cr. 3. *Prereq: C E 334, C E 360, CON E 322 and CON E 340*

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: CON E 221, credit or enrollment in CON E 421*

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: CON E 421, ENGR 160 or C E 160 or equivalent*

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 511. Bioprocessing and Bioproducts.

(Dual-listed with C E 411). (Cross-listed with A E, BIOE, BSE). (3-0) Cr. 3. F. *Prereq: A E 216, 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 515. Railroad Engineering.(3-0) Cr. 3. Alt. S., offered 2014. *Prereq: C E 355*

Railroad industry overview, history, components. Basic track elements and design. Right of way, roadway and drainage. Signals and structures. Passenger, transit and high speed rail. Environmental conditions and permitting. Case studies, project and field trip.

C E 520. Environmental Engineering Chemistry.(Dual-listed with C E 420). (2-3) Cr. 3. *Prereq: CHEM 177 and CHEM 178, MATH 166*

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. Term paper and oral presentation for graduate level only.

C E 521. Environmental Biotechnology.(Dual-listed with C E 421). (2-2) Cr. 3. *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 ENSCI, A E). (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 ENSCI, A E). (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 ENSCI, A E). (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 constraints.

(Dual-listed with C E 424C). (Cross-listed with ENSCI, A E). (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 524D. Air Pollution: Off-gas treatment technology.

(Dual-listed with C E 424D). (Cross-listed with ENSCI, A E). (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 524E. Air Pollution: Agricultural sources of pollution.

(Dual-listed with C E 424E). (Cross-listed with ENSCI, A E). (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 527. Solid Waste Management.

(Cross-listed with ENSCI). (3-0) Cr. 3. *Prereq:* C E 326
Planning and design of solid waste management systems; includes characterization and collection of domestic, commercial, and industrial solid wastes, waste minimization and recycling, energy and materials recovery, composting, incineration, and landfill design.

C E 529. Hazardous Waste Management.

(Cross-listed with ENSCI). (3-0) Cr. 3. *Prereq:* C E 326
Regulatory requirements for the classification, transport, storage and treatment of hazardous wastes. Analysis and design of alternatives for treatment and disposal technologies, including physical, chemical, and biological treatment, solidification, incineration, and secure landfill design. Regulatory requirements and procedures for hazardous waste contaminated site investigations and risk analysis. Analysis and design of remedial action alternatives for site restoration.

C E 532. Structural Analysis II.

(3-0) Cr. 3. F. *Prereq:* C E 332
Analysis of indeterminate structural problems by the force and generalized direct displacement methods. Direct stiffness method for 2-D frames, grids, 3-D frames. Additional topics for the stiffness method.

C E 533. Structural Steel Design II.

(3-0) Cr. 3. *Prereq:* C E 333
Every third semester, offered S 2014. Development of the AISC design equations for and the design of tension members, columns, beams, beam-columns, and plate girders for Load and Resistance Factor Design. Elastic and inelastic buckling of members and member elements. Torsion of W-shapes.

C E 534. Reinforced Concrete Design II.

(2-2) Cr. 3. *Prereq:* C E 334
Every third semester, offered F 2013. Design of reinforced concrete long columns, floor slabs, building frames, isolated footings and combined footings. Design and behavior considerations for torsion, biaxial bending, structural joints and shear friction. Introduction to cold-formed composite steel and composite floor slab design.

C E 535. Prestressed Concrete Structures.

(3-0) Cr. 3. *Prereq:* C E 334
Every third semester, offered S 2014. Design of prestressed concrete structures, review of hardware, stress calculations, prestress losses, section proportioning, flexural design, shear design, deflections, statically indeterminate structures.

C E 536. Masonry and Timber Design.

(Dual-listed with C E 436). (2-2) Cr. 3. Alt. F., offered 2013. *Prereq:* C E 334
Behavior and design of clay and concrete masonry beams, columns, walls, and structural systems. Behavior and design of timber and laminated timber beams, columns, connections, and structural systems. Two additional design problems.

C E 541. Dynamic Analysis of Structures.

(3-0) Cr. 3. Alt. S., offered 2015. *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. S. *Prereq:* C E 532
Use of the finite element method for the analysis of complex structural configurations. Plane stress, plate and shell finite elements. General purpose finite element programs.

C E 545. Seismic Design.

(3-0) Cr. 3. Alt. F., offered 2013. *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 2015. *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. Nonmajor graduate credit.

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

(3-0) Cr. 3. Alt. S., offered 2015. *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 2014. *Prereq:* C E 333, C E 334
Building design in structural steel and reinforced concrete. Investigation of structural behavior of frameworks. Gravity and lateral load resisting systems. Application of current building codes and design specifications. Review of building designs. Preliminary designs include investigating alternative structural systems. Final designs include preparation of design calculations and sketches. Nonmajor graduate credit.

C E 551. Urban Transportation Planning Models.

(Dual-listed with C E 451). (2-2) Cr. 3. F. *Prereq:* C E 350 or C E 355
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. Term project required for graduate credit.

C E 552. Traffic Safety, Operations, and Maintenance.

(2-2) Cr. 3. *Prereq:* C E 355
Engineering aspects of highway traffic safety. Reduction of accident incidence and severity through highway design and traffic control. Accident analysis. Legal implications. Safety in highway design, maintenance, and operation.

C E 553. Traffic Engineering.

(2-2) Cr. 3. *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 intersection, corridor or network analysis computer evaluation and optimization tools.

C E 556. Transportation Data Analysis.

(3-0) Cr. 3. *Prereq:* C E 355, STAT 101 or STAT 105
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. *Prereq: C E 355, 3 credits in statistics or probability*
Travel studies and analysis of data. Travel projections. Public transportation forecasts and analyses. Statewide, regional, and local transportation system planning. Corridor travel planning. Optimization of systems.

C E 558. Transportation Systems Development and Management Laboratory.

(2-2) Cr. 3. *Prereq: C E 350 or C E 355*
Study of designated problems in traffic engineering, urban transportation planning, and urban development. Forecasting and evaluation of social, economic, and environmental impact 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. *Prereq: C E 355 or C E 453, C E 382*
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*
Limiting stress analysis, stress paths, introduction to critical state soil mechanics, constitutive models, soil strength under various drainage conditions, seepage, pore pressure parameters, consolidation, slope stability and retaining wall applications.

C E 561. Applied Foundation Engineering.

(2-3) Cr. 3. *Prereq: C E 460*
Lateral earth pressure theories and retaining structures. Field investigations, in-situ testing, foundations on expansive soils, and analysis and design of shallow and deep foundations. Foundation engineering reports.

C E 562. Site Evaluations for Civil Engineering Projects.

(2-2) Cr. 3. *Prereq: C E 360*
Identification and mapping of engineering soils from airphotos. Use of remote sensing and GIS, planning subsurface investigations, geomaterials prospecting, water resource applications.

C E 563. Experimental Methods in Geo-Engineering.

(1-4) Cr. 3. *Prereq: C E 360*
Principles of geo-engineering laboratory testing including the conduct, analysis, and interpretation of soil classification tests, compaction tests, permeability tests, consolidation, triaxial, direct and ring 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. *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. *Prereq: C E 565*
Soil and aggregate physical and chemical stabilization procedures. Soil stabilization analysis and design. Ground modification methods. Geosynthetics application and design. A term project is required.

C E 568. Dynamics of Soils and Foundations.

(3-0) Cr. 3. *F. 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. Liquefaction concepts and analysis methods. Introduction to geotechnical earthquake engineering.

C E 570. Applied Hydraulic Design.

(2-2) Cr. 3. *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. *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. Design project.

C E 572. Analysis and Modeling Aquatic Environments.

(Cross-listed with ENSCI). (3-0) Cr. 3. *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. *Prereq: C E 372*
Principles of groundwater flow, hydraulics of wells, super-position, slug and pumping tests, streamlines and flownets, and regional groundwater flow. Contaminant transport. Computer modeling. Individual and group projects.

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. *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). (2-2) Cr. 3. *F. Prereq: C E 382*
Asphalt binder characterization, fundamentals of asphalt rheology, asphalt materials behavior under loading and temperature effects. Portland cement concrete admixtures, cements and admixture compatibility, environmental effects on concrete performance, advanced performance testing. A term project is required.

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 mix design; concrete production, quality control, early-age properties and durability. Concrete distress examination, identification, prevention, and nondestructive testing; advanced concrete technology, high-strength and high performance concrete.

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: CON E 322, CON E 340 or C E 306, and 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. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594B. Special Topics Construction Engineering and Mgt.: Computer Applications for Planning and Scheduling.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594C. Special Topics Construction Engineering and Mgt.: Cost Estimating.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594D. Special Topics Construction Engineering and Mgt.: Computer Applications for Cost Estimating.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594E. Special Topics Construction Engineering and Mgt.: Project Controls.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594F. Special Topics Construction Engineering and Mgt.: Computer Applications for Project Controls.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594G. Special Topics Construction Engr and Mgt: Integration of Planning, Scheduling and Project Controls.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594J. Special Topics Construction Engineering and Mgt.: Trenchless Technologies.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594K. Special Topics Construction Engineering and Mgt.: Electrical and Mechanical Construction.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594L. Special Topics Construction Engineering and Mgt.: Advanced Building Construction Topics.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594M. Special Topics Construction Engineering and Mgt.: Design Build Construction.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594N. Special Topics Construction Engineering and Mgt.: Industrial Construction.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594O. Special Topics Construction Engineering and Mgt.: Highway and Heavy Construction.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594P. Special Topics Construction Engineering and Mgt.: Advanced Technologies.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594Q. Special Topics Construction Engineering and Mgt.: Construction Quality Control.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594R. Special Topics Construction Engineering and Mgt.: Risk Management.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 594S. Special Topics Construction Engineering and Mgt.: Building Information Modeling.

Cr. 1-3. Repeatable. *Prereq: CON E 322, CON E 340 or C E 306, and 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 595. Research Methods in Construction Engineering and Management.

(0-1) Cr. 1. *Prereq: Credit or enrollment in C E 501, C E 502, C E 503, or C E 505*

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

C E 596. Special Topics in Transportation Engineering.

Cr. arr. Repeatable. *Prereq: C E 355*

C E 596A. Special Topics in Transportation Engineering: Intelligent Transportation Systems.

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 for 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 for 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 for 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 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 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.