Courses primarily for undergraduates:

**C E 105: Introduction to the Civil Engineering Profession**  
(1-0) Cr. 1. F.S.  
Overview of the civil engineering profession in regards to its nature and scope. Exploration of the various specialty areas within civil engineering through team activities. Review and guidance in relation to academic degree options, career avenues and professional practices involving communication, teamwork, leadership, ethics, networking, life-long-learning goals, and mentoring.

**C E 111: Fundamentals of Surveying I**  
(2-3) Cr. 3. F.S.  
Prereq: MATH 165, C E 160, credit or enrollment in C E 170  

**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: Credit or enrollment in MATH 165  

**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  
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. S.  
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 413: Applied and Environmental Geophysics
(Dual-listed with C E 513). (Cross-listed with ENSCI, GEOL). (2-2) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: GEOL 100 or GEOL 201, algebra and trigonometry
Seismic, gravity, magnetic, resistivity, electromagnetic, and ground-penetrating radar techniques for shallow subsurface investigations and imaging. Data interpretation methods. Lab emphasizes computer interpretation packages. Field work with seismic - and resistivity-imaging systems and radar.

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 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: 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 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 439: Seismic Methods in Geology, Engineering, and Petroleum Exploration
(Dual-listed with C E 539). (Cross-listed with GEOL). (2-2) Cr. 3. Alt. S., offered even-numbered years.
Prereq: GEOL 100 or GEOL 201, algebra and trigonometry
Physics of elastic-wave propagation. Seismic surveys in environmental imaging, engineering, and petroleum exploration. Reflection and refraction techniques. Data collection, processing, and geological interpretation. Field work with state-of-the-art equipment.

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

C E 449: Structural Health Monitoring
(Dual-listed with C E 549). (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.
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

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

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 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 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, investment levels and overall rating of civil engineering infrastructure systems, including highway, bridge, airport, rail, dam, power and port facilities. Complementary assessment of future civil infrastructure sustainability impacts and challenges in relation to autonomous and electric vehicle development. Overview regarding US and global availability and supply of critical infrastructure commodities (e.g., cement, stone, metals, phosphorus, uranium, etc.). Directed course readings and multiple project/design reports.

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.S.S.
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.S.S.
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, project administration, construction process simulation, quality management, and productivity improvement programs.

C E 503: Construction Finance and Business Management
(3-0) Cr. 3. S.
Prereq: Credit or enrollment in CON E 422 or C E 594A or permission of instructor

C E 505: Design of Construction Systems
(3-0) Cr. 3. F.
Prereq: Credit or enrollment in 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 513: Applied and Environmental Geophysics
(Dual-listed with C E 413). (Cross-listed with ENSCI, GEOL). (2-2) Cr. 3. Alt.
S., offered odd-numbered years.
Prereq: GEOL 100 or GEOL 201, algebra and trigonometry
Seismic, gravity, magnetic, resistivity, electromagnetic, and ground- 
penetrating radar techniques for shallow subsurface investigations 
and imaging. Data interpretation methods. Lab emphasizes computer 
interpretation packages. Field work with seismic - and resistivity-imaging 
systems and radar.

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 equilbria, 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 421 or 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
deflection 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 bendin 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 539: Seismic Methods in Geology, Engineering, and Petroleum
Exploration
(Dual-listed with C E 439). (Cross-listed with GEOL). (2-2) Cr. 3. Alt. S.,
offered even-numbered years.
Prereq: GEOL 100 or GEOL 201, algebra and trigonometry
Physics of elastic-wave propagation. Seismic surveys in environmental
imaging, engineering, and petroleum exploration. Reflection and
refraction techniques. Data collection, processing, and geological
interpretation. Field work with state-of-the-art equipment.

C E 541: Dynamic Analysis of Structures
(3-0) Cr. 3.
Prereq: E M 345 and credit or enrollment in C E 532
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). (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
(2-3) 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

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

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

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 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, investment levels and overall rating of civil engineering infrastructure systems, including highway, bridge, airport, rail, dam, power and port facilities. Complementary assessment of future civil infrastructure sustainability impacts and challenges in relation to autonomous and electric vehicle development. Overview regarding US and global availability and supply of critical infrastructure commodities (e.g., cement, stone, metals, phosphorus, uranium, etc.). Directed course readings and multiple project/design reports.

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. Credit may not be applied for graduation for Construction Engineering undergraduate students.

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: Spl Topics Construction Engr and Mgt.: Adv Building Construction Topics - LEED for New Construction
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 Building Energy Systems and Technologies
Cr. 3. F.
Prereq: CON E 352 or graduate standing or permission of instructor
Studies in advanced building technologies including building energy modeling, building energy performance and efficiency assessments, and demand side management for smart grid applications.

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 qualitative research methods to assess and solve 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 quantitative research methods to assess and solve 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 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 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.S.S.
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*