CIVIL ENGINEERING (C E)

Courses primarily for undergraduates:

C E 105: Introduction to the Civil Engineering Profession
(1-0) Cr. 1. F.S.
Overview of the nature and scope of the civil engineering profession. Exploration of the various specialty areas within civil engineering. Bloom’s Taxonomy and creativity. Departmental rules, student services operations, degree requirements, educational objectives, program of study planning, career options, and student organizations.

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

C E 120: Civil Engineering Learning Community
Cr. R. Repeatable.
Integration of first-year students into the Civil Engineering program. Assignments and activities involving teamwork, academic preparation, study skills, and preparation for entry into the Civil Engineering profession. Completed both individually and in learning teams under the direction of faculty and peer mentors. Offered on a satisfactory-fail basis only.

C E 160: Engineering Problems with Computational Laboratory
(2-2) Cr. 3. F.S.
Prereq: MATH 143 or satisfactory scores on mathematics placement examinations; credit or enrollment in MATH 165
Formulation of engineering problems using spreadsheets and Visual Basic for Application for solution. Presenting results using word processing, tables, and graphs. Introduction to engineering economics and statics. Civil engineering applications.

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 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
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
(2-2) 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 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. 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  
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: 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.

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 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).

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 417: Land Surveying  
(2-3) Cr. 3. S.  
Prereq: C E 111  
Legal principles affecting the determination of land boundaries, public domain survey systems. Locating sequential and simultaneous conveyances. Record research, plat preparation, and land description. Study of selected court cases.

C E 420: Environmental Engineering Chemistry  
(Dual-listed with C E 520). (Cross-listed with ENSCI). (2-3) Cr. 3. F.  
Prereq: C E 326, CHEM 178  
Principles of chemical and physical phenomena applicable to the treatment of water and wastewater and natural waters; including chemical equilibria, reaction kinetics, acid-base equilibria, chemical precipitation, redox reactions, and mass transfer principles. Individual laboratory practicals and group projects required.

C E 421: Environmental Biotechnology  
(Dual-listed with C E 521). (2-2) Cr. 3. F.  
Prereq: C E 326  
Fundamentals of biochemical and microbial processes applied to environmental engineering processes, role of microorganisms in wastewater treatment and bioremediation, bioenergetics and kinetics, metabolism of xenobiotic compounds, waterborne pathogens and parasites, and disinfection. Term paper and oral presentation.

C E 424: Air Pollution  
(Dual-listed with C E 524). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.  
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above  
1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

C E 424A: Air Pollution: Air quality and effects of pollutants  
(Dual-listed with C E 524A). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.  
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above  
1 cr. per module. Module A prereq for all modules; module B prereq for D and E.
C E 424B: Air Pollution: Climate change and causes
(Dual-listed with C E 524B). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in
statistics. Senior classification or above
1 cr. per module. Module A prereq for all modules; module B prereq for D
and E.

C E 424C: Air Pollution: Transportation Air Quality
(Dual-listed with C E 524C). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.
Prereq: C E 524A; PHYS 221 or CHEM 178; MATH 166 or 3 credits in
statistics. Senior classification or above.

C E 424D: Air Pollution: Off-gas treatment technology
(Dual-listed with C E 524D). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.
Prereq: 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 436: Masonry and Timber Design
(Dual-listed with C E 536). (2-2) Cr. 3.
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.

C E 440: Bioprocessing and Bioproducts
(Dual-listed with C E 540). (Cross-listed with FS HN). (3-0) Cr. 3. F.
Prereq: C E 326 or equivalent, MATH 160 or MATH 165, CHEM 167 or higher,
BIOL 173 or BIOL 211 or higher, senior or graduate classification
Sustainability, cleaner production. Taxonomy, kinetics, metabolism,
microbial cultivation, aerobic and anaerobic fermentation. Antibiotics,
food supplements, fermented foods, vitamin production. Biofuels,
bioenergy and coproducts. Mass/energy balances, process integration,
pretreatment, separation. Membrane reactors, bioelectrolysis, microbial
fuel cells, nanotechnology, genetic engineering, mutagenesis.

C E 446: Bridge Design
(Dual-listed with C E 546). (2-2) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: C E 333, C E 334
Bridge design in structural steel and reinforced concrete. Application of
AASHTO Bridge Design Specifications. Analysis techniques for
complex structures. Preliminary designs include investigating alternative
structural systems and materials. Final designs include preparation of
design calculations and sketches.

C E 448: Building Design
(Dual-listed with C E 548). (2-2) Cr. 3. Alt. S., offered even-numbered
years.
Prereq: C E 333, C E 334
Building design in structural steel and reinforced concrete. Investigation
of structural behavior. Gravity and lateral load resisting systems.
Application of current building codes and design specifications. In-
depth analysis of gravity and wind loads on buildings. Review of building
designs. Preliminary designs include investigating alternative structural
systems. Approximate methods of structural analysis for gravity and
lateral loads. Final designs include preparation of design calculations and
sketches.

C E 449: Structural Health Monitoring
(Dual-listed with C E 549). (Cross-listed with MAT E). (3-0) Cr. 3.
Prereq: Senior classification in Engineering or permission of instructor
Introductory and advanced topics in structural health monitoring (SHM)
of aeronautical, civil, and mechanical systems. Topics include sensors,
signal processing in time and frequency domains, data acquisition and
transmission systems, design of integrated SHM solutions, nondestructive
evaluation techniques, feature extraction methods, and cutting edge
research in the field of SHM. Graduate students will have a supervisory
role to assist students in 449 and an additional design project or more in-
depth analysis and design.

C E 451: Urban Transportation Planning Models
(Dual-listed with C E 551). (3-0) Cr. 3. F.
Prereq: C E 355, STAT 101 or STAT 105
Urban transportation planning context and process. Project planning
and programming. Congestion, mitigation, and air quality issues.
Transportation data sources. Travel demand and network modeling.
Use of popular travel demand software and applications of geographic
information systems.

C E 453: Highway Design
(2-2) Cr. 3. F.S.
Prereq: C E 306, C E 355
Introduction to highway planning and design. Design, construction,
and maintenance of highway facilities. Level-of-service, stopping sight
distance, highway alignment, earthwork and pavement design. Design
project, oral reports and written reports. Computer applications.

C E 460: Foundation Engineering
(3-0) Cr. 3. F.S.
Prereq: C E 360
Fundamentals of foundation engineering. Exploration, sampling, and
in-situ tests. Shallow and deep foundations. Settlement and bearing
capacity analyses. Stability of excavations and earth retaining structures.

C E 467: Geomaterials Stabilization
(Dual-listed with C E 567). (2-2) Cr. 3. S.
Prereq: C E 360, C E 382 or C E 383
Soil and aggregate physical, chemical and biological stabilization
procedures. Stabilization analysis and design. Ground modification and
compaction methods. Geosynthetics application and design.

C E 473: Groundwater Hydrology
(Dual-listed with C E 573). (3-0) Cr. 3. F.
Prereq: C E 372
Principles of groundwater flow, hydraulics of wells, superposition, slug
and pumping tests, streamlines and flownets, and regional groundwater
assignments required for graduate students.
C E 483: Pavement Analysis and Design
(Dual-listed with C E 583). (3-0) Cr. 3. S.
Prereq: C E 360 and C E 382
Analysis, behavior, performance, and structural design of pavement systems. Topics include climate factors, rehabilitation, life cycle design economics, material and system response, pavement foundations and traffic loadings. Development of models for and analysis of pavement systems. Use of transfer functions relating pavement response to pavement performance. Evaluation and application of current and evolving pavement design practices and procedures. Mechanistic-based pavement design techniques and concepts. Analysis of the effects of maintenance activities on pavement performance and economic evaluation of pavement systems.

C E 484: Advanced Design of Concretes
(Dual-listed with C E 584). (2-2) Cr. 3.
Prereq: C E 382
Asphalt binder characterization, fundamentals of asphalt rheology, asphalt materials behavior under loading and temperature effects. High-strength, light-weight, 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 306, C E 326, C E 333 or C E 334, C E 355, C E 360, C E 372, C E 382, SP CM 212. Course enrollment limited to final graduating semester.
The civil engineering design process, interacting with the client, identification of the engineering problems, development of a technical proposal, identification of design criteria, cost estimating, planning and scheduling, codes and standards, development of feasible alternatives, selection of best alternative, and oral presentation.

C E 488: Sustainable Horizontal Civil Infrastructure Systems
(Dual-listed with C E 588). (3-0) Cr. 3. F.
Prereq: Junior or higher classification in engineering of science
Sustainable planning, life cycle analysis, appropriate engineering design, and overall rating assessment of horizontal civil infrastructure (i.e., versus ‘vertical building’) systems, including highway, bridge, airport, rail, and port facilities. Course readings and final project/design report.

C E 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.

C E 498: Cooperative Education
Cr. R. Repeatable. F.S.S.S.
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: Credit or enrollment in CON E 422 or C E 306
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.
Prereq: Credit or enrollment in CON E 422
Application of engineering and management control techniques to complex construction projects. Construction project control techniques, stochastic estimating and scheduling, equipment selection and utilization, project administration, construction process simulation, Quality Management, and productivity improvement programs.

C E 503: Construction Finance and Business Management
(3-0) Cr. 3.
Prereq: Credit or enrollment in CON E 422

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 422
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 422, 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 520: Environmental Engineering Chemistry
(Dual-listed with C E 420). (Cross-listed with ENSCI). (2-3) Cr. 3. F.
Prereq: C E 326, CHEM 178
Principles of chemical and physical phenomena applicable to the treatment of water and wastewater and natural waters; including chemical equilibria, reaction kinetics, acid-base equilibria, chemical precipitation, redox reactions, and mass transfer principles. Individual laboratory practicals and group projects required.
C E 521: Environmental Biotechnology  
(Dual-listed with C E 421). (Cross-listed with ENSCI). (2-2) Cr. 3. F.  
Prereq: C E 326  
Fundamentals of biochemical and microbial processes applied to  
environmental engineering processes, role of microorganisms in  
wastewater treatment and bioremediation, bioenergetics and kinetics,  
metabolism of xenobiotic compounds, waterborne pathogens and  
parasites, and disinfection. Term paper and oral presentation.

C E 522: Water Pollution Control Processes  
(Cross-listed with ENSCI). (2-2) Cr. 3.  
Prereq: C E 521  
Fundamentals of biochemical processes, aerobic growth in a single  
CSTR, multiple events in complex systems, and techniques for evaluating  
kinetic parameters; unit processes of activated sludge system, attached  
growth systems, stabilization and aerated lagoon systems, biosolids  
digestion and disposal, nutrient removal, and anaerobic treatment  
systems.

C E 523: Physical-Chemical Treatment Process  
(Cross-listed with ENSCI). (2-2) Cr. 3.  
Prereq: C E 520  
Material and energy balances. Principles and design of physical-  
chemical unit processes; including screening, coagulation, flocculation,  
chemical precipitation, sedimentation, filtration, lime softening and  
stabilization, oxidation, adsorption, membrane processes, ion exchange  
and disinfection; recovery of resources from residuals and sludges;  
laboratory exercises and demonstrations; case studies in mineral  
processing and secondary industries.

C E 524: Air Pollution  
(Dual-listed with C E 424). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.  
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in  
statistics. Senior classification or above  
1 cr. per module. Module A prereq for all modules; module B prereq for D  
and E.

C E 524A: Air Pollution: Air quality and effects of pollutants  
(Dual-listed with C E 424A). (Cross-listed with A B E, ENSCI). (1-0) Cr. 1.  
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in  
statistics. Senior classification or above

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

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: 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 528: Solid and Hazardous Waste Management  
(Cross-listed with ENSCI). (3-0) Cr. 3.  
Prereq: C E 326 or background courses in both environmental chemistry and  
microbiology; junior or higher standing  
Evaluation, characterization, assessment, planning and design of solid  
and hazardous waste management systems, regulatory requirements,  
material characterization and collection, minimization and recycling,  
energy and materials recovery, composting, off-gas treatment,  
incineration, stabilization, and landfill design. Design of treatment and  
disposal systems, including physical, chemical, and biological treatment,  
solidification, incineration, secure landfill design, and final disposal site  
closure plus restoration.

C E 532: Structural Analysis II  
(3-0) Cr. 3. F.  
Prereq: C E 332  
Analysis of indeterminate structural problems by the consistent  
deformation and generalized direct displacement methods. Direct  
stiffness method for 2-D frames, grids, 3-D frames. Special topics for the  
stiffness method.

C E 533: Structural Steel Design II  
(3-0) Cr. 3.  
Prereq: C E 333  
Theoretical background and development of AISC Specification  
equations. In-depth analysis and design of tension members, columns,  
beams, beam-columns, and plate girders. Emphasis on Load and  
Resistance Factor Design. Elastic and inelastic buckling of members and  
member elements. Investigation of amplification factors for members  
subject to combined bending and axial load and to combined bending  
and torsion. Effective Length Method and Direct Analysis Method of  
design. Approximate Second-Order Analysis. Biaxial bending. Torsion and  
combined 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 536: Masonry and Timber Design  
(Dual-listed with C E 436). (2-2) Cr. 3.  
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.
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C E 540: Bioprocessing and Bioproducts
(Dual-listed with C E 440). (Cross-listed with BRT, FS HN). (3-0) Cr. 3. F.
Prereq: C E 326 or equivalent, MATH 160 or MATH 165, CHEM 167 or higher,
BIOI 173 or BIOI 211 or higher, senior or graduate classification

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

C E 542: Structural Analysis by Finite Elements
(3-0) Cr. 3. S.
Prereq: C E 532

C E 545: Seismic Design
(3-0) Cr. 3.
Prereq: C E 333, C E 334

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

C E 549: Structural Health Monitoring
(Dual-listed with C E 449). (Cross-listed with M S E). (3-0) Cr. 3.
Prereq: Senior classification in Engineering or permission of instructor
Introductory and advanced topics in structural health monitoring (SHM) of aeronautical, civil, and mechanical systems. Topics include sensors, signal processing in time and frequency domains, data acquisition and transmission systems, design of integrated SHM solutions, nondestructive evaluation techniques, feature extraction methods, and cutting edge research in the field of SHM. Graduate students will have a supervisory role to assist students in 449 and an additional design project or more in-depth analysis and design.

C E 551: Urban Transportation Planning Models
(Dual-listed with C E 451). (3-0) Cr. 3. F.
Prereq: C E 355, STAT 101 or STAT 105
Urban transportation planning context and process. Project planning and programming. Congestion, mitigation, and air quality issues. Transportation data sources. Travel demand and network modeling. Use of popular travel demand software and applications of geographic information systems.

C E 552: Traffic Safety, Operations, and Maintenance
(3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: C E 355
Engineering aspects of highway traffic safety. Reduction of crash incidence and severity through highway design and traffic control. Accident analysis. Safety in highway design, maintenance, and operation.

C E 553: Traffic Engineering
(3-0) Cr. 3. F.
Prereq: C E 355
Driver, pedestrian, and vehicular characteristics. Traffic characteristics; highway capacity; traffic studies and analyses. Principles of traffic control for improved highway traffic service. Application of appropriate computing software and tools.

C E 556: Transportation Data Analysis
(3-0) Cr. 3.
Prereq: C E 355, a Statistics course at the 300 level or higher
Analysis of transportation data, identification of data sources and limitations. Static and dynamic data elements such as infrastructure characteristics, flow and operations-related data elements. Spatial and temporal extents data for planning, design, operations, and management of transportation systems. Summarizing, analyzing, modeling, and interpreting data. Use of information technologies for highways, transit, and aviation systems.

C E 557: Transportation Systems Analysis
(3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: C E 355, 3 credits in statistics or probability
Travel studies and analysis of data. Transportation systems forecasts and analyses. Statewide, regional, and local transportation system planning. Network level systems planning and operations. Optimization of systems.
C E 558: Transportation Systems Development and Management  
(3-0) Cr. 3. Alt. F., offered odd-numbered years.  
*Prereq: C E 355*  
Study of designated problems in traffic engineering, transportation planning, and development. Forecasting and evaluation of social, economic, and environmental impacts of proposed solutions; considerations of alternatives. Formulation of recommendations and publication of a report. Presentation of recommendations in the host community.

C E 559: Transportation Infrastructure/Asset Management  
(3-0) Cr. 3. Alt. F., offered even-numbered years.  
*Prereq: C E 355*  
Engineering management techniques for maintaining and managing infrastructure assets. Systematic approach to management through value engineering, engineering economics, and life cycle cost analysis. Selection and scheduling of maintenance activities. Analysis of network-wide resource needs. Project level analysis.

C E 560: Fundamentals of Soil Mechanics  
(3-0) Cr. 3.  
*Prereq: C E 360*  
Nature of soil deposits, seepage, settlement and secondary compression, consolidation theories and analysis, failure theories, stress paths, introduction to critical state soil mechanics, constitutive models, soil strength under various drainage conditions, liquefaction of soil, pore pressure parameters, selection of soil parameters.

C E 561: Applied Foundation Engineering  
(3-0) Cr. 3.  
*Prereq: C E 460*  
Analysis and design of shallow and deep foundations, lateral earth pressure theories and retaining structures, field investigations, in-situ testing, and foundations on problematic soils. Foundation engineering reports.

C E 562: Site Evaluations for Civil Engineering Projects  
(2-2) Cr. 3. Alt. F., offered even-numbered years.  
*Prereq: C E 360*  
Identification and mapping of engineering soils from airphotos, 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 566: Dynamics of Soils and Foundations  
(3-0) Cr. 3. Alt. F., offered odd-numbered years.  
*Prereq: C E 360, E M 345*  

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: Ground Improvement  
(3-0) Cr. 3. Alt. F., offered odd-numbered years.  
*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 569: 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 ENSECI). (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. Design project.

C E 572: Analysis and Modeling Aquatic Environments
(Cross-listed with ENSECI). (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). (Cross-listed with ENSECI). (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 loads. 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.
Prereq: C E 382
Asphalt binder characterization, fundamentals of asphalt rheology, asphalt materials behavior under loading and temperature effects. High-strength, light-weight, 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 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 588: Sustainable Horizontal Civil Infrastructure Systems
(Dual-listed with C E 488). (3-0) Cr. 3. F.
Prereq: Junior or higher classification in engineering of science
Sustainable planning, life cycle analysis, appropriate engineering design, and overall rating assessment of horizontal civil infrastructure (i.e., versus ‘vertical building’) systems, including highway, bridge, airport, rail, and port facilities. Course readings and final project/design report.

C E 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:
<table>
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Repeatable</th>
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| C E 594B  | Special Topics Construction Engineering and Mgt.: Computer Applications for Planning and Scheduling                      | 1-3     | Repeatable | 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                                                          | 1-3     | Repeatable | 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                                | 1-3     | Repeatable | 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                                                       | 1-3     | Repeatable | 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                              | 1-3     | Repeatable | 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 Engineering and Mgt.: Integration of Planning, Scheduling and Project Controls               | 1-3     | Repeatable | 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 594H  | Special Topics Construction Engineering and Mgt.: Trenchless Technologies                                                 | 1-3     | Repeatable | 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 594I  | Special Topics Construction Engineering and Mgt.: Electrical and Mechanical Construction                                | 1-3     | Repeatable | 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.: Advanced Building Construction Topics                                  | 1-3     | Repeatable | 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.: Design Build Construction                                             | 1-3     | Repeatable | 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.: Industrial Construction                                              | 1-3     | Repeatable | 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.: Highway and Heavy Construction                                       | 1-3     | Repeatable | 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.: Advanced Technologies                                                | 1-3     | Repeatable | 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.: Building Information Modeling                                        | 1-3     | Repeatable | 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  
(1-0) 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 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: 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 assess and solve qualitative construction engineering and management problems.

C E 595B: Research Methods Seminar in Construction Engineering and Management: Quantitative Methods  
(1-0) Cr. 1.  
Prereq: 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 assess and solve quantitative construction engineering and management problems.

C E 595C: Research Methods Seminar in Construction Engineering and Management: Technical Reporting  
(1-0) Cr. 1.  
Prereq: Credit or enrollment in C E 501, C E 502, C E 503, or C E 505 
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 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 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 690: Advanced Topics
Cr. 1-3. Repeatable. F.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