CIVIL, ARCHITECTURAL, AND ENVIRONMENTAL ENGINEERING

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Chair
Paul Anderson

Faculty with Research Interests
For more information regarding faculty visit the Department of Civil, Architectural, and Environmental Engineering website.

The Department of Civil, Architectural, and Environmental Engineering offers graduate instruction in structural engineering, transportation engineering, geotechnical engineering, environmental engineering, public works, construction engineering and management, and architectural engineering. The department maintains relationships with business, industry, and government. An active research program provides highly relevant perspectives on current engineering challenges and issues in the field.

Research Facilities
Research facilities include laboratories devoted to concrete structures, structural models, metal structures, materials, architectural engineering, geotechnical engineering, transportation engineering, construction engineering and management, and environmental engineering.

In addition, faculty and graduate students have access to regional facilities such as the Argonne National Laboratory. Also, the department has a computer-aided engineering and design lab equipped with state-of-the-art hardware and software.

Research Areas
The main research areas in the department are architectural engineering, construction engineering and management, environmental engineering, geotechnical engineering, public works, structural engineering, and transportation engineering.

In architectural engineering, faculty conduct research in the built environment, airflow and thermal modeling, indoor air quality, energy and sustainability, and thermal comfort.

Construction engineering and management research involves construction productivity, scheduling and progress control, dispute resolution, construction company organization, sectorial studies, and project management.

Environmental engineering research areas include air pollution, energy and sustainability, hazardous waste engineering, indoor air quality, and wastewater engineering.

Geotechnical research emphasizes soil mechanics, rock mechanics, engineering geology, earthquake engineering, soil structure, and soil-water interactions.

Research in the public works specialty area includes public policy evaluation, management of engineering operations, maintenance, and rehabilitation and construction of civil infrastructures such as roads, bridges, and traffic safety hardware.

Structural engineering research concentrates on structural dynamics and earthquake resistant design, structural health monitoring, computational mechanics, and bridge engineering.

Transportation engineering research areas include multimodal transportation infrastructure and dynamic traffic network mobility, safety, energy consumption and vehicle emission performance modeling; security, evaluation planning and emergency management; transportation asset management, addressing system integration, risk and uncertainty, and sustainability; and network economics.

Energy/Environment/Economics (E3)
The Energy/Environment/Economics (E3) program was developed to respond to the rapidly changing needs of the energy industry by providing the interdisciplinary research and training required to produce a new breed of engineer—one who specializes in energy technologies and who understands the associated environmental and sustainability issues and economic forces that drive technology choice.
The E3 specialization requires an interdisciplinary thesis in an E3 area of research for M.S. and Ph.D. degrees, and an interdisciplinary graduate project or additional energy and sustainability courses for professional master’s degrees. Graduate students in E3 should also be enrolled in fundamental courses related to the topics of energy, environment, and economics. E3 is designed primarily for students majoring in engineering who are planning careers in energy-related fields. This interdisciplinary training prepares students to be not only creative and expert in a specialized area of energy extraction, conversion, or utilization, but also to possess a broad knowledge base of different energy sources, of sustainability issues related to energy extraction, conversion, and utilization, and of the impact of sustainability principles on the design and operation of energy systems. Furthermore, students will gain sufficient knowledge of sustainability and regulatory issues to enable them to make more viable technology choices.

**Admission Requirements**

**Minimum Cumulative Undergraduate GPA**

3.0/4.0

**Minimum GRE Scores**

- Master's/Master of Science: 292 (quantitative + verbal), 2.5 (analytical writing)
- Ph.D.: 292 (quantitative + verbal), 2.5 (analytical writing)

**Minimum TOEFL Scores**

80/213/80 (internet-based/computer-based/paper-based test scores)

Note: the GRE requirement is waived for master of engineering degree applicants who hold a bachelor of science in a related field from an ABET-accredited university in the U.S. with a minimum GPA of 3.0/4.0.

Meeting the minimum GPA and test score requirements does not guarantee admission. Test scores and GPA are just two of many factors considered.

Admission to graduate degree programs in civil engineering normally requires a bachelor of science degree in civil engineering from an institution accredited by Accreditation Board of Engineering and Technology (ABET). The master’s programs in construction engineering and management and in architectural engineering may also accept a bachelor’s degree in other relevant engineering disciplines, as well as architecture. Students who have completed an accredited program in a related field or in a foreign school may be admitted on a provisional status until any deficiencies in preparation are removed. Architectural engineering students with a previous degree in architecture are typically required to take deficiency courses (e.g. CAE 208, CAE 209).

Admission to graduate degree programs in environmental engineering requires a bachelor’s degree in an appropriate undergraduate field from an accredited institution. Prerequisites for the program are somewhat flexible, but all applicants should have had one year of chemistry and math through differential equations. Qualified applicants with degrees in the life sciences, engineering, and physical sciences will normally be admitted to the program without extensive prerequisites.

Each full-time graduate student is assigned a faculty adviser at the time of initial registration. Part-time or non-degree students who have not been assigned an adviser and who intend to pursue a program toward a degree should contact the department for counseling before registering for courses. Departmental seminars and colloquia (CAE 593) are conducted on a regular basis. All full-time civil and architectural engineering graduate students are expected to register for CAE 593 and attend these seminar meetings regularly for one semester.

**Degree Programs**

- Master of Engineering in Architectural Engineering
- Master of Engineering in Construction Engineering and Management
- Master of Engineering in Environmental Engineering
- Master of Engineering in Geotechnical Engineering
- Master of Engineering in Structural Engineering
- Master of Engineering in Transportation Engineering
- Master of Public Works
- Master of Science in Architectural Engineering
- Master of Science in Civil Engineering with specialization in:
  - Architectural Engineering
  - Construction Engineering and Management
  - Geoenvironmental Engineering
  - Geotechnical Engineering
  - Structural Engineering
Transportation Engineering

- Master of Science in Environmental Engineering
- Doctor of Philosophy in Civil Engineering
- Doctor of Philosophy in Environmental Engineering

Interdisciplinary Programs

- Master of Engineering in Environmental Engineering with Specialization in Energy/Environment/Economics (E3)
- Master of Science in Environmental Engineering with Specialization in Energy/Environment/Economics (E3)
- Doctor of Philosophy in Environmental Engineering with Specialization in Energy/Environment/Economics (E3)

Certificate Program in Architectural Engineering

- Architectural Engineering

Certificate Programs in Civil Engineering

- Construction Management
- Earthquake and Wind Engineering Design
- Infrastructure Engineering and Management
- Transportation Systems Planning

Certificate Programs in Environmental Engineering

- Air Resources
- Hazardous Waste Engineering
- Indoor Air Quality
- Water and Wastewater Treatment
Course Descriptions

CAE 502
Acoustics and Lighting
Lecture: 3 Lab: 0 Credits: 3

CAE 503
Advanced Structural Analysis
Prerequisite(s): CAE 411 with min. grade of C or MMAE 501* with min. grade of C or CAE 514* with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

CAE 506
Seismic Retrofit and Earthquake Hazard Reduction
Prerequisite(s): CAE 529 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 508
Advanced Bridge Engineering
Specifications for bridge design and evaluation. Advanced bridge design and evaluation topics such as design load envelope, seismic load design, bridge condition rating, bridge load rating, and steel bridge fatigue evaluation. Bridge management systems. Life cycle analyses. Use of high performance materials in bridge engineering.
Prerequisite(s): CAE 408 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 510
Dynamics of Fire
Introduction to fire, physics and chemistry, and mass and heat transfer principles, fire fluid mechanic fundamentals, fundamentals and requirements of the burning of materials (gases, liquids, & solids), fire phenomena in enclosures such as pre-flashover and post-flashover.
Lecture: 3 Lab: 0 Credits: 3

CAE 511
Fire Protection of Buildings
Fundamentals of building design for fire and life safety. Emphasis on a systematic design approach. Basic considerations of building codes, fire loading, fire resistance, exit design, protective systems & other fire protection systems. For architects, and engineers not majoring in fire protection and safety engineering.
Lecture: 3 Lab: 0 Credits: 3

CAE 513
Building Science
Study of the physical interaction of climate (humidity, temperature, wind, sun, rain, snow, etc.) and buildings. Topics include psychrometrics, indoor air quality, indoor thermal comfort, heat transfer, air infiltration, solar insolation, and heating and cooling load calculation.
Lecture: 3 Lab: 0 Credits: 3

CAE 514
Mathematical Methods for Structural Engineering
Lecture: 3 Lab: 0 Credits: 3

CAE 515
Building Energy Modeling
Building energy modeling (BEM) is the core of building information modeling (BIM) and sustainable design which are changing the way of architectural design and engineering. This course builds essential knowledge of building performance simulation and provides necessary background to use a building energy simulation software tool. Proven methods for using BEM to deal with such essential building performance and sustainability issues will be presented by using real world examples placing particular emphasis on using BEM-enabled quantitative analysis to evaluate design alternatives for the whole life cycle of a building. Complete with coverage of integrated design and lean construction requirements, this is a valuable course for architects, engineers, and construction professionals involved in energy performance modeling for buildings.
Prerequisite(s): CAE 513 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3
CAE 518
Advanced Reinforced Concrete
Mechanical properties of hardened concrete, including creep phenomena. Ultimate strength of columns, beams and beam-columns. Introduction to limit analysis of frames and yield-line analysis of plates.
Prerequisite(s): CAE 432* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

CAE 520
Buckling of Structures
Prerequisite(s): CAE 431 with min. grade of C and CAE 411 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 522
Structural Model Analysis
Prerequisite(s): CAE 503 with min. grade of C
Lecture: 2 Lab: 2 Credits: 4

CAE 523
Statistical Analysis of Engineering Data
Descriptive statistics and graphs, probability distribution, random sampling, independence, significance tests, design of experiments, regression, time series analysis, statistical process control, and introduction to multivariate analysis.
Lecture: 3 Lab: 0 Credits: 3

CAE 524
Building Enclosure Design
Design of building exteriors, including the control of heat flow, air and moisture penetration, building movements, and deterioration. Study of the principle of rain screen walls and of energy conserving designs. Analytical techniques and building codes are discussed through case studies and design projects.
Prerequisite(s): CAE 513 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 525
Advanced Steel and Composite Structures
Prerequisite(s): CAE 431* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 4 Lab: 0 Credits: 4

CAE 526
Energy Conservation Design in Buildings
Identification of the optimal energy performance achievable with various types of buildings and service systems. Reduction of infiltration. Control systems and strategies to achieve optimal energy performance. Effective utilization of daylight, heat pumps, passive and active solar heaters, heat storage and heat pipes in new and old buildings.
Prerequisite(s): CAE 331 with min. grade of C or CAE 513 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 527
Control of Building Environmental Systems
Prerequisite(s): CAE 513 with min. grade of C or CAE 531 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 529
Dynamics of Structures
Prerequisite(s): CAE 411 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 530
Finite Element Method of Analysis
Advanced and special topics in finite element analysis such as finite element-boundary element method, plates, and shell analysis using finite elements.
Prerequisite(s): CAE 411 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3
CAE 532
Analysis of Plates and Shells
Exact and approximate stress analysis of elastic, isotropic plates of various shapes acted upon by forces in their plane, as well as transverse forces. Stability of plates with various edge conditions, orthotropic plates, elastically supported plates and simple cylinders. Approximate methods such as finite differences, finite elements and the methods of Ritz and Galerkin.
Prerequisite(s): CAE 503 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 533
Theory and Analysis of Thin Shells
Differential geometry of surfaces. Elastic theory of general shells with nonorthogonal curvilinear coordinates. Specialization to cylindrical shells, shells of revolution and translational shells. Exact and approximate solutions applied to the bending membrane theories of thin shells. Approximate methods including finite differences, finite elements and methods associated with Ritz, Galerkin, Puchler and Gaekeler.
Prerequisite(s): CAE 503 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 534
Computational Techniques in Finite Element Analysis
Survey of numerical methods as applied to FEM software. Database management, equation solvers, eigen value routines and schemes for direct integration (both implicit/explicit), all as employed in the development of a finite element program. Topics covered also include band and front minimizers, static and dynamic substructuring via super elements and sensitivity studies. Same as MAE 538.
Prerequisite(s): CAE 530* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

CAE 535
Nonlinear Finite Element Analysis
FEM as applied to nonlinear problems. Contact problems, the mechanics of large deformation, full and updated Lagrange formulations, review of plasticity, solution algorithms, Eulerian approaches, application to FEM to limit analysis. Same as MAE 539.
Prerequisite(s): CAE 442 with min. grade of C or MMAE 501 with min. grade of C or CAE 514 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 537
Homeland Security Concerns in Building Designs
Review of blast effects produced by solid phase weapons and their effects on structures and people. Estimation of the risk of a terrorist attack and the corresponding threat. Review of simplified methods for the analysis and design of structures to meet homeland security concerns and procedures to minimize casualties. Analysis of post event fires and how to prevent them. Review of security measures to minimize the effects of blast on buildings and people.
Lecture: 3 Lab: 0 Credits: 3

CAE 539
Introduction to Geographic Information Systems
Geographic information system (GIS) technology allows users to combine tabular information with maps, creating powerful spatial databases which display and query information in new ways. This course will teach general GIS and GPS skills and concepts, useful to students and practitioners in a variety of disciplines. Students will complete a final GIS project relevant to their field of study. This hands-on class will use ESRI’s ArcView and Spatial Analyst products, as well as Trimble GeocExplorer GPS units.
Lecture: 3 Lab: 0 Credits: 3

CAE 540
Asphalt and Concrete Mix Design
Types of asphalt and physical properties of asphalt. Types of mixes: dense graded, open graded, base courses, and maintenance mixes. Types of pavement structures and hot mix asphalt placement. Aggregate physical properties, tests, and blending. Maintenance and rehabilitation materials. Mixture design procedures, including Marshall and Hveem procedures, and weight-volume relationships. Evaluation of mixture properties, engineering property's importance to performance, resilient modulus, fatigue, and creep testing, and thermal cracking properties. Laboratory included.
Lecture: 2 Lab: 3 Credits: 3

CAE 541
Pavement Evaluation and Management
Pavement management systems (PMS) concepts, network definition, condition survey, pavement condition index (PCI), non-destructive deflection testing (NDT), measurement of roughness and skid resistance, micropaver PMS, PMS implementation, project and network-level management, maintenance alternatives, development of annual and long-range work plans.
Lecture: 3 Lab: 0 Credits: 3

CAE 543
Demand Models for Urban Transportation
Fundamental theory of supply and demand, transportation economics, network equilibrium, land use and transportation equilibrium. Demand models: trip generation, geographical distribution, mode split, route assignment, the direct-demand model and disaggregate-behavioral-demand models. Special properties of models. Relationships among models.
Lecture: 3 Lab: 0 Credits: 3

CAE 544
Urban Transportation Planning
Exploration of the goals of urban transportation. Program planning in relating transportation technology to social, economic, and environmental systems. Systems analysis in forecasting urban land use and travel demand and evaluating alternatives in transportation planning to reach a balance between demand and supply.
Lecture: 4 Lab: 0 Credits: 4

CAE 545
Traffic Operations and Flow Theory
Studies of space and time distribution of speed and other traffic characteristics in the transportation network. Macro, micro, and mesoscopic traffic flow theories. Simulation in traffic networks. Application of flow theories to traffic control and operations.
Lecture: 3 Lab: 0 Credits: 3
CAE 546
Public Transportation Systems
Lecture: 3 Lab: 0 Credits: 3

CAE 547
Advanced Traffic Engineering
Data collection, statistical analysis, and interpretation of traffic information. Advanced traffic engineering topics such as signaling, street-and-highway capacity analysis, and highway safety research.
Lecture: 3 Lab: 0 Credits: 3

CAE 548
Transportation Systems Management
Transportation as a system. Problems of traffic congestion, land use/transportation interaction; intersection control; freeway and arterial incident management; safety considerations; evaluation of strategies; case studies.
Lecture: 3 Lab: 0 Credits: 3

CAE 549
Transportation Economics, Development and Policy
Application of managerial, micro- and macroeconomic concepts to transportation systems. Investment and impact analysis. Transport policy as it relates to social, economic and environmental issues. Legislative actions affecting transport issues.
Lecture: 3 Lab: 0 Credits: 3

CAE 550
Applied Building Energy Modeling
This course introduces students to building energy modeling software and techniques that are widely used in industry applications. The course is practice-oriented and builds upon building energy modeling methods as they are practiced in engineering offices (using IES software). The course centers on the two most common types of energy models in practice: (1) models for LEED and code compliance, and (2) parametric models for evaluating energy conservation measures. During the first half of the course, students will learn modeling methods and assumptions to create an energy model of an actual building project for the LEED Energy and Atmosphere credit with all supporting documents required for LEED submission. In the second half of the course, students will learn to analyze energy conservation measures using parametric energy models. The course will also focus on advanced energy modeling topics, such as modeling HVAC systems and controls, passive techniques, composite fenestration, thermal bridges, thermal mass, and others. At the end of the course, students will have two complete energy models that they can use in their portfolio.
Prerequisite(s): CAE 513 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 551
Prestressed Concrete
Theory and design of prestressed concrete members and structure. Applications to both simple and continuous girder and frames subjected to stationary or moving loads. Prestressed cylindrical shells.
Prerequisite(s): CAE 432* with min. grade of C, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

CAE 553
Measurement and Instrumentation in Architectural Engineering
Hands-on experience with energy and indoor air quality measurements in buildings including experimental design, data analysis, and experimental statistics. Measurements and techniques covered include: thermal performance (e.g., thermal conductivity and resistance, heat flux, and temperature); fluid flows and HVAC characteristics (e.g., velocity, pressure, and airflow); energy performance (e.g., current, voltage, and power draw); whole building diagnostics (e.g., blower door and duct blaster); and indoor air quality (e.g., tracer gas techniques for air exchange, particle measurements, and gas measurements). Course combines lectures and field measurements in buildings on campus.
Prerequisite(s): CAE 513 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 555
Transportation Systems Evaluation
Concepts and principles of transportation economic analysis, transportation costs and benefits, user and nonuser consequences, needs studies, finance and taxation, methods for evaluation of plans and projects, cost-efficiency, cost-effectiveness, environmental impact assessment, and economic development assessment.
Lecture: 3 Lab: 0 Credits: 3

CAE 556
Net Zero Energy Home Design Competition I
This is a project-based course in which students will compete in the Department of Energy's annual Race to Zero home design competition. The goal is for an interdisciplinary team of students to design and provide full documentation for a home that meets the Department of Energy's Zero Energy Ready Home Requirements. Teams are expected to effectively and affordably integrate principles of building science, construction engineering and management, economic analysis, and architectural design in an integrated design process. Teams will be required to submit full sets of plans, drawings, renderings, construction details, and analyses for energy efficiency, costs, and affordability. The competition is designed to provide the next generation of architects, engineers, construction managers, and entrepreneurs with skills and experience to start careers in clean energy and generate creative solutions to real-world problems. CAE 556 is the first course in a two-course series. CAE 556 focuses on aspects of the building design. Priority is given to Architectural Engineering and Architecture majors.
Lecture: 3 Lab: 0 Credits: 3
CAE 557
Net Zero Energy Home Design Competition II
This is a project-based course in which students will compete in the Department of Energy's annual Race to Zero home design competition. The goal is for an interdisciplinary team of students to design and provide full documentation for a home that meets the Department of Energy’s Zero Energy Ready Home Requirements. Teams are expected to effectively and affordably integrate principles of building science, construction engineering and management, economic analysis, and architectural design in an integrated design process. Teams will be required to submit full sets of plans, drawings, renderings, construction details, and analyses for energy efficiency, costs, and affordability. The competition is designed to provide the next generation of architects, engineers, construction managers, and entrepreneurs with skills and experience to start careers in clean energy and generate creative solutions to real-world problems. CAE 557 is the second course of a two-course series. CAE 557 focuses on the final project reporting and submission. Priority is given to Architectural Engineering and Architecture majors.
Prerequisite(s): CAE 556 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 560
Plastic Methods
Prerequisite(s): CAE 431* with min. grade of C and CAE 503* with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 4 Lab: 0 Credits: 4

CAE 561
Structural Reliability and Probabilistic Bases of Design
Fundamentals of probability theory and stochastic processes; statistical analysis of engineering data; probabilistic modeling of structural loads and material properties. Reliability analysis and design of structure, reliability-based design criteria. Evaluation of existing design codes. Safety analysis of structures under fatigue loads. Fault and event tree analysis.
Prerequisite(s): CAE 307 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 562
Engineering Behavior of Soil
Soil mineralogy and soil fabric, soil-water electrolyte system, dispersive clay, stress and strain analyses, elastic equilibrium in soil masses, plastic equilibrium in soil masses, in situ and laboratory stress paths, shear strength of sands and clays, thermal properties of soils, critical state soil mechanics principles, nonlinear pseudo elastic and elastoplastic constitutive models.
Lecture: 4 Lab: 0 Credits: 4

CAE 563
Advanced Soil Mechanics Laboratory
Advanced aspects of soil property measurement with application to design and analysis, system characteristics on soil sediment, pinhole test for identifying dispersive clays, consolidation, triaxial compression and triaxial extension with porewater measurement, cyclic triaxial test, permeability with back pressure, determination of critical void ratio.
Prerequisite(s): CAE 323 with min. grade of C and CAE 562* with min. grade of C. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 1 Lab: 3 Credits: 1

CAE 564
Design of Foundations, Embankments and Earth Structures
Consolidation phenomena, derivation of bearing capacity equations, beams and slabs on soils, piles and pile groups, compaction, earth pressure theories and pressure in embankment, slope stability analyses, retaining structures, embankment design, soil structure interaction during excavation, design of anchors for landslide stabilization and retaining structures and instrumentation.
Prerequisite(s): CAE 323 with min. grade of C and CAE 457 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 565
Rock Mechanics and Tunneling
Rock classification for engineering purposes, mechanical behavior of rocks, in situ stresses in rock, stresses around underground openings, rock slope engineering, design of underground structures, design of deep support excavation and tunnels, primary and secondary linings of tunnels, mined shafts, instrumentation.
Prerequisite(s): CAE 457 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4

CAE 566
Earthquake Engineering and Soil Dynamics
Earthquakes and their intensity, influence of group motion, review of I-DOF and M-DOF systems, wave propagation theories, vibration due to blast and shock waves, design earthquake motion, dynamic properties of soils, soil liquefaction, bearing capacity during earthquakes and design of machine foundations, isolation of foundations, pile foundation, and dynamic analysis, earth pressure during earthquakes on retaining structures and embankment.
Prerequisite(s): CAE 323 with min. grade of C and CAE 420 with min. grade of C
Lecture: 4 Lab: 0 Credits: 4
CAE 568  
Transportation Asset Management  
Processes and techniques for managing the preservation and expansion of highway transportation facilities such as pavements, bridges, and traffic control and safety hardware; system usage concerning mobility, safety and security, energy consumption, and vehicle emissions; and economic development impacts. Five component management systems are first examined: pavements, bridges, traffic control and safety hardware, roadway maintenance, safety, and congestion. Finally, the methodology for overall transportation asset management is discussed. The primary emphasis is on data collection, database management, performance modeling, needs assessment, project evaluation, project selection, program development strategies, risk and uncertainty modeling, and institutional issues.  
Lecture: 3 Lab: 0 Credits: 3

CAE 570  
Legal Issues in Civil Engineering  
This course introduces students to the legal aspects of engineering and construction, contract documents, and contract clauses. Upon completion of this course, students will be able to do the following: (1) identify the elements of contract formation; (2) interpret contract clauses; (3) explain the rights and duties of the parties involved in design and construction; and (4) evaluate changes and their root causes. Students will also be able to objectively identify and analyze legal liabilities and the expected professional standard of architects, engineers, and contractors.  
Lecture: 3 Lab: 0 Credits: 3

CAE 571  
Lean Construction and Control  
This course introduces students to lean principles and the lean project delivery system (LPDS) applied to the construction industry. Lean construction and lean project delivery embrace concepts and techniques originally conceived in the automobile manufacturing industry and adopted by the construction industry. In the manufacturing sector, lean production has revolutionized product manufacturing, resulting in significant gains in plant productivity, reliability, and reductions in defects. Specific concepts that will be covered in this course include Plan-Do-Check-Act continuous improvement, A3 reporting, value stream mapping, pull systems and pull planning, kanban, 5S, standardization, and the Choosing by Advantages Decisionmaking System.  
Lecture: 3 Lab: 0 Credits: 3

CAE 572  
Construction Cost Accounting and Control  
Lecture: 3 Lab: 0 Credits: 3

CAE 573  
Construction Management with Building Information Modeling  
Fundamentals and practical use of information technologies in the construction industry; basic concepts of building information modeling (BIM); review of software and technology available for BIM; practical use of BIM including design and clash detection; impact of BIM on construction management functions; construction scheduling and sequencing using BIM; cost estimating using BIM; facility management with BIM; integrated approach to navigate BIM as a multi-disciplinary design, analysis, construction, and facility management technology; class exercise to create a BIM model and to use it in scheduling, sequencing, cost estimating, management, and simulation of a construction project.  
Lecture: 3 Lab: 0 Credits: 3

CAE 574  
Economic Decision Analysis in Civil Engineering  
Basic economic concepts including interest calculations, economic comparison of alternatives, replacement decisions, depreciation and depletion, tax considerations, and sensitivity analysis. Evaluation of public projects, the effect of inflation, decision making under risk and/or uncertainty, economic decision models. Case studies from the construction industry.  
Lecture: 3 Lab: 0 Credits: 3

CAE 575  
Systems Analysis in Civil Engineering  
Management and system concepts, linear programming, graphical methods, Simplex, two-phase Simplex, the transportation problem, the assignment problem, integer programming, and sensitivity analysis. System modeling by activity networks; maximal-low flow, longest-path and shortest-path analyses, flow graphs, decision-tree analysis, stochastic-network modeling, queuing systems, and analysis of inventory systems. Case studies from the construction industry.  
Lecture: 3 Lab: 0 Credits: 3

CAE 577  
Construction Equipment Management  
Factors affecting the selection of construction equipment. Descriptions, operating methods, production rates, unit costs related to excavating equipment. Power shovels, draglines, clam shells, and trenching machines. Engineering fundamentals. Moving construction equipment, including trucks, wagons, scrapers, dozers, soil-stabilization and compaction equipment. Belt conveyors, compaction and drilling equipment, pile driving equipment, pumps and crushers.  
Lecture: 3 Lab: 0 Credits: 3
CAE 578  
Construction Claims Management  
This course provides a basic explanation of construction contract claims by types such as delays, acceleration, and scope issues, the underlying legal theories of the contract construction and claims, elements required for each claims type defenses to the claim, prophylactic claims measures. The claims process within the contract and extra-contractual basis’s for claims are examined. Resolution of claims by ADR techniques and the formal litigation process are explained. AIA, AGC, and federal claims provisions are described. In addition to construction contract claims other types of claims associated with construction projects are covered such as Surety bond claims and various insurance claims (CGL, Builder’s Risk, workers comp, etc)  
Prerequisite(s): CAE 473 with min. grade of C  
Lecture: 3 Lab: 0 Credits: 3

CAE 579  
Real Estate Fundamentals for Engineers and Architects  
The objective of this course is to introduce civil engineering students to the real estate process. Students will learn techniques and methodologies for evaluating real estate investment opportunities using engineering economic analysis principles. Students will use Time Value of Money analysis for evaluating real estate transactions, including how to carry out calculations using formulas, financial calculators, and spreadsheets. This course will help civil engineering students learn financial skills that can be applied to professional and personal investment decisions.  
Lecture: 3 Lab: 0 Credits: 3

CAE 580  
Intelligent Transportation Systems  
The concept of intelligent transportation systems (ITS) involves the use of rapidly emerging information and communication technologies in mitigating congestion and attendant problems. A substantial amount of research and development activities have taken place over the last few decades. This course will provide an introduction to the various aspects of ITS and will focus on ITS planning, technology, big data analysis, and evaluation. In addition, such topics as deployment, financing, and management are also discussed. The course will include guest lectures and possibly field visits.  
Lecture: 3 Lab: 0 Credits: 3

CAE 581  
Algorithms in Transportation  
Modeling and analysis of transportation network problems through the design, analysis, and implementation of algorithms. Emphasis on the use of quantitative and qualitative methods of operations research to model system performance. Covers fundamental data structures, complexity analysis, memory management, recursive programs, application of graph theory, and network analysis to transportation problems, analytical formulations, and solution algorithms for origin-destination estimation, static and dynamic traffic assignments, and transportation resource allocation.  
Lecture: 3 Lab: 0 Credits: 3

CAE 582  
Structural Wind and Earthquake Engineering  
Introduction to nature of wind, aerodynamic wind-loading and design. Strong ground motion phenomenon. Investigation of the response of structures to dynamic and pseudo dynamic wind, earthquake, shock waves and other deterministic and probabilistic loadings. Design criteria for buildings and nuclear power stations, special topics in lifeline earthquake engineering.  
Prerequisite(s): CAE 529 with min. grade of C  
Lecture: 4 Lab: 0 Credits: 4

CAE 583  
Performance-Based Structural and Seismic Design of Buildings and Bridges  
This course covers performance-based structural and seismic design (PBSSD) for buildings and bridges. The course will begin with brief reviewing and critical discussion on conventional code-based seismic design followed by the development of the concept and applicability of this new alternative and advanced PBSSD. Computer methods in linear dynamic, nonlinear static, and dynamic analyses will be surveyed and discussed as primary tools in PBSSD. Ample case studies from real-world projects are carried out throughout the course. These case studies include the PBSSD of special structures, tall buildings, and those that building code-based design is not applicable.  
Prerequisite(s): CAE 529 with min. grade of C  
Lecture: 3 Lab: 0 Credits: 3

CAE 584  
Stormwater Management  
Basic principles of storm water management; hydrology and hydraulics of excess water; excess water management and design; sewer system design and management, storm water detention systems; flood plain system design; risk based design of drainage systems; practical and case study problems.  
Prerequisite(s): CAE 301 with min. grade of C  
Lecture: 3 Lab: 0 Credits: 3

CAE 586  
Seismic Design of Building and Bridge Structures  
The course covers six topics, as listed in the course outline, on seismic design of steel and R/C building structures and bridges. In addition to offer fundamentals and experiences in seismic design through design examples, it is also assumed that structural engineers who are preparing for their Structural Engineer License Exam might find extremely helpful.  
Prerequisite(s): CAE 431 with min. grade of C and CAE 432 with min. grade of C  
Lecture: 3 Lab: 0 Credits: 3

CAE 589  
Groundwater Hydrology and Sampling  
Lecture: 3 Lab: 0 Credits: 3
CAE 590
Geotechnical Landfill Design and Maintenance
Regulatory and legal issues, site selection and assessment, geotechnical-subsurface investigation, clay mineralogy and clay-water-electrolyte system, linear and leachate-control-systems design, stability of landfill slopes, cover design, construction and operation, final use and remediation design.
Prerequisite(s): CAE 323 with min. grade of C
Lecture: 3 Lab: 0 Credits: 3

CAE 591
Research and Thesis for M.S. Degree
Research and Thesis for M.S. Degree.
Credit: Variable

CAE 593
Civil Engineering Seminar
Reports on current research. Graduate students are expected to register and attend.
Lecture: 0 Lab: 1 Credits: 0

CAE 594
Research Problems
Credit: Variable

CAE 597
Special Problems
Graduate course work in the problem subject matter. Subject matter will vary with the interests and background of students and instructor. Design or research problems may be assigned from the areas of architectural, construction, geotechnical, geoenvironmental, structural, or transportation engineering.
Credit: Variable

CAE 598
Special Topics
A special topic in civil or architectural engineering at the graduate level.
Credit: Variable

CAE 599
Graduate Workshop
Graduate workshop.
Lecture: 0 Lab: 0 Credits: 0

CAE 691
Research and Thesis for Ph.D. Degree
Research and Thesis for Ph.D. degree.
Credit: Variable

CAE 724
Introduction to Acoustics
This short course provides a brief introduction to the fundamentals of acoustics and the application to product noise prediction and reduction. The first part focuses on fundamentals of acoustics and noise generation. The second part of the course focuses on applied noise control.
Lecture: 2 Lab: 0 Credits: 2

ENGR 595
Product Development for Entrepreneurs
Elements of product development (mechanical and electrical), manufacturing and production planning, supply chain, marketing, product research, and entrepreneurship concepts are taught in this class. In this course, student teams will be required to create a compelling product that has potential to be sold in today's marketplace. They will be required to create functional prototypes of their product for people to use and critique. If successful, students will be allowed to put their product on Kickstarter.com and take orders for delivery after the class is complete while potentially fostering their own business as a result of this course.
Lecture: 3 Lab: 0 Credits: 3

ENGR 596
Practical Engineering Training
This course is a mentored, immersive practical engineering training. Students learn under the direction of professional engineers and practicing engineers by working on real engineering projects. The student will perform hands-on engineering, including learning and developing/applying engineering principles and concepts to complete the project assigned to the student. The student will apply engineering ethics and safety during their practical engineering training. Students will communicate the results of their work in written and oral communications. Students will receive assignments of varying complexity consistent with their graduate standing.
Lecture: 0 Lab: 9 Credits: 3

ENGR 598
Technological Entrepreneurship in Drug Development: Pharmaceutical Entrepreneurship
This course will give students an understanding of what is involved in technology commercialization, development of a business plan, and understand/experience what it is like working for a startup company by working on a real life project. Students from various educational fields (engineering, business, biology, chemistry, industrial technology/management) are welcome to be a part of a cross functional team that will participate in the National Institute of Health (NIH) Startup Challenge Business Plan Competition. Students will understand how to translate an idea to a business and also experience what it is like to work in a startup company in the field of engineering, science, and technology. Students will also gain an understanding of what it takes to bring a drug to the market. Furthermore, students will get the opportunity to obtain guidance on the business from expert advisors from the pharmaceutical industry, entrepreneurs, and venture capitalists. Permission of the instructor is required.
Lecture: 3 Lab: 0 Credits: 3

ENGR 599
Graduate Research Immersion: Individual
This course provides a faculty-mentored immersive research experience. Research topics are determined by the faculty mentor's area of research. In addition to the mentored research, students participate in seminars, prepare a written report of their research findings, and present their research findings at a poster expo.
Lecture: 3 Lab: 0 Credits: 3
ENVE 501
Environmental Chemistry
Chemical processes in environmental systems with an emphasis on equilibrium conditions in aquatic systems. Processes examined include acid-base, dissolution precipitation, air-water exchange, and oxidation-reduction reactions. Methods presented for describing chemical speciation include analytical and graphical techniques as well as computer models.
Lecture: 3 Lab: 0 Credits: 3

ENVE 506
Chemodynamics
Processes that determine the fate and transport of contaminants in the environment. Upon successful completion of this course, students should be able to formulate creative, comprehensive solutions to transport problems, critically evaluate proposed solutions to transport problems, and acquire and integrate new information to build on these fundamentals.
Lecture: 3 Lab: 0 Credits: 3

ENVE 513
Biotechnological Processes in Environmental Engineering
Fundamentals and applications of biological mixed culture processes for air, water, wastewater, and hazardous waste treatment. Topics include biochemical reactions, stoichiometry, enzyme and microbial kinetics, detoxification of toxic chemicals, and suspended growth and attached growth treatment processes. The processes discussed include activated sludge process and its modifications, biofilm processes including trickling filters and biofilters, nitrogen and phosphorous removal processes, sludge treatment processes including mesophilic and thermophilic systems, and natural systems including wetlands and lagoons.
Lecture: 3 Lab: 0 Credits: 3

ENVE 528
Modeling of Environmental Systems
To introduce students to mathematical modeling as a basic tool for problem solving in engineering and research. Environmental problems will be used as examples to illustrate the procedures of model development, solution techniques, and computer programming. These models will then be used to demonstrate the application of the models including simulation, parameter estimation, and experimental design. The goal is to show that mathematical modeling is not only a useful tool but also an integral part of process engineering.
Lecture: 3 Lab: 0 Credits: 3

ENVE 542
Physiochemical Processes in Environmental Engineering
Fundamentals and applications of physicochemical processes used in air, water, wastewater, and hazardous waste treatment systems. Topics include reaction kinetics and reactors, particle characterization, coagulation and flocculation, sedimentation, filtration, membrane separation, adsorption, and absorption.
Lecture: 3 Lab: 0 Credits: 3

ENVE 551
Industrial Waste Treatment
Industrial waste sources and characteristics, significance of industrial waste as environmental pollutants; applications of standard and special treatment processes including physical, chemical, and biological systems. Prerequisite(s): ENVE 513* or ENVE 542*. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

ENVE 551*
Industrial Waste Treatment
Industrial waste sources and characteristics, significance of industrial waste as environmental pollutants; applications of standard and special treatment processes including physical, chemical, and biological systems. Prerequisite(s): ENVE 513* or ENVE 542*. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

ENVE 561
Design of Environmental Engineering Processes
Design of water and wastewater treatment systems. System economics and optimal design principles. Prerequisite(s): ENVE 513* or ENVE 542*. An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3

ENVE 570
Air Pollution Meteorology
Physical processes associated with the dispersion of windborne materials from industrial and other sources. Atmospheric motion including turbulence and diffusion, mathematical models, and environmental impact assessment.
Lecture: 3 Lab: 0 Credits: 3

ENVE 576
Indoor Air Pollution
Indoor air pollution sources, indoor pollutant levels, monitoring instruments and designs, and indoor pollution control strategies; source control, control equipment and ventilation; energy conservation and indoor air pollution; exposure studies and population time budgets; effects of indoor air population; risk analysis; models for predicting source emission rates and their impact on indoor air environments.
Lecture: 3 Lab: 0 Credits: 3

ENVE 577
Design of Air Pollution Control Devices
Principles and modern practices employed in the design of engineering systems for the removal of pollutants. Design of control devices based on physical and chemical characteristics of polluted gas streams.
Lecture: 3 Lab: 0 Credits: 3

ENVE 578
Physical and Chemical Processes for Industrial Gas Cleaning
Application of physical and chemical processes in the design of air treatment systems; fundamentals of standard and special treatment processes.
Lecture: 3 Lab: 0 Credits: 3

ENVE 580
Hazardous Waste Engineering
Sources and characteristics of hazardous wastes, legal aspects of hazardous waste management, significance of hazardous wastes as air, water, and soil pollutants. Principles and applications of conventional and specialized hazardous waste control technologies. Prerequisite(s): ENVE 506*, An asterisk (*) designates a course which may be taken concurrently.
Lecture: 3 Lab: 0 Credits: 3
ENVE 590
Environmental Engineering Seminar
Current topics in environmental engineering featuring presentations by practitioners from a range of institutions such as academia, industry, consulting, research laboratories, or government.
Lecture: 0 Lab: 1 Credits: 0

ENVE 591
Research and Thesis M.S.
Graduate research.
Credit: Variable

ENVE 597
Special Problems
Independent study and project. (Variable credit)
Credit: Variable

ENVE 691
Research and Thesis Ph.D.
Graduate research.
Credit: Variable