

CIVIL, ARCHITECTURAL, AND ENVIRONMENTAL ENGINEERING

The department offers specialization in architectural engineering, construction engineering management, environmental, geotechnical, materials, structural and water resources engineering. All of the department's programs prepare graduates to provide leadership in their careers by providing a strong foundation in the fundamental and applied engineering principles. Program faculty have diverse backgrounds including civil, environmental, mechanical, aerospace, architectural, and chemical engineering. All programs include strong design and research components, while having the flexibility to tailor curricula to individual needs. Faculty in all programs collaborate extensively with faculty and researchers from other departments, at Missouri S&T and elsewhere. The Civil, Architectural, and Environmental Engineering Department's motto is "Change the World," and through our cutting edge educational programs and research, our graduates are well prepared to meet that goal.

Recent and ongoing funded graduate student research includes: advanced infrastructure materials, natural hazard mitigation for structures, smart cities, river mechanics, constitutive modeling of reinforced and prestressed structures, blast- and impact- protection of critical infrastructure, real-time instrumentation of civil infrastructure, phytoremediation of organic contaminants, aerosol generation and transport, compact low-energy wastewater treatment, green infrastructure, sustainable pavement systems, nanomaterials design and use in infrastructure, durability of concrete, climate adaptation of infrastructure, remote sensing for geo engineering and environmental assessments, and 3D printing of infrastructure materials.

The basic prerequisite for admission to graduate study in the department is a Bachelor of Science degree in Engineering from an ABET accredited school or equivalent. Students who have a degree from a non-accredited school, or hold a Bachelor of Science degree in a field other than engineering, may be required to take engineering prerequisites to prepare for graduate courses. Specific prerequisites will depend on the student's academic background and intended area of specialization. Degree programs offered are the master of science in civil engineering (MSCE), master of science in environmental engineering (MSEnVE), the doctor of engineering (DE), and the doctor of philosophy (PhD).

The MS degrees are available on campus online via streaming video for place-bound students. Also, the department offers online graduate certificate programs in contemporary structural engineering, geoenvironmental engineering, infrastructure renewal, and project engineering and construction management. Advanced graduate offerings in advanced materials for sustainable infrastructure, surface water resources, and building systems engineering.

The department is housed in Butler-Carlton Hall, which is also home to outstanding research and teaching facilities, including: the high-bay Structural Engineering Research Laboratory (SERL), the Reese Bituminous Materials Laboratory, the Clayco Advanced Construction and Materials Laboratory (ACML), concrete materials laboratory, System and Process Assessment Research Laboratory (SPAR), geotechnical laboratory, Mathes Environmental Research Laboratories, and water resources laboratory. The Baker Greenhouse is used to study environmental research on plants for controlling groundwater pollution, wetlands and air pollution. All laboratories are equipped with the latest testing, data acquisition and control equipment. The department has its own machine and electronics shops and trained technical staff used for

design, construction and maintenance of specialized mechanical and electronic testing equipment needed to support research and teaching.

The department is also home to the Center for Research in Energy and Environment (CREE), the Wei-Wen Yu Center for Cold-Formed Steel Structures (CCFSS), and is active in three separate University Transportation Centers as well as having active partnerships with the Center for Infrastructure Engineering Studies (CIES), the Center for Intelligent Infrastructure (CII) and the Missouri Local Training and Resource Center (MLTRC).

The mission of the Center for Research in Energy and Environment (CREE) is to establish the infrastructure and coordinated faculty base to conduct a wide range of large-scale externally-funded research initiatives designed to protect public health from emerging contaminants and improve our energy systems from generation to utilization. The center helps a diverse group of researchers from across the university to share resources necessary to tackle national and global energy and environmental challenges.

The Center for Intelligent Infrastructure (CII) aims to transform currently disparate design, construction, and operation phases of cyber-physical infrastructures into an open-source, cloud-based application featuring computer simulations of physical infrastructures overlaid with cyber and social infrastructure. Such a digital infrastructure initiative enables grand-scale fundamental and convergent research on the integrated design-build-operation process of infrastructure.

The Center for Infrastructure Engineering Studies (CIES) is an interdisciplinary research center that provides leadership in research and education aimed at solving the problems affecting the nation's aging infrastructure. CIES seeks to be the primary conduit for communication among faculty members on the Missouri S&T campus interested in infrastructure studies through the following mechanisms: interdisciplinary R&D, student education, technology transfer, preparing major infrastructure proposals.

The University Transportation Center program was established to advance United States technology and expertise in the many disciplines comprising transportation through the mechanisms of education, research, and technology transfer at university-based centers of excellence. The theme of this center is to address national needs in the areas of transportation infrastructure focusing on advanced materials, infrastructure resilience and non-destructive testing (NDT) technologies.

The mission of the Wei-WenYu Center for Cold-Formed Steel Structures Center (CCFSS) is to provide an integrated approach for handling research, teaching, engineering education, technical services, and professional activity. The center brings together the technical resources of interested parties, i.e., university researchers, steel producers, product manufacturers, consultants, building officials, government agencies, and others with a common goal of continued improvement of cold-formed steel design and construction.

The Missouri Local Training and Resource Center (MLTRC) provides a resource center available for use by local agencies throughout the state of Missouri. Its regular activities include the Proactive Training and Customized Transportation Education Programs (PTP and CTEP, respectively), ongoing development of transportation lending and distribution lending libraries, management of MoDOT's Cooperative Purchasing Program, production of a quarterly newsletter, and

functioning as a transportation technical assistance resource for individuals and agencies around the state.

Advanced Materials for Sustainable Infrastructure Certificate

(Offered in Civil Engineering Discipline)

Choose four courses with a minimum of two courses from the first group of courses (advanced construction materials) and remaining courses from the second group of courses (electives).

I. Advanced Construction Material Courses (Choose two courses):

CIV ENG 5112	Bituminous Materials	3
CIV ENG 5113	Composition And Properties Of Concrete	3
CIV ENG 6801	Advanced Concrete Science and Technology	3

II. Related Topics (Choose two courses):

ARCH ENG 5448	Green Engineering: Analysis of Constructed Facilities	3
CIV ENG 5118	Smart Materials And Sensors	3
CIV ENG 5231	Infrastructure Strengthening with Composites	3
MECH ENG 5282	Introduction to Composite Materials & Structures	3

Building Systems Engineering Certificate

(Offered in Civil Engineering discipline)

ENVIRONMENTAL BUILDING SYSTEM COURSES (Choose TWO courses from the following):

ARCH ENG 4800	Principles of HVAC I	3
ARCH ENG 4850	Building Electrical Systems	3
ARCH ENG 5820	Building Lighting Systems	3

CONSTRUCTION BUILDING SYSTEM COURSES (Choose ONE courses from the following):

ARCH ENG 5445	Construction Methods	3
ARCH ENG 5449	Engineering and Construction Contract Specifications	3
CIV ENG 6442	Construction Administration, Planning and Control	3
CIV ENG 6445	Advanced Construction Engineering	3

BUILDING MANAGEMENT COURSES (Choose ONE courses from the following):

ENG MGT 5111	Management for Engineers and Scientists	3
ENG MGT 5210	Economic Decision Analysis	3
ENG MGT 5320	Project Management	3
SYS ENG 5101	System Engineering and Analysis	3

Contemporary Structural Engineering Certificate

Choose one course from each of the following three groups (analysis, design, and structural system) and the fourth course from any of the three groups.

I. Structural Analysis Courses:

CIV ENG 5203/ ARCH ENG 5203	Applied Mechanics In Structural Engineering	
CIV ENG 5205/ ARCH ENG 5205	Structural Analysis II	
CIV ENG 5207/ ARCH ENG 5207	Computer Methods of Structural Analysis	

CIV ENG 5208/ ARCH ENG 5208	Structural Dynamics	
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II. Structural Design Courses:

CIV ENG 5210/ ARCH ENG 5210	Advanced Steel Structures Design	
CIV ENG 5220/ ARCH ENG 5220	Advanced Concrete Structures Design	
CIV ENG 5222/ ARCH ENG 5222	Prestressed Concrete Design	
CIV ENG 5231/ ARCH ENG 5231	Infrastructure Strengthening with Composites	

III. Structural System Courses:

CIV ENG 5206/ ARCH ENG 5206	Low-Rise Building Analysis and Design	
CIV ENG 6213	Advanced Design in Steel and Lightweight Structures	
AERO ENG 5234/ MECH ENG 5234	Stability of Engineering Structures	

IV. Combined Structural Courses:

CIV ENG 5203/ ARCH ENG 5203	Applied Mechanics In Structural Engineering	
CIV ENG 5205/ ARCH ENG 5205	Structural Analysis II	
CIV ENG 5206/ ARCH ENG 5206	Low-Rise Building Analysis and Design	
CIV ENG 5207/ ARCH ENG 5207	Computer Methods of Structural Analysis	
CIV ENG 5208/ ARCH ENG 5208	Structural Dynamics	
CIV ENG 5210/ ARCH ENG 5210	Advanced Steel Structures Design	
CIV ENG 5220/ ARCH ENG 5220	Advanced Concrete Structures Design	
CIV ENG 5222/ ARCH ENG 5222	Prestressed Concrete Design	
CIV ENG 5231/ ARCH ENG 5231	Infrastructure Strengthening with Composites	
CIV ENG 6213	Advanced Design in Steel and Lightweight Structures	
AERO ENG 5234/ MECH ENG 5234	Stability of Engineering Structures	

Geoenvironmental Engineering Certificate

A minimum of two of the following geotechnical courses must be taken:

CIV ENG 5744	Geosynthetics in Engineering	
CIV ENG 5715	Intermediate Soil Mechanics	
CIV ENG 5729	Foundation Engineering II	

A minimum of two of the following environmental courses must be taken:

CIV ENG 5360	Water Resources And Wastewater Engineering	
CIV ENG 5640	Environmental Law And Regulations	
CIV ENG 5630	Remediation of Contaminated Groundwater and Soil	
CIV ENG 5650	Public Health Engineering	
CIV ENG 5670	Solid Waste Management	
CIV ENG 5642	Sustainability, Population, Energy, Water, and Materials	

Geotechnical Earthquake Engineering Certificate

The following courses are required:

CIV ENG 5716	Geotechnical Earthquake Engineering
CIV ENG 6713	Dynamics of Earth Materials

Two of the following three courses are required:

CIV ENG 5715	Intermediate Soil Mechanics
CIV ENG 5729	Foundation Engineering II
CIV ENG 6712	Computer Modeling in Geotechnical Engineering

Infrastructure Renewal Certificate

Two of the following courses are required:

CIV ENG 5231	Infrastructure Strengthening with Composites
AERO ENG 5282	Introduction to Composite Materials & Structures
CIV ENG 5744	Geosynthetics in Engineering

One of the following courses is required:

CIV ENG 5210	Advanced Steel Structures Design
CIV ENG 5220	Advanced Concrete Structures Design
CIV ENG 5222	Prestressed Concrete Design

One of the following courses is required:

CIV ENG 5445	Construction Methods
CIV ENG 5729	Foundation Engineering II
CIV ENG 6205	Structural Dynamics and Earthquake Engineering
AERO ENG 6284	Analysis of Laminated Composite Structures

Project Engineering and Construction Management Certificate

(Offered in both civil engineering and engineering management disciplines)

Two of the following courses are required:

CIV ENG 5445	Construction Methods
CIV ENG 5449	Engineering and Construction Contract Specifications
CIV ENG 6442	Construction Administration, Planning and Control
CIV ENG 6445	Advanced Construction Engineering

Two of the following courses are required:

ENG MGT 5111	Management for Engineers and Scientists
ENG MGT 5210	Economic Decision Analysis
ENG MGT 5320	Project Management
ENG MGT 6323	Global Project Management

Surface Water Resources Certificate

(Offered in Civil Engineering Discipline)

WATER RESOURCES ENGINEERING COURSES (Choose THREE courses from the following):

CIV ENG 5330	Unsteady Flow Hydraulics	3
CIV ENG 5331	Hydraulics Of Open Channels	3
CIV ENG 5338	Hydrologic Engineering	3
CIV ENG 6338	Advanced Hydrology	3
CIV ENG 6340	Urban Hydrology	3

RELATED COURSES (Chose ONE course from the following):

CIV ENG 5605	Environmental Systems Modeling	3
CIV ENG 5642	Sustainability, Population, Energy, Water, and Materials	3

Magdy Abdelrahman, Professor¹

PHD University of Illinois at Urbana-Champaign
Interdisciplinary aspects of asphalt technology, modified asphalt binders, recycled materials in pavement application, infrastructure sustainability of pavement design, materials and performance.

Stuart W Baur, Associate Professor⁴

PHD University of Missouri-Rolla
Integrated building systems, advanced technologies in building systems, green construction, rehabilitation of historic structures, materials and methods of construction.

Joel G Burken, Curators Distinguished Professor^{1,5}

PHD University of Iowa
Phytoremediation of organic contaminants and heavy metals, green infrastructure, remote sensing and computer visualization of plant stress for contaminant delineation and vegetative restoration.

Genda Chen, Professor¹

PHD State University of New York at Buffalo
Infrastructure preservation and resilience, structural health monitoring, structural (robotic) dynamics and control, structural mechanics and deterioration, multi-hazard assessment and mitigation.

Islam El-adaway, Professor¹

PHD Iowa State University
Construction engineering and management, modeling and simulation, sustainable infrastructure management, resilient hazard management, energy management, contractual and dispute management, decision and risk management.

Mohamed Abdelmonem ElGawady, Professor

DE Swiss Federal Institute of Technology
Reinforced concrete and masonry structures, prestressed concrete and masonry, bridges, segmental bridge construction, accelerated bridge construction, earthquake engineering, impact protection devices, tire derived aggregate, geopolymer, rubberized chip seal, rubberized concrete, and sustainable materials.

Dimitri Feys, Associate Professor

PHD Ghent University, Belgium
Behavior of fresh cement-based materials, including mixing and placement, in particular pumping; advanced rheology of cement-based materials, focusing on measurement protocols, interactions with hydration and applications for digital fabrication; rheology of other complex materials and suspensions, and fluid mechanics.

Mark W Fitch, Associate Professor

PHD University of Texas-Austin
Membrane bioreactors, constructed wetlands/biochemical reactors for metals removal, metal immobilization, nutrient removal by floating treatment wetlands in urban waterbodies.

William Gillis, Assistant Teaching Professor^{1,6}

PHD Missouri University of Science and Technology
Building systems, green building design and construction, and building commissioning.

XianBiao Hu, Assistant Professor

PHD University of Arizona
Smart transportation systems, connected and autonomous vehicles, electric vehicles, transportation big data analytics, traffic flow and system modeling.

Kamal Khayat, Professor¹

DE University of California-Berkeley

Advanced cement-based materials, including high-performance concrete and self-consolidating concrete, concrete rheology and repair of infrastructure.

Nicholas Ali Libre, Assistant Teaching Professor

PHD University of Tehran, Iran

Teaching innovations and educational technologies, numerical simulation and computational mechanics, meshfree methods, development and characterization of cement based construction materials for infrastructure systems, additive manufacturing with cement based fiber reinforced composites (FRC).

Jenny Liu, Professor¹

PHD Texas A&M University

Engineering characterization and modeling of civil infrastructure materials, sustainable materials and resilient infrastructure adapting to climate change and extreme events, pavement design, testing, and evaluation, pavement preservation, and non-destructive testing.

Hongyan Ma, Assistant Professor

PHD Hong Kong University of Science and Technology

Future cements, solid waste upcycling, energy storage and massive CO₂ sequestration, smart systems for NDT/E, material characterization, multi-scale modeling (from molecular dynamics to macroscopic FEM) of concrete, and mechanisms and mitigation of concrete deterioration.

Cesar Mendoza, Associate Professor

PHD Colorado State University

Sediment transport, river mechanics, environmental fluid mechanics, hydrodynamics, and mathematical modeling.

John J Myers, Professor¹

PHD University of Texas-Austin

Advanced concrete structural behavior and durability performance (PC and RC) including HPC, HSC, HS-SCC, UHPC, HVFA-SCC and sustainable concretes; development of infrastructure systems and monitoring techniques; fiber-reinforced polymers (FRP) and fiber-reinforced cementitious matrix (FRCM) in structural repair and strengthening applications with an emphasis related to structural behavior, blast resistance, bond, substrate characterization, and durability performance.

Daniel B Oerther, Professor^{1,5}

PHD University of Illinois-Urbana

Environmental biotechnology, urban sustainability, global development, ensuring universal access to water and sanitation, combating the obesity epidemic, and eliminating extreme poverty.

Guney Olgun, Assistant Professor

PHD Virginia Polytechnic Institute and State University

Energy geotechnology, geothermal foundations and shallow geothermal systems, geotechnical earthquake engineering, soil improvement, liquefaction, granular geomechanics, fluvial erosion, and disaster resilience.

William P Schonberg, Professor¹

PHD Northwestern University

Assistant chair for distance education and remote programs; armor/anti-armor, penetration mechanics, spacecraft shielding against meteoroid and orbital debris impacts, hypervelocity impact phenomena, building failure and collapse, design and construction of Moon and Mars habitats.

William Eric Showalter, Teaching Professor^{1,6}

PHD Purdue University

Construction engineering and management, cost effectiveness, sustainable design and construction.

Lesley Haynes Sneed, Associate Professor¹

PHD Purdue University

Reinforced and prestressed concrete structural members and systems, structural models and experimental methods, innovative methods of repair and strengthening of structures subjected to seismic loading or other extreme hazards, evaluation of existing structures, design codes for structural concrete.

Sanjay Tewari, Assistant Teaching Professor

PHD Texas A&M University

Capacitive deionization, electro-kinetics and soil remediation, electro-coagulation, desalination, sustainability, hydrogeology and water quality challenges, GIS applications for climate change and resiliency of infrastructure.

Jeffery S Thomas, Associate Teaching Professor¹

PHD Missouri University of Science & Technology

Mechanical characterization and engineering mechanics.

Jianmin Wang, Professor¹

PHD University of Delaware

Sustainable wastewater treatment and reuse, nanoparticle ecotoxicity, fate and transport of heavy metals in environment.

Yang Wang, Assistant Professor

PHD Washington University, St. Louis

Air quality and monitoring, aerosol instrumentation, climate impact of aerosols, combustion synthesis of nanoparticles, and low-cost air quality sensors.

Chenglin Wu, Assistant Professor

PHD, PHD University of Texas-Austin, Missouri University of Science and Technology

Nano-mechanics, nanomaterials, nanomanufacturing; sensing and energy materials; machine learning assisted material design and characterization; and 3D printing infrastructural materials.

Guirong Yan, Assistant Professor

PHD Harbin Institute of Technology, China

Computational Wind Engineering (CFD simulations of tornadoes and hurricanes); improvement of risk awareness and decision-making of natural hazards through virtual reality animation, social science, psychology and behavior finance; wind hazard mitigation and community resilience by structural health monitoring and condition assessment.

Xiong Zhang, Associate Professor¹

PHD Texas A&M University

Advanced testing techniques for geo-material characterization, modeling of couple hydro-chem-thermo-mechanical behavior of geo-materials, numerical methods and modeling, soil structure interaction, soil stabilization and ground improvement, frozen ground engineering, climatic effects on infrastructure, and remote sensing for geo-engineering applications.

ARCH ENG 5000 Special Problems (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

ARCH ENG 5001 Special Topics (LAB 1.0 and LEC 2.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

ARCH ENG 5203 Applied Mechanics In Structural Engineering (LEC 3.0)

A study of basic relationships involved in the mechanics of structures. Topic include basic elasticity, failure criteria, fundamental theories of bending and buckling of plates and cylindrical shells for practical application in analysis and design of bridge building floors and shell roofs. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Civ Eng 5203).

ARCH ENG 5205 Structural Analysis II (LEC 3.0)

Classical displacement and force methods applied to structures of advanced design. Analysis of indeterminate structures such as continuous beams, arches, cables, and two and three dimensional frames, and trusses. Analysis of indeterminate structures involving temperature and support settlements effects. Prerequisites: Civ Eng 3201 or Arch Eng 3201. (Co-listed with Civ Eng 5205).

ARCH ENG 5206 Low-Rise Building Analysis And Design (LEC 3.0)

Characterization of various design loads, load combinations, general methodology of structural designs against lateral loads, code-oriented design procedures, distribution of lateral loads in structural systems, application of the International Building Code in design of loadbearing wall systems, building frame system and moment-resisting frame systems. Prerequisite: Preceded and/or accompanied by Civ -Arch Eng 3210 or Civ-Arch Eng 3220. (Co-listed with Civ Eng 5206).

ARCH ENG 5207 Computer Methods of Structural Analysis (LEC 3.0)

Force and displacement matrix methods and computer methods applied to structural analysis. Analysis of indeterminate structures such as continuous beams, and two and three dimensional frames and trusses. Analysis of indeterminate structures involving temperature and support settlements effects using computer methods formulation. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Civ Eng 5207).

ARCH ENG 5208 Structural Dynamics (LEC 3.0)

This course deals with fundamental concepts and structural responses under dynamic loads. Hand calculations and computer methods are developed. Specific topics include resonance, beating phenomenon, equation of motion, dynamic properties, frequencies and mode shapes, and modal and Ritz analyses. Prerequisites: Mech Eng 2350 or equivalent; Civ/Arch Eng 3201 or equivalent. (Co-listed with Civ Eng 5208).

ARCH ENG 5210 Advanced Steel Structures Design (LEC 3.0)

The design of structural steel systems into a final integrated structure. Plate girders, composite systems, stability, connections, rigid frames, single and multistory buildings, and similar type problems of interest to the student. Use of the computer as a tool aid in the design will be emphasized. Prerequisite: Arch Eng 3210 with a grade of "C" or better. (Co-listed with Civ Eng 5210).

ARCH ENG 5220 Advanced Concrete Structures Design (LEC 3.0)

The design of structural concrete systems into a final integrated structure. Two-way slabs, long columns, connections, and discontinuity regions, deflections and cracking of beams and slabs, ACI design criteria, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Arch Eng 3220 with a grade of "C" or better. (Co-listed with Civ Eng 5220).

ARCH ENG 5222 Prestressed Concrete Design (LEC 3.0)

Behavior of steel and concrete under sustained load. Analysis and design of pre-tensioned and post-tensioned reinforced concrete members and the combining of such members into an integral structure. Prerequisite: Arch Eng 3220 with a grade of "C" or better. (Co-listed with Civ Eng 5222).

ARCH ENG 5231 Infrastructure Strengthening with Composites (LEC 3.0)

The course presents composite materials and includes principles of reinforcing and strengthening for flexure, shear, and ductility enhancement in buildings and bridges. It covers the design of existing members strengthened with externally bonded laminates and near surface mounted composites. Case studies are discussed. Prerequisites: Arch Eng / Civ Eng 3201, Arch Eng / Civ Eng 3220. (Co-listed with Civ Eng 5231).

ARCH ENG 5260 Analysis And Design Of Wood Structures (LEC 3.0)

A critical review of theory and practice in design of modern wood structures. Effect of plant origin and physical structure of wood on its mechanical strength; fasteners and their significance in design; development of design criteria and their application to plane and three dimensional structures. Prerequisite: Arch Eng 3201 with a grade of "C" or better. (Co-listed with Civ Eng 5260).

ARCH ENG 5270 Structural Masonry Design (LEC 3.0)

Review of the theory and practice of analyzing low-rise masonry structures, materials and assembly types, constructability considerations, structural masonry components, repair and strengthening, and model code requirements to ensure adequate load resisting buildings. Prerequisites: Arch Eng 3201 or Civ Eng 3201. (Co-listed with Civ Eng 5270).

ARCH ENG 5442 Construction Planning and Scheduling Strategies (LEC 3.0)

The goal of this course is to assist participants in gaining an understanding of schedule control techniques and the application of tools such as Primavera Software. Content areas to be addressed include: development of baseline schedules, progress monitoring and updating, recovery schedules, resource application and leveling. Prerequisite: Civ Eng or Arch Eng 4448. (Co-listed with Civ Eng 5442).

ARCH ENG 5445 Construction Methods (LEC 3.0)

Introduction to construction planning selection of equipment and familiarization with standard methods for horizontal and vertical construction. Application of network analysis and schedules to project control. Prerequisite: Arch Eng 4448 with a grade of "C" or better. (Co-listed with Civ Eng 5445).

ARCH ENG 5446 Management Of Construction Costs (LEC 3.0)

Management of construction projects from inception to completion: estimates, role of network preplanning, project monitoring and control. Prerequisite: Arch Eng 4448 with a grade of "C" or better. (Co-listed with Civ Eng 5446).

ARCH ENG 5448 Green Engineering: Analysis of Constructed Facilities (LEC 3.0)

Environmentally sound design and construction practices. Includes design issues, material selection and site issues that can reduce the impact on the environment caused by the construction process. LEED certification covered in depth. Prerequisites: Civ Eng 4448 or Arch Eng 4448; and Junior Standing. (Co-listed with Civ Eng 5448).

ARCH ENG 5449 Engineering and Construction Contract Specifications (LEC 3.0)

Legal and business aspects of contracts and contracting procedure in the construction industry. Topics include formulation of contracts in common law, engineering services contracts, and construction project contract documents and contract administration issues. Prerequisite: Arch Eng 4448 with a grade of "C" or better. (Co-listed with Civ Eng 5449).

ARCH ENG 5642 Sustainability, Population, Energy, Water, and Materials (LEC 3.0)

This course will examine the concepts regarding the continued advancement of humankind while maintaining our ecological niche on earth. Key topics include: population growth, poverty, and impacts of development; energy consumption, sources, storage, conservation and policy; water quality and quantity; materials and building; and policy implications. Prerequisite: Senior or graduate standing. (Co-listed with Env Eng 5642 and Civ Eng 5642).

ARCH ENG 5665 Indoor Air Pollution (LEC 3.0)

By developing a practical understanding of indoor air pollution sources, physics, chemistry and consequences, students will learn how radon, cigarette smoke, VOCs from furnishings, and so forth affect indoor air quality and apply engineering analyses to specify ventilation rates, choose furnishings and minimize occupant exposure to pollutants. Prerequisite: Civ Eng 2601 or Mech Eng 5571 or Graduate Status. (Co-listed with Civ Eng 5665 and Env Eng 5665).

ARCH ENG 5729 Foundation Engineering II (LEC 3.0)

Classical earth pressure theories. Analysis of shallow and deep foundations to include bearing capacity and settlement of footings, rafts, piles, and drilled piers. Analysis of stability and design of retaining walls and anchored bulkheads. Prerequisites: Civ Eng 4729 with a grade of "C" or better. (Co-listed with Civ Eng 5729).

ARCH ENG 5820 Building Lighting Systems (LEC 3.0)

Design and specifications for interior and exterior building illumination systems. Work includes study of applicable NFPA 70 (NEC) and related building codes. Prerequisites: Senior standing and Physics 2135.

ARCH ENG 5850 Residential Renewable Energy Systems (LAB 1.0 and LEC 2.0)

Applications of renewable energy systems for residential use will be covered, including system selection and sizing. Economic and life cycle analysis will be used to evaluate solar, geothermal and wind power systems. Prerequisites: Senior standing and consent of instructor, or Mech Eng 2527 or Civ Eng 3842.

ARCH ENG 6001 Special Topics (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

ARCH ENG 6801 Advanced Concrete Science and Technology (LEC 3.0)

The course covers advanced notions of concrete science and technology. It discusses various aspects related to cement manufacturing, cement hydration and microstructure, use of supplementary cementitious materials and chemical admixtures, rheology and workability, mechanical properties, dimensional stability, durability, and sustainability of concrete. Prerequisites: Civ Eng 5113 or equivalent; or consent of the instructor with Graduate Standing. (Co-listed with Civ Eng 6801).

CIV ENG 5000 Special Problems (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

CIV ENG 5001 Special Topics (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

CIV ENG 5010 Seminar (LEC 1.0)

Discussion of current topics. Prerequisite: Senior standing.

CIV ENG 5070 Teaching Engineering (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Env Eng 5070, Comp Eng 5070, Elec Eng 5070).

CIV ENG 5112 Bituminous Materials (LAB 1.0 and LEC 2.0)

Properties, types, and grades of bituminous materials are presented. Emphasis is placed on usage, distress, surface treatment design, and asphalt concrete mix properties, behavior, design manufacture, and construction. Prerequisite: Preceded or accompanied by Civ Eng 3116.

CIV ENG 5113 Composition And Properties Of Concrete (LEC 3.0)

Properties of plastic and hardened concrete and the influence of cements, aggregates, water and admixtures upon these properties. The microstructure of cement gel and other factors are related to the behavior of hardened concrete under various types of loading and environments, drying shrinkage, creep and relaxation, fatigue, fracture, and durability. Introduction to statistical quality control of concrete production. Prerequisite: Civ Eng 3116 with a grade of "C" or better.

CIV ENG 5117 Asphalt Pavement Design (LEC 3.0)

Structural design of flexible pavements including loading characteristics, properties of pavement components, stress distribution, and the effects of climatic variables on design criteria. Prerequisite: Civ Eng 3116 with a grade of "C" or better.

CIV ENG 5118 Smart Materials And Sensors (LAB 1.0 and LEC 2.0)

Smart structures with fiber reinforced polymer (FRP) composites and advanced sensors. Multidisciplinary topics include characterization, performance, and fabrication of composite structures; fiber optic, resistance, and piezoelectric systems for strain sensing; and applications of smart composite structures. Laboratory and team activities involve manufacturing, measurement systems, instrumented structures, and performance tests on a large-scale smart composite bridge. Prerequisites: Senior Standing and Math 3304. (Co-listed with Aero Eng 5229, Mech Eng 5229 and Elec Eng 5270).

CIV ENG 5156 Pavement Design (LEC 3.0)

Principles of flexible and rigid pavement design including stress analysis, load and environmental effects and material characteristics; Introduction to AASHTO, PCA, AI, FAA, MEPDG, and other design methods; design of overlays and drainage system; pavement performance evaluation and rehabilitation techniques. Prerequisite: Civ Eng 3116 with a grade of "C" or better.

CIV ENG 5203 Applied Mechanics In Structural Engineering (LEC 3.0)

A study of the basic relationships involved in the mechanics of structures. Topics include basic elasticity, failure criteria, fundamental theories of bending and buckling of plates and cylindrical shells for practical application in analysis and design of bridge, building floors, and shell roofs. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Arch Eng 5203).

CIV ENG 5205 Structural Analysis II (LEC 3.0)

Classical displacement and force methods applied to structures of advanced design. Analysis of indeterminate structures such as continuous beams, arches, cables, and two and three dimensional frames, and trusses. Analysis of indeterminate structures involving temperature and support settlements effects. Prerequisites: Civ Eng 3201 or Arch Eng 3201. (Co-listed with Arch Eng 5205).

CIV ENG 5206 Low-Rise Building Analysis and Design (LEC 3.0)

Characterization of various design loads, load combinations, general methodology of structural designs against lateral loads, code-oriented design procedures, distribution of lateral loads in structural systems, application of the International Building Code in design of loadbearing wall systems, building frame system and moment-resisting frame systems. Prerequisite: Preceded and/or accompanied by Civ -Arch Eng 3210 or Civ-Arch Eng 3220. (Co-listed with Arch Eng 5206).

CIV ENG 5207 Computer Methods of Structural Analysis (LEC 3.0)

Force and displacement matrix methods and computer methods applied to structural analysis. Analysis of indeterminate structures such as continuous beams, and two and three dimensional frames and trusses. Analysis of indeterminate structures involving temperature and support settlements effects using computer methods formulation. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Arch Eng 5207).

CIV ENG 5208 Structural Dynamics (LEC 3.0)

This course deals with fundamental concepts and structural responses under dynamic loads. Hand calculations and computer methods are developed. Specific topics include resonance, beating phenomenon, equation of motion, dynamic properties, frequencies and mode shapes, and modal and Ritz analyses. Prerequisites: Mech Eng 2350 or equivalent; Civ/Arch Eng 3201 or equivalent. (Co-listed with Arch Eng 5208).

CIV ENG 5209 Wind Engineering (LEC 3.0)

Introduction of wind engineering to advanced undergraduate and entry-level graduate students through structural engineering and atmospheric science fundamentals. Prerequisites: A grade of "C" or better in Civ Eng 3201. (Co-listed with Arch Eng 5001).

CIV ENG 5210 Advanced Steel Structures Design (LEC 3.0)

The design of structural steel systems into a final integrated structure. Plate girders, composite systems, stability, connections, rigid frames, single and multistory buildings, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Civ Eng 3210 with a grade of "C" or better. (Co-listed with Arch Eng 5210).

CIV ENG 5220 Advanced Concrete Structures Design (LEC 3.0)

The design of structural concrete systems into a final integrated structure. Two-way slabs, long columns, connections, and discontinuity regions, deflections and cracking of beams and slabs, ACI design criteria, and similar type problems of interest to the student. Use of the computer as a tool to aid in the design will be emphasized. Prerequisite: Civ Eng 3220 with a grade of "C" or better. (Co-listed with Arch Eng 5220).

CIV ENG 5222 Prestressed Concrete Design (LEC 3.0)

Behavior of steel and concrete under sustained load. Analysis and design of pre-tensioned and post-tensioned reinforced concrete members and the combining of such members into an integral structure. Prerequisite: Civ Eng 3220 with a grade of "C" or better. (Co-listed with Arch Eng 5222).

CIV ENG 5231 Infrastructure Strengthening with Composites (LEC 3.0)

The course presents composite materials and includes principles of reinforcing and strengthening for flexure, shear, and ductility enhancement in buildings and bridges. It covers the design of existing members strengthened with externally bonded laminates and near surface mounted composites. Case studies are discussed. Prerequisites: Civ Eng / Arch Eng 3201, Civ Eng / Arch Eng 3220. (Co-listed with Arch Eng 5231).

CIV ENG 5250 Air Transportation (LAB 1.0 and LEC 2.0)

Runway configuration, airfield capacity, geometrics and terminal layout and design. Aircraft performance; navigation and air traffic control; airport planning and design; airline operations; aviation systems planning. Prerequisite: Civ Eng 3500 with a grade of "C" or better.

CIV ENG 5260 Analysis And Design Of Wood Structures (LEC 3.0)

A critical review of theory and practice in design of modern wood structures. Effect of plant origin and physical structure of wood on its mechanical strength; fasteners and their significance in design; development of design criteria and their application to plane and three dimensional structures. Prerequisite: Civ Eng 3201 with grade of "C" or better. (Co-listed with Arch Eng 5260).

CIV ENG 5270 Structural Masonry Design (LEC 3.0)

Review of the theory and practice of analyzing low-rise masonry structures, materials and assembly types, constructability considerations, structural masonry components, repair and strengthening, and model code requirements to ensure adequate load resisting buildings.

Prerequisites: Arch Eng 3201 or Civ Eng 3201. (Co-listed with Arch Eng 5270).

CIV ENG 5330 Unsteady Flow Hydraulics (LEC 3.0)

The study of unsteady flow and its effect on closed water systems and in open channels. Prerequisites: Civ Eng 3330 with a grade of "C" or better.

CIV ENG 5331 Hydraulics Of Open Channels (LEC 3.0)

The phenomena accompanying the flow of water in open channels, such as uniform and varied flow, critical conditions, backwater curves, hydraulic jump, hydraulic drop and applications are studied in detail.

Prerequisite: Civ Eng 3330 with a grade of "C" or better.

CIV ENG 5332 Transport Processes in Environmental Flows (LEC 3.0)

Dynamics, mixing and contaminant transport in surface water bodies, including rivers and lakes. Buoyancy modifications to the mixing and dynamics of pollutant discharges and surface water bodies. Transport of sediments. Exchange processes at the air/water and sediment/water interfaces. Prerequisite: At least a "C" in Civ Eng 3330.

CIV ENG 5333 Intermediate Hydraulic Engineering (LEC 3.0)

Application of fluid mechanics principles to the design. Kinematics of fluid motion, conservation of mass, linear and angular momentum, and energy. Requirements for similarity of fluid flow. Introduction to dynamics of fluid flows and viscous incompressible flows. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

CIV ENG 5335 Water Infrastructure Engineering (LAB 1.0 and LEC 2.0)

Fundamental principles underlying comprehensive water infrastructure development; sanitary sewers, sanitary treatment facilities, stormwater sewers, stormwater detention, water power development, and hydraulic structures. The student is responsible for the planning and design of a water infrastructure development project. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

CIV ENG 5337 River Mechanics And Sediment Transport (LEC 3.0)

Formation of rivers and the laws governing river regulation and improvements, including navigation and flood protection. Principles governing sediment transport. Prerequisite: Civ Eng 3330 with a grade of "C" or better.

CIV ENG 5338 Hydrologic Engineering (LEC 3.0)

A study of current up-to-date hydrologic techniques involving design of hydrologic input for bridges, culverts, reservoirs. Techniques involve extreme value statistics, model hydrographs, routing, etc. Prerequisite: Civ Eng 3334 with a grade of "C" or better.

CIV ENG 5360 Water Resources And Wastewater Engineering (LEC 3.0)

Application of engineering principles to the planning and design of multipurpose projects involving water resources development and wastewater collection/treatment/disposal/systems. Latest concepts in engineering analysis are applied to evaluation of alternative solutions. Prerequisites: Civ Eng 3333, 3335, 3615. (Co-listed with Env Eng 5360).

CIV ENG 5404 Legal Aspects Of Boundary Surveying (LEC 3.0)

The U.S. Public Land Survey System (USPLSS): original GLO survey instructions and procedures. Resurveys on the USPLSS law, standards, procedures with emphasis on Missouri. Rights in real property; statute, case and administrative law applied to boundaries. Simultaneous and sequence conveyances. Unwritten rights in real property. Riparian boundaries. Writing and interpreting boundary descriptions. Land surveyor duties and responsibilities. Prerequisite: Civ Eng 2401 with grade of "C" or better.

CIV ENG 5406 Surveying Systems (LEC 3.0)

Celestial observations for azimuths. Introduction to State Plane Coordinate systems. Theory and calculations. Route surveying and geometrics, horizontal, spiral and vertical curves. Surveying aspects of residential and commercial subdivision design: lot layout, rights of way, easements, setbacks, platting, planning and zoning constraints, application of surveying software. Instrumentation: total stations, electronic levels, instrument calibrations. Prerequisite: Civ Eng 2401 with grade of "C" or better.

CIV ENG 5441 Professional Aspects Of Engineering Practice (LEC 3.0)

A study of engineering registration laws, regulations, rules of professional responsibility and standards of practice. Review of causative factors of selected failures and their relationship to professional responsibility. Prerequisite: Senior standing.

CIV ENG 5442 Construction Planning and Scheduling Strategies (LEC 3.0)

The goal of this course is to assist participants in gaining an understanding of schedule control techniques and the application of tools such as Primavera Software. Content areas to be addressed include: development of baseline schedules, progress monitoring and updating, recovery schedules, resource application and leveling. Prerequisite: Civ Eng or Arch Eng 4448. (Co-listed with Arch Eng 5442).

CIV ENG 5445 Construction Methods (LEC 3.0)

Introduction to construction planning, selection of equipment and familiarization with standard methods for horizontal and vertical construction. Application of network analysis and schedules to project control. Prerequisite: Civ Eng 4448 with a grade of "C" or better. (Co-listed with Arch Eng 5445).

CIV ENG 5446 Management Of Construction Costs (LEC 3.0)

Management of construction projects from inception to completion: estimates, role of network preplanning, project monitoring and control. Prerequisites: Civ Eng 4448 with a grade of "C" or better. (Co-listed with Arch Eng 5446).

CIV ENG 5448 Green Engineering: Analysis of Constructed Facilities (LEC 3.0)

Environmentally sound design and construction practices. Includes design issues, material selection and site issues that can reduce the impact on the environment caused by the construction process. LEED certification covered in depth. Prerequisites: Civ Eng 4448 or Arch Eng 4448; and Junior Standing. (Co-listed with Arch Eng 5448).

CIV ENG 5449 Engineering and Construction Contract Specifications (LEC 3.0)

Legal and business aspects of contracts and contracting procedure in the construction industry. Topics include formulation of contracts in common law, engineering services contracts, and construction project contract documents and contract administration issues. Prerequisite: Civ Eng 4448 with a grade of "C" or better. (Co-listed with Arch Eng 5449).

CIV ENG 5451 Information Technology Applications in the Construction Industry (LEC 3.0)

Study of IT in construction industry including building information modeling and mobile sensing. Topics will include: collaborative design, clash detection, level of development, BIM contracts, automated code checking, and finally, information systems specific functions such as estimating, scheduling and cost control, lean, and integrated project delivery. Prerequisites: Civ Eng 2451.

CIV ENG 5452 Pre-Project Planning and Feasibility Studies (LEC 3.0)

Overview of the studies and tools needed to make go-ahead decisions for construction projects including assimilation of client needs, surveys of project area and infrastructure conditions, scope validation, team development, project planning and cost estimation, and financial feasibility. Prerequisites: Civ Eng 4448 or both Eng Mgt 3320 and Eng Mgt 1210.

CIV ENG 5453 Logistics for Construction Industry (LEC 3.0)

Overview of construction site layout, team organization, information flow, and complexities as related to: productivity improvement approaches, data gathering for analysis of construction operations, process innovation, and safety practices. Prerequisites: Civ Eng 4448 or Eng Mgt 3320.

CIV ENG 5454 Construction Technology for High-Rise Buildings (LEC 3.0)

Overview of latest construction practices and processes for high-rise buildings from foundation to roof including advanced methods, materials, equipment and systems used for the construction of high-rise buildings, as well as the associated principles of sustainable construction. Prerequisites: Civ Eng 4448 or Eng Mgt 3320.

CIV ENG 5455 Construction Industry Best Practices (LEC 3.0)

Overview of the best practices developed by the Construction Industry Institute (CII), and how they are implemented by the leading owners and contractors in the construction industry. Guest lecturers include CII staff and visiting industry subject matter experts. Prerequisites: Civ Eng 4448 or Eng Mgt 3320.

CIV ENG 5510 Geometric Design Of Highways (LAB 1.0 and LEC 2.0)

Development and applications of concepts of geometric design for rural and urban highways. Design controls and criteria; elements of design, including sight distance, horizontal and vertical alignment; cross-section elements; highway types; intersection design elements; types of interchanges and interchange design elements; grade separations and clearance; development of visual elements. Prerequisite: Civ Eng 3500 with grade of "C" or better.

CIV ENG 5513 Traffic Engineering (LEC 3.0)

Introduction to multimodal transportation systems and the factors that influence the planning, design, control, operation and safety of the systems will be made. This course will also include the discussion of Intelligence Transportation Systems and how emerging technologies are changing transportation systems. Prerequisite: Civ Eng 3500 with a grade of "C" or better.

CIV ENG 5515 Advanced Traffic Operations and Capacity Analysis (LEC 3.0)

This course will introduce students to advanced traffic operation and capacity analysis as applied to an urban highway network. It will focus on the operations and management of freeway and arterials where a signalized intersection is one of the key elements affecting traffic flow operation and determining highway capacity. Prerequisite: Civ Eng 3500 with a grade of "C" or better.

CIV ENG 5605 Environmental Systems Modeling (LEC 3.0)

Introductory course in modeling environmental systems. Course will focus on contaminant fate and transport in the environment. Models will be developed that will include physical, chemical and biological reactions and processes that impact this fate. Prerequisites: Env Eng/Civ Eng 2601, Env Eng/Civ Eng 2602 and Env Eng/ Civ Eng 3603; or Graduate standing. (Co-listed with Env Eng 5605).

CIV ENG 5619 Environmental Engineering Design (LAB 1.0 and LEC 2.0)

Functional design of water and wastewater facilities and other environmental cleanup systems. Prerequisite: Civ Eng 3615 or Env Eng 3615. (Co-listed with Env Eng 5619).

CIV ENG 5630 Remediation of Contaminated Groundwater and Soil (LAB 1.0 and LEC 2.0)

Course covers current in-situ and ex-situ remediation technologies. Current literature and case studies are utilized to provide the focus for class discussions and projects. Prerequisites: Civ Eng 3615, Geo Eng 5237 or Graduate Standing. (Co-listed with Env Eng 5630).

CIV ENG 5635 Phytoremediation and Natural Treatment Systems: Science and Design (LEC 3.0)

Students learn the scientific basics of chemical transport in soil and groundwater and learn fundamental plant physiology and processes. Students then learn how these processes are utilized in design of phytoremediation and natural treatment systems, including the most up to date literature and design guidance available. Prerequisites: Civ Eng 3615 or Env Eng 3615.(Co-listed with Env Eng 5635).

CIV ENG 5640 Environmental Law And Regulations (LEC 3.0)

This course provides comprehensive coverage of environmental laws and regulations dealing with air, water, wastewater, and other media. The primary focus is permitting, reporting, and compliance protocols. The course topics include U.S. and international legal systems and judicial processes, liability, enforcement, Clean Air Act, Clean Water Act (NPDES permitting), Safe Drinking Water Act, OSGA, TSCA, RCRA, AND CERCLA. Case studies will be emphasized. (Co-listed with Env Eng 5640).

CIV ENG 5642 Sustainability, Population, Energy, Water, and Materials (LEC 3.0)

This course will examine the concepts regarding the continued advancement of humankind while maintaining our ecological niche on earth. Key topics include: population growth, poverty, and impacts of development; energy consumption, sources, storage, conservation and policy; water quality and quantity; materials and building; and policy implications. Prerequisite: Senior or graduate standing. (Co-listed with Env Eng 5642 and Arch Eng 5642).

CIV ENG 5650 Public Health Engineering (LEC 3.0)

A comprehensive course dealing with the environmental aspects of public health. Prerequisite: Civ Eng 2601 with a grade of "C" or better. (Co-listed with Env Eng 5650).

CIV ENG 5660 Introduction To Air Pollution (LEC 3.0)

Introduction to the field of air pollution dealing with sources, effects, federal legislation, transport and dispersion and principles of engineering control. Prerequisite: Civ Eng 3330; or graduate standing. (Co-listed with Env Eng 5660).

CIV ENG 5662 Air Pollution Control Methods (LEC 3.0)

Study of the design principles and application of the state-of-the-art control techniques to gaseous and particulate emissions from fossil fuel combustion, industrial and transportation sources. Prerequisite: Civ Eng 3330; or graduate standing. (Co-listed with Env Eng 5662).

CIV ENG 5665 Indoor Air Pollution (LEC 3.0)

By developing a practical understanding of indoor air pollution sources, physics, chemistry and consequences, students will learn how radon, cigarette smoke, VOCs from furnishings, and so forth affect indoor air quality and apply engineering analyses to specify ventilation rates, choose furnishings and minimize occupant exposure to pollutants. Prerequisite: Civ Eng 2601 or Mech Eng 5571 or Graduate Status. (Co-listed with Env Eng 5665 and Arch Eng 5665).

CIV ENG 5670 Solid Waste Management (LEC 3.0)

A systematic study of the sources, amounts and characteristics of solid wastes and methods used for their collection, reclamation, and ultimate disposal. Prerequisite: Civ Eng 2601 with grade of "C" or better; or graduate standing. (Co-listed with Env Eng 5670).

CIV ENG 5702 Geomatics (LEC 3.0)

Horizontal and vertical geodetic datums and networks. Theory, calculations and applications of State Plane Coordinate Systems. Introduction to Geographic and Land Information Systems: hardware and software issues; data quality and accuracy; resource, environmental, cadastral and governmental applications; databases; GIS/LIS trends. Introduction to Global Positioning Systems (GPS): Project planning, data collection, data processing and network adjustment applications, Kinematic and RealTime GPS applications, hardware and software options and costs. Prerequisite: Civ Eng 2401 with grade of "C" or better.

CIV ENG 5715 Intermediate Soil Mechanics (LEC 3.0)

General principles of soil mechanics and their applications, including mineralogy, soil structure, flow through porous media, shear strength, slope stability and consolidation. Prerequisites: Civ Eng 3715 with grade of "C" or better.

CIV ENG 5716 Geotechnical Earthquake Engineering (LEC 3.0)

Geotechnical earthquake hazards and mitigations, damage to structures, plate tectonics, seismicity, wave propagation, characterization of ground motions, theory of vibrations (1-DOF), effect of local soil conditions on ground response, development of design ground motions, liquefaction, dynamic lateral earth pressures and slope stability/deformation. Prerequisites: Civ Eng 3715 with a grade of "C" or better.

CIV ENG 5729 Foundation Engineering II (LEC 3.0)

Classical earth pressure theories. Analysis of shallow and deep foundations to include bearing capacity and settlement of footings, rafts, piles, and drilled piers. Analysis of stability and design of retaining walls and anchored bulkheads. Prerequisites: Civ Eng 4729 with a grade of "C" or better. (Co-listed with Arch Eng 5729).

CIV ENG 5744 Geosynthetics in Engineering (LEC 3.0)

Geotechnical principles are applied to design of geosynthetic systems for foundation support, earth retention, drainage, and disposal of hazardous conventional wastes. Geosynthetic testing and identification. Emphasis is on design of geosynthetic earth reinforcement, roadway stabilization, filters, and waste containment systems. Prerequisite: Civ Eng 3715 with grade of "C" or better.

CIV ENG 5750 Transportation Applications of Geophysics (LAB 1.0 and LEC 2.0)

Overview of geophysical and non-destructive test methods that are commonly used to investigate transportation structures and their foundations. Emphasis is placed on bridge system substructure, bridge system superstructure, pavement, roadway subsidence, subsurface characterization and vibration measurements. Prerequisite: Junior level standing or higher. (Co-listed with Geo Eng 5761 and Geophys 5761).

CIV ENG 6000 Special Problems (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of instructor required.

CIV ENG 6001 Special Topics (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

CIV ENG 6010 Seminar (RSD 0.0-6.0)

Discussion of current topics.

CIV ENG 6040 Oral Examination (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

CIV ENG 6050 Continuous Registration (IND 1.0)

Doctoral candidates who have completed all requirements for the degree except the dissertation, and are away from the campus must continue to enroll for at least one hour of credit each registration period until the degree is completed. Failure to do so may invalidate the candidacy. Billing will be automatic as will registration upon payment.

CIV ENG 6099 Research (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Consent of instructor required.

CIV ENG 6123 Pavement Management, Evaluation and Rehabilitation (LAB 1.0 and LEC 2.0)

Advanced knowledge of pavement performance; pavement evaluation; implementation of pavement management at network and project levels; maintenance and rehabilitation strategies; life-cycle cost analysis. Prerequisites: Graduate Standing.

CIV ENG 6131 Fundamentals of Rheology & Self Consolidating Concrete (LEC 3.0)

Discuss various rheological testing protocols & models applicable to cement-based materials and present relationships between rheological parameters and workability of grout and concrete. Understand key performance characteristics of specialty concretes, including self-consolidating, underwater, pumped & shotcrete. Prerequisites: Graduate Standing.

CIV ENG 6141 Principles of Rheology (LEC 3.0)

The relation of the flow/deformation behavior of materials (liquids and flowing solids) and their internal structure is studied theoretically. The tools and most common procedures to measure the rheological properties of these materials are introduced and demonstrated. Different applications of rheology are presented and special problems discussed. Prerequisites: Civ Eng 2210 and Civ Eng 3330.

CIV ENG 6201 Analysis And Design Of Plates And Shells I (LEC 3.0)

Fundamental theories of bending and buckling of plates for practical applications in analysis and design of bridge and building floors, highway and airport pavements, and structural plate components. Shell theory with application to tanks, pressure vessels, shell roofs, and folded plate construction. Prerequisite: Preceded or accompanied by Civ Eng 5207.

CIV ENG 6205 Structural Dynamics and Earthquake Engineering (LEC 3.0)

Behavior of structural materials, elements, and systems under earthquake loads; computer methods for response analysis of lumped and distributed mass models, eigensolution techniques, response spectral analysis, design of 2-D and 3-D seismic resistant structures with current design codes. Prerequisite: Civ/Arch Eng 5208 or equivalent.

CIV ENG 6206 Stochastic Theory of Structural Dynamics (LEC 3.0)

Probability theory and application in structural dynamics. Stochastic models for earthquake-induced forces and wind effects on structure. Solutions for linear and nonlinear structures. Reliability-based evaluation of structural performance under random loading. Simulation of stochastic processes. Prerequisites: Math 3304; Mech Eng 5307 or Civ Eng 6205, and Stat 3115.

CIV ENG 6207 Finite Element Application in Structural Design (LEC 3.0)

Concepts of analysis and design. Generalized coordinate models and isoparametric derivations for one, two, and three dimensional elements. Systems with plate and shell elements. Structural instability problems. Elastic and inelastic systems for static and dynamic loads. Studies of computer programs.

CIV ENG 6208 Analysis Of Nonlinear Structures (LEC 3.0)

Inelastic behavior of structural members and connections; formulation of various models for steel and reinforced concrete including elasto-plastic, bilinear, trilinear, Ramberg-Osgood, Cheng-Mertz, and Cheng-Lou; matrix analysis of 2-D and 3-D building structures for geometric and material nonlinearity; dynamic and stability analysis. Prerequisite: Preceded or accompanied by Civ Eng 5207.

CIV ENG 6211 Plastic Analysis And Design Of Metal Structures (LEC 3.0)

Behavior of engineering materials in the inelastic stress range. Analysis and design of elementary structural members and frames.

CIV ENG 6213 Advanced Design in Steel and Lightweight Structures (LEC 3.0)

A critical evaluation of the theories of design and actual behavior of metal components and their connections. The basis of the development of the pertaining codes will be considered. Prerequisite: Preceded or accompanied by Civ Eng 5207.

CIV ENG 6221 Advanced Behavior Of Reinforced And Prestressed Concrete (LEC 3.0)

Behavior of reinforced and prestressed concrete sections, members and wall/shell-type elements subjected to bending, axial load, shear and torsion. Confinement of concrete. Various truss model theories applicable to main members and strut-tie model applicable to disturbed regions, joints, and connections. Prerequisite: Civ Eng 3220 with grade of "C" or better.

CIV ENG 6331 Advanced Hydraulics And Hydraulic Engineering (LEC 3.0)

Studies in the field of hydraulic engineering to fit the needs of a particular student or class. Each student makes a complete design of a hydraulic development in one of the following fields; water power, sanitation, river and harbor projects. Prerequisite: Civ Eng 3330.

CIV ENG 6335 Hydraulic Structures (LEC 3.0)

Gravity, arch, multiple arch, and buttress dams including appurtenances such as spillways, penstocks and gates. Latter part of course is designed to needs of the individual student with applications to river and harbor structures, canal and irrigation structures, and sewage structures. Prerequisites: Civ Eng 3220 and 3330.

CIV ENG 6338 Advanced Hydrology (LEC 3.0)

A study of methods used in modern hydrologic analysis and design. Items of study include hydrography analysis, maximum possible storm, infiltration, design flood determination and project feasibility. Prerequisite: Civ Eng 3333.

CIV ENG 6340 Urban Hydrology (LEC 3.0)

Studies of the influence of urban areas on their hydrology. Special emphasis on the principles of spatially varied unsteady flow. Model hydrographs leading toward determination of design storm flow are utilized to obtain information necessary for design of storm sewers, channels, and hydraulic structures common to urban areas. Prerequisite: Civ Eng 3333.

CIV ENG 6442 Construction Administration, Planning and Control (LEC 3.0)

Study of construction project development and execution, ranging from preliminary engineering to project turnover. Key topics include bidding strategies, quality control, conceptual estimating, scheduling, progress and cost control, value engineering, safety and construction productivity. Prerequisite: Preceded or accompanied by Civ Eng 5445.

CIV ENG 6443 Contract Formulation And Project Delivery Systems (LEC 3.0)

Project life-cycle planning and management. Roles and responsibilities of contract participants. Construction contract formulation. Obtaining work by negotiating and by bidding. Forms and variations of project delivery systems. Prerequisite: Civ Eng 5445 or Civ Eng 5449.

CIV ENG 6445 Advanced Construction Engineering (LEC 3.0)

Study of the temporary structures and plant used in construction. Key topics include legal implications, codes and regulations, falsework, slipforming, bridge construction supports, and protection of adjacent facilities. Prerequisite: Preceded or accompanied by Civ Eng 5445.

CIV ENG 6501 Transportation Planning (LEC 3.0)

Study of urban development, mobility patterns, and the transportation network. Transportation modeling techniques; transportation control plans to improve air quality; consideration of the transportation disadvantaged; transportation planning in smaller cities and rural areas. Access management and site impact analysis of traffic generators. Prerequisite: Civ Eng 5513 or consent of instructor.

CIV ENG 6505 Traffic Modeling and Simulation (LEC 3.0)

Fundamentals of system simulation, components of a simulation model, traffic flow simulation approaches, traffic flow simulation software and their applications, building simulation models, verification and validation of a simulation model, output analysis, variance reduction techniques, role of simulation in Intelligent Transportation Systems (ITS). Prerequisites: Stat 3113, Civ Eng 3500 preceded or accompanied by Civ Eng 5513.

CIV ENG 6509 Traffic Flow Theory and Characteristics (LEC 3.0)

This course will cover advanced theories of traffic flow, traffic flow characteristics, statistical distributions of traffic flow parameters, traffic stream models, car following models, shock wave analysis, queuing analysis, traffic flow models for intersections, traffic simulation. Prerequisites: Preceded or accompanied by Civ Eng 5513, knowledge of statistics, graduate standing or consent of instructor.

CIV ENG 6511 Transportation Systems Analysis (LEC 3.0)

Concepts and principles fundamental to the planning, design, operation, and management of transportation systems using a systems perspective to transportation problems. Concepts from economics, engineering, operations research, management, psychology, and public policy analysis are used throughout. Topics include linear and non-linear programming, dynamic programming, supply-demand microeconomic framework, analysis of transportation demand, system performance, network equilibrium, simulation and associated case studies. Prerequisite: Civ Eng 5513.

CIV ENG 6600 Chemical Principles In Environmental Engineering (LEC 3.0)

The course develops fundamental chemical and physical principles underlying environmental engineering systems including drinking water, groundwater, and wastewater treatment; and natural environmental processes. Topics include adsorption, complex formation, acid-base equilibria, solubility, mass transfer and diffusion, electrochemistry, and chemical kinetics. Prerequisite: Graduate Standing. (Co-listed with Env Eng 6600).

CIV ENG 6601 Biological Principles In Environmental Engineering Systems (LAB 1.0 and LEC 2.0)

Course covers the fundamental biological and biochemical principles involved in natural and engineered biological systems. (Co-listed with Env En 6601).

CIV ENG 6602 Environmental Chemistry (LAB 1.0 and LEC 2.0)

This course covers the fundamental and applied aspects of environmental chemistry including inorganic, organic, and analytical chemical principles. The course emphasizes the aquatic environmental and covers gas laws and solubility, chemical modeling, equilibria, acid-base and complexation relationships, oxidation and photochemical reactions. Prerequisite: Graduate standing in engineering or science curricula. (Co-listed with Env En 6602).

CIV ENG 6608 Environmental Engineering Analysis Laboratory (LAB 2.0 and LEC 1.0)

Environmental Engineering analytical principles and techniques applied to the quantitative measurement of water, wastewater and natural characteristics, and application of advanced instrumentation methods in Environmental Engineering. Prerequisite: Civ Eng 2601 or equivalent, with a grade of "C" or better. (Co-listed with Env Eng 6608).

CIV ENG 6611 Physicochemical Operations In Environmental Engineering Systems (LEC 3.0)

Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption, ion exchange. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Env Eng 6611 and Chem Eng 6330).

CIV ENG 6612 Biological Operations In Environmental Engineering Systems (LEC 3.0)

Course covers biological operations and design in water, wastewater and aqueous hazardous waste treatment systems including modeling of biological treatment processes; and design of activated sludge systems, trickling filters, rotating biological contractors, lagoons, nitrification and denitrification, and digestion processes. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Env Eng 6612).

CIV ENG 6671 Industrial And Hazardous Waste Treatment (LAB 1.0 and LEC 2.0)

Course covers fundamentals of industrial and hazardous wastewater treatment systems and characterization including physical, chemical and biological processes and laboratory pilot plant investigations. (Co-listed with Env En 6671).

CIV ENG 6712 Computer Modeling in Geotechnical Engineering (LEC 3.0)

Survey of computer methods of analyzing and modeling complex geotechnical engineering problems. Computer applications, data analysis, and result interpretations. Topics include constitutive modeling, foundation engineering, seepage, unsaturated flow problem, slope stability analysis, consolidation, excavation, tunneling, and dynamic soil-structure interaction. Prerequisite: Civ Eng 3715 and graduate standing.

CIV ENG 6713 Dynamics of Earth Materials (LEC 3.0)

Theory of vibration, spectral response, site-specific response spectra, detailed design of retaining structures, pile and machine foundations, soil structure interaction. Dynamic soil properties, including degradation of soil properties and liquefaction, seismic slope stability analysis problem solving. Select research topics and use of computer codes. Prerequisite: Preceded or accompanied by Civ Eng 5715.

CIV ENG 6714 Measurement Of Soil Properties (LAB 1.0 and LEC 2.0)

Laboratory determination of soil properties with emphasis on practical. Applications of test data. Tests include classification, atterberg limits, consolidation, compaction, triaxial shear tests with pore pressure measurement, and direct shear tests. Preparation of technical reports. Prerequisites: CIV ENG 3715.

CIV ENG 6715 Advanced Soil Mechanics (LEC 3.0)

Advanced topics and recent advances in theoretical soil mechanics. Topics may include stress distribution, failure theories, shear failure in ideal soils, consolidation and settlement, physico-chemical properties, and clay mineralogy. Prerequisite: Civ Eng 5715.

CIV ENG 6716 Soil Stabilization (LEC 3.0)

The application of mineralogical and physicochemical principles to soil stabilization problems and stabilization techniques for highway and foundation applications. Prerequisite: Civ Eng 5715.

CIV ENG 6717 Earth Dams And Related Problems (LEC 3.0)

The exploration for and selection of site and materials, seepage analysis, slope stability and design, embankment design, compaction, instrumentation and construction operations as they pertain to earth and rockfill dams. Prerequisite: Civ Eng 5715.

CIV ENG 6729 Foundation Engineering III (LEC 3.0)

A critical study of modern concepts of foundation engineering including current procedure for the application of soil mechanics principles to the design of foundations, embankments and retaining structures. Case histories will be emphasized with the student making successive design decisions.

CIV ENG 6760 Inca Civilization Geotechnical Engineering Practices (LEC 3.0)

An in-depth study of geotechnical engineering practices in the mountains of Peru, including the Cuzco-Machu Picchu corridor, with emphasis on the inter-relationships between tectonics, geology, geomorphology, climate, hydrology, agriculture, quarrying, construction practices, irrigation, culture and history. A week-long field trip to Peru during Spring Break is required at student's expense. Prerequisite: Geo Eng 1150 or Civ Eng 3715 or Geo Eng 5471 or equivalent; Graduate standing. (Co-listed with Geo Eng 6407).

CIV ENG 6801 Advanced Concrete Science and Technology (LEC 3.0)

The course covers advanced notions of concrete science and technology. It discusses various aspects related to cement manufacturing, cement hydration and microstructure, use of supplementary cementitious materials and chemical admixtures, rheology and workability, mechanical properties, dimensional stability, durability, and sustainability of concrete. Prerequisites: Civ Eng 5113 or equivalent; or consent of the instructor with Graduate Standing. (Co-listed with Arch Eng 6801).

ENV ENG 5000 Special Problems (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department.

ENV ENG 5001 Special Topics (LAB 0.0 and LEC 0.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

ENV ENG 5070 Teaching Engineering (LEC 3.0)

Introduction to teaching objectives and techniques. Topics include: using course objectives to design a course; communication using traditional and cutting-edge media; textbook selection; assessment of student learning; grading; student learning styles; cooperative/active learning; and student discipline. Prerequisite: Graduate standing. (Co-listed with Eng Mgt 5070, Comp Eng 5070, Elec Eng 5070, Civ Eng 5070).

ENV ENG 5360 Water Resources And Wastewater Engineering (LEC 3.0)

Application of engineering principles to the planning and design of multipurpose projects involving water resources development and wastewater collection/treatment/disposal systems. Latest concepts in engineering analysis are applied to evaluation of alternative solutions. Prerequisites: Civ Eng 3333, 3335, 3615. (Co-listed with Civ Eng 5360).

ENV ENG 5605 Environmental Systems Modeling (LEC 3.0)

Introductory course in modeling environmental systems. Course will focus on contaminant fate and transport in the environment. Models will be developed that will include physical, chemical and biological reactions and processes that impact this fate. Prerequisites: Env Eng/Civ Eng 2601, Env Eng/Civ Eng 2602 and Env Eng/ Civ Eng 3603; or Graduate standing. (Co-listed with Civ Eng 5605).

ENV ENG 5619 Environmental Engineering Design (LAB 1.0 and LEC 2.0)

Functional design of water and wastewater facilities and other environmental cleanup systems. Prerequisite: Civ Eng 3615 or Env Eng 3615. (Co-listed with Civ Eng 5619).

ENV ENG 5630 Remediation of Contaminated Groundwater And Soil (LAB 1.0 and LEC 2.0)

Course covers current in-situ and ex-situ remediation technologies. Current literature and case studies are utilized to provide the focus for class discussions and projects. Prerequisites: Civ Eng 3615, Geo Eng 5237 or Graduate Standing. (Co-listed with Civ Eng 5630).

ENV ENG 5635 Phytoremediation and Natural Treatment Systems: Science and Design (LEC 3.0)

Students learn the scientific basics of chemical transport in soil and groundwater and learn fundamental plant physiology and processes. Students then learn how these processes are utilized in design of phytoremediation and natural treatment systems, including the most up to date literature and design guidance available. Prerequisite: Env Eng 3615 or Civ Eng 3615 or graduate standing. (Co-list with Civ Eng 5635).

ENV ENG 5640 Environmental Law And Regulations (LEC 3.0)

This course provides comprehensive coverage of environmental laws and regulations dealing with air, water, wastewater, and other media. The primary focus is permitting, reporting, and compliance protocols. The course topics include U.S. and international legal systems and judicial processes, liability, enforcement, Clean Air Act, Clean Water Act (NPDES) permitting), Safe Drinking Water Act, OSGA, TSCA, RCRA, and CERCLA. Case studies will be emphasized. (Co-listed with Civ Eng 5640).

ENV ENG 5642 Sustainability, Population, Energy, Water, and Materials (LEC 3.0)

This course will examine the concepts regarding the continued advancement of humankind while maintaining our ecological niche on earth. Key topics include: population growth, poverty, and impacts of development; energy consumption, sources, storage, conservation and policy; water quality and quantity; materials and building; and policy implications. Prerequisite: Senior or graduate standing. (Co-listed with Civ Eng 5642 and Arch Eng 5642).

ENV ENG 5650 Public Health Engineering (LEC 3.0)

A comprehensive course dealing with the environmental aspects of public health. Prerequisite: Civ Eng 2601 with grade of "C" or better. (Co-listed with Civ Eng 5650).

ENV ENG 5660 Introduction To Air Pollution (LEC 3.0)

Introduction to the field of air pollution dealing with sources, effects, federal legislation, transport and dispersion and principles of engineering control. Prerequisite: Civ Eng 3330 or equivalent; or graduate standing. (Co-listed with Civ Eng 5660).

ENV ENG 5662 Air Pollution Control Methods (LEC 3.0)

Study of the design principles and application of the state-of-the-art control techniques to gaseous and particulate emissions from fossil fuel combustion, industrial and transportation sources. Prerequisite: Civ Eng 3330 or equivalent; or graduate standing. (Co-listed with Civ Eng 5662).

ENV ENG 5665 Indoor Air Pollution (LEC 3.0)

By developing a practical understanding of indoor air pollution sources, physics, chemistry and consequences, students will learn how radon, cigarette smoke, VOCs from furnishings, and so forth affect indoor air quality and apply engineering analyses to specify ventilation rates, choose furnishings and minimize occupant exposure to pollutants. Prerequisite: Civ Eng 2601 or Mech Eng 5571 or Graduate Status. (Co-listed with Civ Eng 5665 and Arch Eng 5665).

ENV ENG 5670 Solid Waste Management (LEC 3.0)

A systematic study of the sources, amounts and characteristics of solid wastes and methods used for their collection, reclamation, and ultimate disposal. Prerequisite: Civ Eng 2601 with grade of "C" or better; or graduate standing. (Co-listed with Civ Eng 5670).

ENV ENG 6000 Special Problems (IND 0.0-6.0)

Problems or readings on specific subjects or projects in the department. Consent of the instructor required.

ENV ENG 6001 Special Topics (LEC 0.0-6.0)

This course is designed to give the department an opportunity to test a new course. Variable title.

ENV ENG 6010 Seminar (IND 0.0)

Discussion of current topics.

ENV ENG 6040 Oral Examination (IND 0.0)

After completion of all other program requirements, oral examinations for on-campus M.S./Ph.D. students may be processed during intersession. Off-campus M.S. students must be enrolled in oral examination and must have paid an oral examination fee at the time of the defense/comprehensive examination (oral/ written). All other students must enroll for credit commensurate with uses made of facilities and/or faculties. In no case shall this be for less than three (3) semester hours for resident students.

ENV ENG 6099 Research (IND 0.0-15)

Investigations of an advanced nature leading to the preparation of a thesis or dissertation. Prerequisite: Consent of instructor.

ENV ENG 6600 Chemical Principles In Environmental Engineering (LEC 3.0)

The course develops fundamental chemical and physical principles underlying environmental engineering systems including drinking water, groundwater, and wastewater treatment; and natural environmental processes. Topics include adsorption, complex formation, acid-base equilibria, solubility, mass transfer and diffusion, electrochemistry, and chemical kinetics. Prerequisite: Graduate Standing. (Co-listed with Civ Eng 6600).

ENV ENG 6601 Biological Principles In Environmental Engineering Systems

(LAB 1.0 and LEC 2.0)

Course covers the fundamental biological and biochemical principles involved in natural and engineered biological systems. (Co-listed with Civ Eng 6601).

ENV ENG 6602 Environmental Chemistry (LAB 1.0 and LEC 2.0)

This course covers the fundamental and applied aspects of environmental chemistry including inorganic, organic, and analytical chemical principles. The course emphasizes the aquatic environmental and covers gas laws and solubility, chemical modeling, equilibria, acid-base and complexation relationships, oxidation and photochemical reactions. Prerequisite: Graduate standing in engineering or science curricula. (Co-listed with Civ Eng 6602).

ENV ENG 6608 Environmental Engineering Analysis Laboratory (LAB 2.0 and LEC 1.0)

Environmental Engineering analytical principles and techniques applied to the quantitative measurement of water, wastewater and natural characteristics, and application of advanced instrumentation methods in Environmental Engineering. Prerequisite: Civ Eng 2601 or equivalent, with a grade of "C" or better. (Co-listed with Civ Eng 6608).

ENV ENG 6611 Physicochemical Operations In Environmental Engineering Systems (LEC 3.0)

Course covers physicochemical operations and design in water, wastewater and aqueous hazardous waste treatment systems including coagulation, precipitation, sedimentation, filtration, gas transfer, chemical oxidation and disinfection, adsorption, ion exchange. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Civ Eng 6611 and Chem Eng 6330).

ENV ENG 6612 Biological Operations In Environmental Engineering Systems (LEC 3.0)

Course covers biological operations and design in water, wastewater and aqueous hazardous waste treatment systems including modeling of biological treatment processes; and design of activated sludge systems, trickling filters, rotating biological contractors, lagoons, nitrification and denitrification, and digestion process. Prerequisite: Civ Eng 3330 or equivalent. (Co-listed with Civ Eng 6612).

ENV ENG 6671 Industrial And Hazardous Waste Treatment (LAB 1.0 and LEC 2.0)

Course covers fundamentals of industrial and hazardous wastewater treatment systems and characterization including physical, chemical and biological processes and laboratory pilot plant investigations. (Co-listed with Civ Eng 6671).
