DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Chairman

Dr. Salah U. Al-Dulaijan

Faculty

Al-Abdul Wahhab	Abduljauwad	Ahmadi
Aiban	Al-Amoudi	Al-Attas
Azad	Bader	Baig
Baluch	Bouchama	Bukhari
Chowdhury	Al-Dulaijan	Ebrahim
Essa	Al-Gadhib	Al-Gahtani, A.
Al-Gahtani, H	Al-Ghamdi	Al Hajyaseen
Khathlan	Al-Malack	Al-Ofi
Osta	Ratrout	Al-Senan
Shamshad	Sharif	Al-Shayea
Al-Sughaiyer	Al-Suwaiyan	Vohra
Al-Zahrani, M.A.	Al-Zahrani, M.M.	

The Department of Civil and Environmental Engineering offers graduate programs leading to Master of Science, Master of Engineering and Doctorate Degrees in Civil Engineering in four options: Structural Engineering, Water Resources and Environmental Engineering,
Geotechnical Engineering, and Transportation Engineering.
Research in structures and materials focuses on concrete behavior with a blend of computational and experimental modeling to characterize diversified phenomena such as corrosion, durability modeling, shrinkage, creep, repair and fatigue. Other areas of research include concrete durability; finite element modeling of intact or damaged structures for assessment, strengthening and/or repair, nonlinear finite element analysis of mitered bends, laminated shell elements, steel connections, reinforced concrete and slabs on grade; structural optimization, boundary elements, structural dynamics, and nondestructive testing.
Water-resources projects include recharge problems, groundwater contamination problems and sea water intrusion, numerical techniques, remote sensing applications in water resources, watershed modeling of rain-fall-runoff relationships, evapotranspiration studies in arid zones, and urban hydrology. Research in the environmental engineering area emphasizes petrochemical and hazardous waste treatment, evaluation of wastewater treatment plants, disinfection and biological treatment, removal of viruses through slow sand filtration, and reuse of wastewater effluents for desert greening.
Research in the geotechnical engineering area includes soil-structure interaction, local soil and foundation problems, mineralogy and fabric of soils, constitutive modeling of soils, nonlinear numerical analysis, soil stabilization, soil dynamics and geoenvironment.
Research in transportation includes areas of highway safety, intersection safety, pedestrian safety, signal optimization, intercity transportation demand modeling, disaggregate behavior modeling, pavement materials specification, modification, modeling, analysis and pavement management system, and quality control and quality assurance.

The department has the following laboratories which are all equipped with state of the art equipment:

- Structural Laboratories: Concrete testing laboratory, stress analysis laboratory, structural mechanics laboratory, heavy structures laboratory, building research station, and corrosion laboratory,
- Highway Materials Laboratory,
- Graphics Laboratories,
- Water Resources/Environmental Laboratories: Open channel laboratory, hydraulics laboratory, and environmental and sanitary laboratory,
- Traffic Engineering Laboratory,
- Photogrammetry Laboratory,
- Surveying Laboratory,
- Geotechnical Engineering Laboratory.

Admission Requirements

Admission to the graduate programs requires fulfilling all requirements of the Deanship of Graduate Studies. Graduates in engineering and science from recognized institutions are eligible to apply for admission as regular students in the Master's program. To be considered for admission to the doctoral program, an applicant must hold a Master of

Science degree from a university of recognized standing in Civil Engineering. Holders of Master of Engineering (non-thesis) can be considered with certain deficiency courses.

MASTER OF SCIENCE IN CIVIL ENGINEERING

(STRUCTURES AND CIVIL ENGINEERING MATERIALS)

Degree Requirements

(a) Core Courses (15 credit hours)		Credit Hours
Concrete Materials	CE 501	3
Advanced Structural Analysis and Vibrations	CE 511	3
Advanced Structural Mechanics	CE 510	3
Seminar	CE 599	0
Thesis	CE 610	6

(b) Elective Courses (15 credit hours) **Credit Hours**

	Structures Option	Materials Option	
CE Option Elective I	One of: CE 521, 522, 523		3
CE Option Elective II	From Structural Design/ Mechanics/ Materials		3
Option Elective III	CE 517	CHE 501 or CE 5xx	3
Math Elective	MATH 513	MATH 560	3
Technical Elective	XXX 5xx		3

Degree Plan

COURSE	TITLE	LT	LB	CR	COURSE	TITLE	LT	LB	CR
First Year									
CE 501	Concrete Materials	2	3	3	CE 510	Advanced Structural Mechanics	3	0	3
CE 511	Adv. Structural Analysis and Vibrations	3	0	3	CE 5xx	CE Option Elective I	3	0	3
MATH 5xx	Math Elective	3	0	3	CE 5xx	CE Option Elective II	3	0	3
					CE 599	Seminar	1	0	0
		8	**3**	**9**			**10**	**0**	**9**
Second Year									
XXX 5xx	Option Elective III	3	0	3	XXX 5xx	Technical Elective	3	0	3
CE 610	Thesis	0	0	IP	CE 610	Thesis	0	0	6
		3	**0**	**3**			**3**	**0**	**9**
Total credit hours required in Degree Program : 30									

- The order of taking the courses can be different from above, but students must take the core courses before electives.

MASTER OF SCIENCE IN CIVIL ENGINEERING
(TRANSPORTATION ENGINEERING)

Degree Requirements

(a) Core Courses (15 credit hours) **Credit Hours**

	Pavement Eng. Option	Transportation Eng. Option	
Mathematics	MATH 560		3
Transportation Core I	CE 574	CE 571	3
Transportation Core II	CE 579	CE 582	3
Seminar	CE 599		0
Thesis	CE 610		6

(b) Elective Courses (15 credit hours) **Credit Hours**

Three Transportation Elective Courses	CE 5xx	9
One CE Elective Course	CE xxx	3
One Technical Elective Course	XXX 5xx	3

Degree Plan

COURSE	TITLE	LT	LB	CR	COURSE	TITLE	LT	LB	CR
First Year									
MATH 560	App. Regression and Experimental Design	3	0	3	CE 5xx	Transportation Elective I	3	0	3
CE 5xx	Transportation Core I	3	0	3	CE 5xx	Transportation Elective II	3	0	3
CE 5xx	Transportation Core II	-	-	3	CE 5xx	Transportation Elective III	3	0	3
CE 599	Seminar	1	0	0					
		7+	**0+**	**9**			**9**	**0**	**9**
Second Year									
CE xxx	CE Elective	3	0	3	XXX 5xx	Technical Elective	3	0	3
CE 610	Thesis	0	0	IP	CE 610	Thesis	0	0	6
		3	**0**	**3**			**3**	**0**	**9**
Total credit hours required in Degree Program : 30									

- The order of taking the courses can be different from above, but students must take the core courses before electives.

MASTER OF SCIENCE IN CIVIL ENGINEERING
(GEOTECHNICAL ENGINEERING)

Degree Requirements

(a) Core Courses (15 credit hours)		Credit Hours
Nature of Behavior of Soils	CE 550	3
Foundation Engineering	CE 552	3
Advanced Soil Mechanics	CE 561	3
Seminar	CE 599	0
Thesis	CE 610	6

(b) Elective Courses (15 credit hours)		
Two Geotechnical Elective Courses	CE 5xx	6
One CE Elective Course	CE 5xx	3
Technical Elective	XXX 5xx	3
Mathematics	MATH 513 or MATH 560	3

Degree Plan

COURSE	TITLE	LT	LB	CR	COURSE	TITLE	LT	LB	CR
First Year									
MATH 5xx	Math Elective	3	0	3	CE 552	Foundation Engineering	3	0	3
CE 550	Nature of Behavior of Soils	3	0	3	CE 5xx	Geotechnical Elective I	3	0	3
CE 561	Advanced Soil Mechanics	3	0	3	CE 5xx	Geotechnical Elective II	3	0	3
CE 599	Seminar	1	0	0					
		10	**0**	**9**			**9**	**0**	**9**
Second Year									
CE 5xx	CE Elective	3	0	3	XXX 5xx	Technical Elective	3	0	3
CE 610	Thesis	0	0	IP	CE 610	Thesis	0	0	6
		3	**0**	**3**			**3**	**0**	**9**
Total credit hours required in Degree Program : 30									

- The order of taking the courses can be different from above, but students must take the core courses before electives.

MASTER OF SCIENCE IN CIVIL ENGINEERING
(WATER RESOURCES AND ENVIRONMENTAL ENGINEERING)

Degree Requirements

(a) Core Courses (9 credit hours)		Credit Hours
Groundwater Flow and Contaminant Transport	CE 533	3
Seminar	CE 599	0
Thesis	CE 610	6

(b) Elective Courses (21 credit hours)		
Option Elective I	CE 531 or CE 541	3
Two Option Elective Courses	CE 5xx	6
Two CE Elective Courses	CE xxx	6
Technical Elective	XXX 5xx	3
Mathematics	MATH 513 or MATH 560	3

Degree Plan

COURSE	TITLE	LT	LB	CR	COURSE	TITLE	LT	LB	CR
First Year									
MATH 5xx	Math Elective	3	0	3	CE 5xx	Option Elective II	3	0	3
CE 533	Groundwater Flow and Contaminant Trans.	3	0	3	CE 5xx	Option Elective III	3	0	3
CE 5xx	Option Elective I	-	-	3	CE xxx	CE Elective I	3	0	3
					CE 599	Seminar	1	0	0
		6+	**0+**	**9**			**10**	**0**	**9**
Second Year									
CE xxx	CE Elective II	3	0	3	XXX 5xx	Technical Elective	3	0	3
CE 610	Thesis	0	0	IP	CE 610	Thesis	0	0	6
		3	**0**	**3**			**3**	**0**	**9**
Total credit hours required in Degree Program : 30									

- The order of taking the courses can be different from above, but students must take the core courses before electives.

MASTER OF ENGINEERING IN CIVIL ENGINEERING
(STRUCTURES AND CIVIL ENGINEERING MATERIALS)

Degree Requirements

(a) Core Courses (18 credit hours)		Credit Hours
Concrete Materials	CE 501	3
Structural Mechanics	CE 506	3
Advanced Reinforced Concrete Design	CE 521	3
Behavior and Design of Steel Structures	CE 523	3
Construction Contracting and Administration	CEM 520	3
Master of Engineering Report	CE 600	3

(b) Elective Courses (15 credit hours)		Credit Hours
Three CE Elective Courses from any option	CE xxx	9
Mathematics	MATH 513 or MATH 560	3
Business/Non-Technical Course	XXX 5xx	3

Degree Plan

COURSE	TITLE	LT	LB	CR	COURSE	TITLE	LT	LB	CR
First Year									
CE 501	Concrete Materials	2	3	3	CE 521	Advanced Reinforced Concrete Design	3	0	3
CE 506	Structural Mechanics	3	0	3	CEM 520	Construction Contracting and Admin.	3	0	3
		5	**3**	**6**			**6**	**0**	**6**
Second Year									
CE 523	Behavior and Design of Steel Structures	3	0	3	CE xxx	CE Elective I	3	0	3
MATH 5xx	Math Elective	3	0	3	XXX 5xx	Business/Non-Technical Elective	3	0	3
		6	**0**	**6**			**6**	**0**	**6**
Third Year									
CE xxx	CE Elective II	3	0	3					
CE xxx	CE Elective III	3	0	3					
CE 600	Master of Engineering Report	0	6	3					
		6	**6**	**9**					
Total credit hours required in Degree Program : 33									

- The order of taking the courses can be different from above, but students must take the core courses before electives.

MASTER OF ENGINEERING IN CIVIL ENGINEERING
(TRANSPORTATION ENGINEERING)

Degree Requirements

(a) Core Courses (15 credit hours)		Credit Hours
Pavement Evaluation, Maintenance and Rehabilitation	CE 575	3
Geometric Design of Highways	CE 576	3
Mathematics	MATH 560	3
Construction Contracting and Administration	CEM 520	3
Master of Engineering Report	CE 600	3

(b) Elective Courses (18 credit hours)		Credit Hours
Two CE Transporation Elective Courses	CE 5xx	6
Three CE Elective Courses	CE xxx	9
Business/Non-Technical Course	XXX 5xx	3

Degree Plan

COURSE	TITLE	LT	LB	CR	COURSE	TITLE	LT	LB	CR
First Year									
MATH 560	App. Regression and Experimental Design	3	0	3	CE 576	Geometric Design of Highways	2	3	3
CE 575	Pavement Eval., Maint. and Rehabilitation	2	3	3	CE 5xx	Transportation Elective I	3	0	3
		5	**3**	**6**			**5**	**3**	**6**
Second Year									
CEM 520	Construction Contracting and Admin.	3	0	3	CE xxx	CE Elective I	3	0	3
XXX 5xx	Business/Non-Technical Elective	3	0	3	CE 5xx	Transportation Elective II	3	0	3
		6	**0**	**6**			**6**	**0**	**6**
Third Year									
CE xxx	CE Elective II	3	0	3					
CE xxx	CE Elective III	3	0	3					
CE 600	Master of Engineering Report	0	6	3					
		6	**6**	**9**					
Total credit hours required in Degree Program : 33									

- The order of taking the courses can be different from above, but students must take the core courses before electives.

MASTER OF ENGINEERING IN CIVIL ENGINEERING
(GEOTECHNICAL ENGINEERING)

Degree Requirements

(a) Core Courses (18 credit hours)		Credit Hours
Nature of Behavior of Soils	CE 550	3
Foundation Engineering	CE 552	3
Soil and Site Improvement	CE 553	3
Advanced Soil Mechanics	CE 561	3
Construction Contracting and Administration	CEM 520	3
Master of Engineering Report	CE 600	3

(b) Elective Courses (15 credit hours)		Credit Hours
Three CE Elective Courses	CE xxx	9
Mathematics	MATH 513 or MATH 560	3
Business/Non-Technical Course	XXX 5xx	3

Degree Plan

COURSE	TITLE	LT	LB	CR	COURSE	TITLE	LT	LB	CR
First Year									
CE 550	Nature of Behavior of Soils	3	0	3	CE 552	Foundation Engineering	3	0	3
CE 561	Advanced Soil Mechanics	3	0	3	CE 553	Soil and Site Improvement	3	0	3
		6	**0**	**6**			**6**	**0**	**6**
Second Year									
MATH 5xx	Math Elective	3	0	3	CE xxx	CE Elective I	3	0	3
CEM 520	Construction Contracting and Admin.	3	0	3	CE xxx	CE Elective II	3	0	3
		6	**0**	**6**			**6**	**0**	**6**
Third Year									
CE xxx	CE Elective III	3	0	3					
XXX 5xx	Business/Non-Technical Elective	3	0	3					
CE 600	Master of Engineering Report	0	6	3					
		6	**6**	**9**					
Total credit hours required in Degree Program : 33									

- The order of taking the courses can be different from above, but students must take the core courses before electives.

MASTER OF ENGINEERING IN CIVIL ENGINEERING
(WATER RESOURCES AND ENVIRONMENTAL ENGINEERING)

Degree Requirements

(a) Core Courses (18 credit hours)		Credit Hours
Advanced Engineering Hydrology	CE 531	3
Groundwater Flow and Contaminant Transport	CE 533	3
Chemistry in Environmental Engineering	CE 541	3
Physical and Chemical Processes	CE 547	3
Construction Contracting and Administration	CEM 520	3
Master of Engineering Report	CE 600	3

(b) Elective Courses (15 credit hours)		Credit Hours
Three CE Elective Courses	CE xxx	9
Mathematics	MATH 513 or MATH 560	3
Business/Non-Technical Course	XXX 5xx	3

Degree Plan

COURSE	TITLE	LT	LB	CR	COURSE	TITLE	LT	LB	CR
First Year									
CE 541	Chemistry in Environmental Engineering	2	3	3	CEM 520	Construction Contracting and Admin.	3	0	3
CE 533	Groundwater Flow and Contaminant Trans.	3	0	3	CE 531	Advanced Engineering Hydrology	3	0	3
		5	**3**	**6**			**6**	**0**	**6**
Second Year									
MATH 5xx	Math Elective	3	0	3	CE xxx	CE Elective I	3	0	3
CE 547	Physical and Chemical Processes	3	0	3	CE xxx	CE Elective II	3	0	3
		6	**0**	**6**			**6**	**0**	**6**
Third Year									
CE xxx	CE Elective III	3	0	3					
XXX 5xx	Business/Non-Technical Elective	3	0	3					
CE 600	Master of Engineering Report	0	6	3					
		6	**6**	**9**					
Total credit hours required in Degree Program : 33									

- The order of taking the courses can be different from above, but students must take the core courses before electives.

PHD IN CIVIL ENGINEERING
(ALL AREAS)

Degree Requirements

(a) Core Courses (12 credit hours)		Credit Hours
Seminar	CE 699	0
PhD Pre-Dissertation	CE 711	3
PhD Dissertation	CE 712	9

(b) Elective Courses (30 credit hours)		Credit Hours
Six CE Core Elective Courses	CE 5xx	18
Two Technical Non-CE Elective Courses	XXX 5xx	6
Two Free Elective Courses	XXX 6xx	6

Degree Plan

COURSE	TITLE	LT	LB	CR	COURSE	TITLE	LT	LB	CR
First Year									
CE 5xx	Core Elective I	3	0	3	CE 5xx	Core Elective IV	3	0	3
CE 5xx	Core Elective II	3	0	3	CE 5xx	Core Elective V	3	0	3
CE 5xx	Core Elective III	3	0	3	CE 5xx	Core Elective VI	3	0	3
		9	**0**	**9**			**9**	**0**	**9**
Second Year									
XXX 5xx	Technical Elective I	3	0	3	XXX 6xx	Free Elective II	3	0	3
XXX 5xx	Technical Elective II	3	0	3	CE 699	Seminar	1	0	0
XXX 6xx	Free Elective I	3	0	3	CE 711	PhD Pre-Dissertation	0	0	3
		9	**0**	**9**			**4**	**0**	**6**
Third Year									
CE 712	PhD Dissertation	0	0	IP	CE 712	PhD Dissertation	0	0	9
		0	**0**	**0**			**0**	**0**	**9**
Total credit hours required in Degree Program : 42									

- The order of taking the courses can be different from above, but students must take the core courses before electives.

CIVIL ENGINEERING

STRUCTURES AND CIVIL ENGINEERING MATERIALS

CE 500 Concept of Engineering Practice (3-0-3)
Appropriate exposure to engineering ethics, code of conduct, compliance to local regulations and laws and social responsibility; equity, and public and worker safety; concept of economy, sustainable development and environmental stewardship; team-work, project management, writing and presentation skills, professional liability and financial issues; importance of life-long learning and professional development.
Prerequisite: Graduate Standing

CE 501 Concrete Materials (2-3-3)
Properties of concrete constituents with emphasis on local aggregates and industrial by-products; cement hydration; fresh and hardened properties of concrete; durability tests; introduction to durability problems in concrete structures; concept of durable concrete design considering national and international code specifications. Special concretes including high strength, high performance, ultra-high performance, fiber reinforced, self-compacting, light-weight and sulfur concretes.
Prerequisite: Graduate Standing

CE 502 Evaluation and Testing of Concrete Structures (2-3-3)
Introduction to testing and planning of test programs, and evaluation of concrete structures; various Non-Destructive Tests (NDT) and partially destructive tests for assessment of strength and quality of in-situ concrete; combined method; in-situ load testing; introduction to durability characteristics and composition of concrete and its contamination by chloride, carbonation, sulfate, and alkali; reinforcement corrosion monitoring using half-cell, linear polarization, and ground penetrating radar methods; recent advances in NDT; condition assessment with case studies; types of concrete repair, repair strategy, compatibility and selection of repair materials, patch repair, corrosion repair and crack repair.
Prerequisite: Graduate Standing

CE 504 Corrosion in Reinforced Concrete (2-3-3)
Introduction; Mechanism of corrosion of steel in concrete including corrosion cells, forms of corrosion, passivity, Pourbaix diagrams, and polarization of electrochemical reactions; Corrosion mechanisms of reinforcing steel in concrete structures including time dependence and adverse effects on structural behavior; Effects of environmental and concrete quality factors; Introduction to modeling related to reinforcement corrosion; Introduction to structural design for durability; Assessment of causes and extent of corrosion damage in reinforced concrete structures; Protection measures against reinforcement corrosion; Repair and rehabilitation of reinforced concrete structures damaged by reinforcement corrosion.
Prerequisite: CE 501

CE 506 Structural Mechanics (3-0-3)
Bending of beams of non-symmetrical sections; shear center; curved beams; torsion of prismatic members; beams on elastic foundations; column buckling; failure theories and

members with cracks; energy methods; introduction to finite difference and finite element methods.
Prerequisite: Graduate Standing

CE 510 Advanced Structural Mechanics (3-0-3)
Introduction to Cartesian tensors; tensorial transformation of stress; finite and infinitesimal strain tensors; stress and strain tensor transformation in 3-D; anisotropic elasticity; theory of anisotropic laminates; yield failure criteria; flow rules in plasticity; elasticity in rectangular and polar coordinates.
Prerequisite: Graduate Standing

CE 511 Advanced Structural Analysis and Vibrations (3-0-3)
Review of matrix algebra, solution of equations, review of energy principles, virtual work; structural indeterminacies;, formalized flexibility method of structural analysis, development of element stiffness matrices, direct stiffness method of analysis for 2D and 3D structures, computer applications and software development, axial force effects; fundamental of vibrations; equations of motion for SDOF-systems; analysis of harmonic motion; analysis of un-damped and damped motions.
Prerequisite: Graduate Standing

CE 513 Plates and Shells (3-0-3)
Static analysis of elastic plates, including rectangular and circular geometry; energy methods; orthotropic plate bending theory; finite element formulation of plate bending; use of ANSYS for plate bending problems under mechanical and thermal loading; membrane theory of shells of surface of revolution; bending theory of circular cylindrical shells; axisymmetric bending of spherical shells; ANSYS application to problems of shells under mechanical loading.
Prerequisite: Graduate Standing

CE 514 Structural Stability (3-0-3)
Introduction to common areas of stability problems in structures, conservative and non-conservative loads, elastic and inelastic buckling of columns; stability of members under combined bending and axial loads; buckling of frames; torsional-buckling of open sections; lateral stability of beams and buckling of thin plates and shells; design consideration for stability; computer applications.
Prerequisite: Graduate Standing

CE 515 Structural Dynamics (3-0-3)
Equations of motion; free and forced vibrations of single degree of freedom systems; multi-degree of freedom systems (MDOF); free vibration analysis of MDOF structures, forced vibrations by harmonic analysis, generalized, impulsive loadings; numerical solutions; introduction to earthquake engineering; earthquake analysis of linear systems; base-isolations; structural dynamics considerations in building codes.
Prerequisite: CE 511 or equivalent

CE 517 Finite Element Methods (3-0-3)
Stiffness method; finite element method (FEM) for trusses in 2- and 3-D; FEM formulation for beams; plane frames and grids; FEM for plane elasticity; FEM for plate

bending; isoparametric formulation; stiffness matrix using numerical integration, Software ELAS2D, area coordinates, Galerkin's finite element approach for 2-D field problems; derivative boundary conditions; heat transfer by conduction and convection; groundwater flow using Galerkin FEM; time dependent field problems using consistent and lumped formulations. Students will learn how to develop their own software for the various problems areas discussed in this course and also be exposed to commercial software.
Prerequisite: Graduate Standing

CE 518 Continuum Mechanics (3-0-3)
Tensors, indicial notation, transformation of coordinates; analysis of stress, principal stresses; 3D Mohr's circle; analysis of deformation and strain; velocity fields and compatibility conditions; constitutive equations; isotropy; mechanical properties of solids and fluids; field equations; applications to elasticity, viscoelasticity, plasticity, and fluid mechanics; introduction to continuum damage mechanics.
Note: Can not be taken for credit with ME 551.
Prerequisite: Graduate Standing

CE 519 Boundary Element Method (3-0-3)
Weighted residual methods; weak formulations; inverse formulations; fundamental solutions; BEM for 1-D problems; BEM for 2-D potential problems; BEM for plane elasticity; BEM for plate bending; introduction to other mesh reduction and mesh-less methods; algorithm design and software development.
Prerequisite: Graduate Standing

CE 521 Advanced Reinforced Concrete Design (3-0-3)
Moment-curvature for RC members; flat slab flooring system; yield line analysis for beams and slabs; analysis and design of buildings for lateral loads; design of shear walls; design of slender columns; design for torsion; strut-and-tie models for reinforced concrete; deflection of RC members; design considerations for seismic loading.
Prerequisite: Graduate Standing

CE 522 Prestressed Concrete (3-0-3)
Prestressing systems; materials; behavior of prestressed concrete beams; criteria for analysis and design; losses; analysis of stresses; flexural design; shear; end blocks; deflection; composite members; continuous beams; partial prestress, design applications; introduction to segmental construction.
Prerequisite: Graduate Standing

CE 523 Behavior and Design of Steel Structures (3-0-3)
Elastic-plastic concepts of structural behavior, review of Load and Resistance Factor Design (LRFD), plastic analysis and design of beams and frames, steel plate girder design, steel-concrete composite design, simple and rigid framing connections, design considerations for torsion, design of rigid frames, computer applications for analysis and design of frames.
Prerequisite: CE 408 or equivalent

CE 524 Masonry and Precast Structures (3-0-3)

Masonry units and their applications, materials of masonry construction, flexural analysis and design, columns, walls under gravity and transverse loads, shear walls, retaining and subterranean walls, general design and construction considerations, anchorage to masonry, design aids and tables, precast frame analysis, precast floor slabs, precast concrete beams, columns and shear walls, floor diaphragms, joints and connections, beam and column connections, ties in precast concrete structures.
Prerequisite: Graduate Standing

CE 529 Structural Health Monitoring (2-3-3)
General concepts in structural health monitoring systems, commonly used techniques to diagnose structural damage, determinations of critical measurement types and locations, data acquisition systems, distant communication, simulation, condition evaluation, damage detections.
Prerequisite: Graduate Standing

CE 590 Advanced Topics in Structural Engineering (3-0-3)
Advanced topics selected from the broad area of structural engineering to provide the student with knowledge of recent advances in the analysis, design and computational modeling of structures.
Prerequisite: Graduate Standing

CE 601 Advanced Concrete Materials (3-0-3)
Introduction; macro and micro environmental factors affecting mechanical properties, shrinkage and durability of concrete; local durability problems and remedial measures; performance of concrete under carbonation curing, wet-dry cycles, thermal cycles, and elevated temperatures; mechanisms of deterioration due to salt-weathering, sulfate attack, carbonation and reinforcement corrosion; modeling of transport phenomena with emphasis on water, oxygen, and carbonation penetration and chloride diffusion into concrete; concrete cracking phenomena.
Prerequisite: CE 501

CE 603 Repair and Rehabilitation of Concrete Structures (3-0-3)
Characteristics and compatibility of repair materials; shrinkage and creep mechanisms in repair mortars; modeling of structural cracking due to constraints; design of steel and carbon fibre plate bonding for repair and strengthening; durability and fatigue resistance of plate-bonded RC members.
Prerequisite: CE 501, CE 521

CE 609 Rheology and Flow Modeling of Fresh Concretes (2-3-3)
This course addresses the issues of estimating, modelling, controlling and monitoring the flow of fresh concrete, as the properties of fresh concrete before it has set can have a significant impact on performance. The course begins with dealing with the rheology and rheometry of complex fluids, followed by specific measurements and testing techniques for concrete. The course then moves on to the impact of mix design on the rheological behaviour of concrete, looking at additives including super plasticizers and viscosity agents. Finally, the course concludes with topics related to concrete casting, such as shear thinning, shear thickening, thixotropy and formwork pressure.
Prerequisite: CE 501

CE 612 Elasticity and Plasticity (3-0-3)
Basic equations of continuum mechanics and tensors; plane elasticity; Airy's stress function; solution to biharmonic equation; deformation and strain tensors including Lagrangian and Eulerian description. Foundation of Plasticity theories including yield criteria, plastic flow rule, and generalized elasto-plastic shear strain relations; application of finite elements in elasticity and plasticity including the use of commercial software packages.
Prerequisite: CE 510

CE 613 Advanced Finite Element Methods (3-0-3)
Special isoparametric beam elements; plate and shell elements; introduction to geometric nonlinearities including buckling and large deformation; introduction to material nonlinearities (nonlinear elastic, plastic and fracture/cracks); accuracy, convergence, and errors.
Prerequisite: CE 517

CE 615 Earthquake Engineering (3-0-3)
This course will cover basic principles of structural dynamics including multiple degree of freedom systems, damping and response spectra. Static lateral force procedure for buildings, multistory structures, load combinations, lateral force resisting system, torsion and rigidity, seismically isolated buildings, dynamic lateral force procedure for buildings, application of modal analysis to buildings, seismic design of reinforced concrete structures, special moment resisting frames, shear walls, seismic design of steel structures, braced frames, seismic design of masonry structures.
Prerequisite: CE 511

CE 616 Fracture and Fatigue of Materials (3-0-3)
Stress intensity computations in linear elastic fracture mechanics (LEFM); finite element including singularity elements in LEFM, compliance calibration for critical energy release rate computations, mixed mode fracture criteria, elasto-plastic fracture principles, crack propagation under cyclic loading; applications of fracture mechanics to plain and reinforced concrete; fatigue-life prediction laws; fatigue of reinforced concrete beams and slabs.
Prerequisite: CE 517

CE 617 Analysis and Design of Tall Buildings (3-0-3)
Introduction to the different forms of tall buildings, choices of structural systems to resist vertical and horizontal loads, choice between different materials (concrete vs steel), Fundamental approaches to analysis, dynamic loadings of wind and earthquake forces, the modeling of tall buildings for both preliminary and final analysis, preliminary design of various structural systems of tall buildings, computer applications for tall building analysis.
Prerequisite: CE 521, CE 523

CE 618 Analysis of Bridge Systems (3-0-3)
Bridge systems and loading; load combinations and design requirements; deck structures and idealization; orthotropic plate theory and its application to bridge decks; design

considerations for composite bridge decks, Prestressed pseudo slab, multi-beam and box girder bridge decks; analysis of horizontally curved bridge decks; use of advanced materials in bridge design and rehabilitation; design consideration for substructures; computer modeling of bridges and application of software.
Prerequisite: CE 521, CE 523

CE 620 Blast Loading of Structures (3-0-3)
Design considerations, basic principles, general considerations in the design process; risk analysis and reduction; criteria for acceptable performance; materials performance under the extraordinary blast environment; performance verification for technologies and solution methodologies. Blast phenomena and loading, the explosion environment, loading functions needed for blast response analysis, fragmentation and associated methods for effects analysis. System analysis and design, the analysis and design considerations for structural, building envelope, component space, site perimeter, and building system designs. Blast resistant detailing, the use of concrete, steel, and masonry in new designs as well as retrofitting existing structures.
Prerequisite: CE 511

CE 622 Limit State Design of Concrete Structures (3-0-3)
Concept of limit state design; moment-curvature and load deflection characteristics; plastic analysis and rotational capacity of hinges; upper and lower bound theorems; limit state design of continuous beams and frames; rigid plastic theory, flow rule and applications; yield line and strip method for slabs; shear strengths of beams and slabs; limit states of serviceability; deflection and crack control.
Prerequisite: CE 521

CE 623 Constitutive Modeling of Materials (3-0-3)
Geometric representation of stress and concept of Pi-plane; strain energy and complementary energy density in elastic solids; non-linear elastic stress-strain relations; Cauchy and hyperelastic models; incremental (hypoelastic) model for isotropic materials; multi-parameter failure criteria; elastic perfectly plastic fracture models; finite elements in elastoplastic problems; including plane stress, plane strain and axisymmetric; software PLAS2D; nonlinear finite elements in reinforced concrete, smeared cracking, tension stiffening, plastic-damage models.
Prerequisite: CE 510

CE 625 Mechanics of Composite Materials (3-0-3)
Introduction to composite materials; micro and macro-mechanical behavior of a lamina; classical lamination theory; analysis of laminated beams and plates; applications of energy methods and the finite element method; inter-laminar stresses and delamination; failure of laminates.
Prerequisite: CE 510 or CE 518 or ME 551

CE 630 Damage Mechanics (3-0-3)
Phenomological aspects of damage; manifestation of damage and measurement and mechanical representation of damage; thermodynamics and micromechanics of damage; potential dissipation function and strain-damage coupled constitutive equations; damage

evolution equations; brittle versus ductile damage; anisotropic damage of concrete; fatigue damage; local and averaged damaged; elasto-plastic damage of concrete structures; finite element modeling of damage; nanoscale modeling of materials.
Prerequisite: CE 510

TRANSPORTATION ENGINEERING

CE 571 Urban Transportation Planning and Modeling (3-0-3)
Transportation planning processes, transportation land use interaction, travel evaluation and demand estimation, traffic generation theories and assignment models, and transit analysis.
Corequisite: MATH 560

CE 574 Pavement Structures (3-0-3)
Fundamentals of pavement-vehicle interaction and the mechanics of pavement response; stress analysis in flexible and rigid pavements; material characterization; design of flexible and rigid pavements for highways and airports; surface, base and subgrade courses evaluation and design; modern design techniques and their applications; cost analysis and pavement selection; computer applications in pavement analysis and design.
Prerequisite: Graduate Standing

CE 575 Pavement Evaluation, Maintenance and Rehabilitation (2-3-3)
New concepts, methods and practices for the evaluation, maintenance, and rehabilitation of highway and airport pavement systems; nondestructive techniques for structural evaluation of pavements to assess performance; rehabilitation design; recycling and overlay design; quality control/assurance; computer applications in pavement evaluation and maintenance; selection of cost effective alternatives.
Prerequisite: Graduate Standing

CE 576 Geometric Design of Highways (2-3-3)
Geometric configuration of streets, expressways, busways to meet the characteristics of vehicle performance and operator limitations; roadside and guardrail design. Intersection and interchange design; parking facilities; and software applications.
Prerequisite: Graduate Standing

CE 577 Airport Planning and Design (3-0-3)
Planning and design of airport facilities; aircraft geometric and operational characteristics; passenger demand analysis; air-traffic control procedures; configuration and orientation of runway; geometric and structural design of runways and taxiways; terminal design; airport capacity; airport noise; airport master planning.
Prerequisite: Graduate Standing

CE 579 Pavement Materials (2-3-3)
The nature, engineering characteristics, and selection of materials for highway and airport pavements; composition, physical behavior, production and performance of bituminous materials and mixtures; concrete mixes for rigid pavements; durability of concrete and

asphalt mixes; polymer materials and additives; recent developments in pavement materials.
Prerequisite: Graduate Standing

CE 581 Public Transportation Systems (3-0-3)
Introduction to mass transit operation and management including the development in urban public transportation modes; systems and services; transit characteristics and vehicle technology; demand forecasting; routing and scheduling problems; land-use impact; Public policy and financing.
Prerequisite: CE 571

CE 582 Traffic Flow Theory (3-0-3)
Macroscopic and microscopic characteristics of flow, speed and density; statistical distribution of traffic characteristics; time-space diagram; shock wave analysis; queuing theory; bottleneck analysis; application of theory of traffic flow to design and control of traffic; traffic simulations; fundamentals and applications of existing tools and softwares.
Prerequisite: Graduate Standing

CE 583 Railroad Transportation Engineering (3-0-3)
Principles and analysis of railroad engineering. Introduction to railroad infrastructure. Computation of train speed, power, and acceleration requirements; introduction to railway traffic control and signaling. Quantitative analytical tools for rail-transportation decision-making and optimization.
Prerequisite: Graduate Standing

CE 593 Advanced Topics in Transportation Engineering (3-0-3)
Advanced topics selected from the broad areas of transportation engineering to provide the knowledge with the recent applications and development.
Prerequisite: Consent of Instructor

CE 594 Transportation Data Analysis (3-0-3)
Methods and statistics of model estimation; linear and non-linear regression analysis; error propagation and parameters sensitivity analysis, analysis of variance with their applications; hypothesis testing; questionnaire design; sampling; advanced data analysis techniques.
Prerequisite: Math 560

CE 595 Advanced Demand Modeling (3-0-3)
Advanced theories and applications for analysis and forecasting of user behavior and demand. Formulation and estimation of discrete choice models; their application in the characterization of choice behavior including analysis of panel data; analysis of complex choices; estimation and forecasting with large choice sets; multidimensional probabilistic choice models; advanced choice models, including probit, logit mixtures, hybrid choice models, hidden Markov models, Monte Carlo simulation and Bayesian methods.
Prerequisite: CE 571

CE 670 Advanced Pavement Design (3-0-3)
Non-linear analysis; fatigue and permanent deformation; back calculation of layer moduli; mechanistic empirical design methods; theories of pavement behavior; application of theory to the analysis and design of airport and highway pavement systems including rehabilitation design and computer applications; development of improved design and rehabilitation practices and procedures.
Prerequisite: CE 574

CE 671 Advanced Pavement Materials (3-0-3)
Pavement material characterization procedures; simulation of in-service conditions; experimental program for fatigue cracking modeling and plastic deformation modeling under repetitive loading; development of constitutive laws; advancement in accelerated environmental conditioning and loading simulation, durability testing, and material performance based evaluation.
Prerequisite: CE 579

CE 672 Pavement Maintenance Management (3-0-3)
Techniques of network and project level pavement management; introduction to mapping/facility management system; field evaluation methods and equipment; performance modeling; maintenance and rehabilitation strategies; priority ranking procedures; overlay design procedures; maintenance specifications; computer applications in pavement management.
Prerequisite: CE 575

CE 677 Traffic Control and Operation (3-0-3)
Traffic control at road segments and intersections, traffic signal theory, signal actuation and coordination, multimodal signal operation, freeway control (ramp metering), roundabouts control; capacity analysis; urban traffic management, relevant ITS technologies in vehicle detection and advanced control systems.
Prerequisite: CE 582

CE 678 Transportation Safety Analysis (3-0-3)
Traffic safety challenges and influencing factors; Safety impact studies and design of potential countermeasures; Safety in cross-section and roadside design; Safety auditing; Traffic conflict analysis and other surrogate techniques; safety indices; Crash prediction methods; Implications of ITS concepts for traffic safety.
Prerequisite: Math 560

CE 679 Sustainable Transportation Systems (3-0-3)
The integration of transportation and environment, energy, and climate-change concerns for sustainability, with an emphasis upon; (1) current trends, climate and energy science, and the policy context; (2) vehicle technology, fuels, emissions estimation methodologies, air quality impact and life cycle benefit assessment of alternative fuels/vehicles and traffic control strategies; (3) Intelligent Transportation Systems (ITS) solutions; and (4) land use, public transportation, and demand management.
Prerequisite: CE 571

CE 680 Management of Surface Transportation Systems (3-0-3)
Advanced studies on traffic management systems, travelers information systems, public transportation systems and commercial vehicle operation. Urban Transportation system evaluation and the use of optimization techniques in transportation.
Prerequisite: CE 571

CE 681 Analysis of Urban Transportation Networks (3-0-3)
Design and analysis of urban transportation networks, including formulations and solution procedures for deterministic user equilibrium and stochastic user equilibrium. Advanced topics in network analysis and design.
Prerequisite: CE 571

GEOTECHNICAL ENGINEERING

CE 550 Nature of Behavior of Soils (3-0-3)
Soil formation, composition, crystallography, and mineralogy; soil-water-electrolyte system; physio-chemical nature of soil; soil fabric and structure; relationship between soil composition and mechanical behavior; time-deformation processes; compressibility and value change in clay soils; conduction phenomena.
Prerequisite: Graduate Standing

CE 552 Foundation Engineering (3-0-3)
Bearing capacity of shallow foundations; factors affecting bearing capacity; immediate and consolidation settlement of shallow foundations; mat founda¬tions; analysis, design, and installation of pile foundations; capacity and settle-ment of piles and pile groups; drilled piers and caissons.
Prerequisite: CE 561 or Consent of Instructor

CE 553 Soil and Site Improvement (3-0-3)
Behavior of natural soils; shallow and deep mechanical modifications; improve¬ment by admixtures; grouting; hydraulic modifications; thermal and electrical treatments; modifications by inclusions and confinement; development of mar¬ginal lands; treatment of local problematic soils; landfills.
Prerequisite: CE 561 or Consent of Instructor

CE 556 Earth Structures (3-0-3)
Shear strength of soils and its relevance to earth structures; methods of analysis including limit analysis, limit equilibrium and numerical methods; earth pres¬sure theories taking into account seepage and pore pressure dissipation; design and analysis of retaining structures (slopes, retaining walls, sheet piles, and braced excavation).
Prerequisite: CE 561 or Consent of Instructor

CE 557 Designing with Geosynthetics (2-3-3)
Functions of geosynthetics (separation, reinforcement, filtration, drainage and liquid containment); geosynthetics properties and their measurements; design and construction using geotextiles, geogrids, geonets, geomembranes, geosynthetic clay liners and

geocomposites.
Prerequisite: CE 556

CE 558 Environmental Geotechnics (3-0-3)
Geotechnical engineering of land disposal of hazardous and non-hazardous wastes; fate and transport of contaminants; compacted clay and synthetic linears; leachate collection and removal system; landfill cover and gas venting systems; design and stability of landfill elements; construction quality assurance and con¬trol performance monitoring; remediation technologies.
Prerequisite: Graduate Standing

CE 559 Rock Engineering (2-3-3)
Geological classification and index properties of rocks; strength and deformability behavior of intact and jointed rock masses; in-situ stresses; lab and field test methods; aspects of structural geology; stability of rock slopes; applications to surface excavations, underground openings and tunnels; foundations on rocks.
Prerequisite: Graduate Standing

CE 561 Advanced Soil Mechanics (3-0-3)
Stresses and strains in soil media; lateral earth pressure; shear strength of soils; stress path; constitutive models for soils; failure criteria; critical state soil mechanics; unsaturated soils; consolidation theory; elasticity, viscoelasticity, and plasticity theories applied to geomaterials; constitutive, numerical, and experimental modeling.
Prerequisite: Graduate Standing

CE 562 Field Testing Techniques and Experimental Methods in Geotechnical Engineering (2-3-3)
Geotechnical Measurements and Exploration (instrumentation, data collection, precision, analysis and interpretation); Laboratory testing (triaxial and plane strain testing taking into account dilation, back pressure, pore pressure parameters, stress path, monotonic and cyclic; permeability testing; consolidation testing; thermal tests; chemical tests; XRD); subsurface investigation; in-situ investigation methods (CPT, SPT, pressure meter, vane shear, plate bearing tests, and geophysical Techniques), testing of foundation (settlement, vibrations, pile integrity), geotechnical investigation report; Computer applications.
Prerequisite: Graduate Standing

CE 563 Tunneling and Excavation (3-0-3)
Methods for excavation of tunnels and deep openings; Tunneling procedures for various soil and rock (tunnel boring machines, shielded and drill-and-blast operations); Methods of installation and dewatering; Underground construction (planning, scheduling, costing, monitoring); Design and construction of different types of tunnels (cut and cover, rock, soft ground, immersed tub, jacked); instrumentations; Soil liner interaction; Design of permanent and temporary supports (retaining walls, bracing of open cuts, anchored bulkheads, liners) for deep excavation systems, Field trip to visit tunneling site; Computer applications.
Prerequisite: CE 561

CE 592 Advanced Topics in Geotechnical Engineering (3-0-3)
Advanced topics selected from the broad area of geotechnical engineering to provide the students with knowledge of recent applications and developments in this specialty.
Prerequisite: Consent of Instructor

CE 651 Dynamics of Soils and Foundations (3-0-3)
Theory of vibration; wave propagation in elastic media; dynamic properties of soils and their measurement; vibration transmission and attenuation through soils; foundation vibration theories; dynamic earth pressure; dynamic bearing capacity of shallow foundations; dynamic analysis of foundations; design of machine foundations; vibration isolation; soil liquefaction; introduction to geotechnical earthquake engineering.
Prerequisite: CE 561

CE 652 Advanced Foundation Engineering (3-0-3)
Soil-structure interaction; numerical methods for analysis of foundation; bearing capacity and settlement of foundation using in-situ tests; load-deformation behavior of axially-loaded piles; prediction of pile capacity during driving; beams and plates on foundations; laterally-loaded piles; foundation on difficult soils.
Prerequisite: CE 552 or equivalent

CE 658 Geotechnics of Problematic Soils (3-0-3)
Types of problematic soil conditions and their local distributions; geological fac¬tors; site investigation; behavior of unsaturated soils; expansive soils; collaps¬ing soils; sabkha soils; calcareous sediments; uncontrolled and deep fills; lime¬stone solution cavities; case studies.
Prerequisite: CE 552

CE 663 Modeling of Wind-Blown Sand and Desert/Arid Climate Geotechnical Challenges (3-0-3)
Sand classification, wind energy, cycle of erosion/transportation/deposition, sediment transport mechanics and morphodynamics, prediction / protection / remedial measures, analytical / experimental modeling and simulation, numerical / statistical analyses, wind tunnel, computer applications.
Prerequisite: CE 550

CE 665 Geotechnical Earthquake Engineering (3-0-3)
Earthquake reconnaissance; Ground motion characterization; seismic site response; seismic zonation; Analysis of earthquake-induced ground failures (soil liquefaction, cyclic softening of clays, surface fault rupture, and seismic slope stability); Wave propagation through soils; Dynamic properties of geomaterials; Strength and deformation characteristics of cyclically loaded soils; Experimental analysis (cyclic tests, shake table, centrifuge testing); Dynamic soil-structure interaction; seismic code provision; Analysis and design of foundations under seismic load; Seismic analysis and stability of slopes; Computer applications.
Prerequisite: CE 651

CE 666 Soil Structure Interaction (3-0-3)
Concepts and constitutive models relevant to structural elements, geomaterials, interface elements, and joints; Treatment of soils interaction with structures subjected to static and dynamic loading including liquefaction; Determination of material parameters and idealization of structures, loading, and boundary conditions; Surface foundation under static and seismic loading; Soil-foundation-structure interaction; analysis of deformations of piles and pile groups; Analysis of stress and deformations of flexible ground retaining systems using Winkler-type spring or continuum models; Analysis of underground structures; Foundations subjected to ground deformation.
Prerequisite: CE 552

WATER RESOURCES AND ENVIRONMENTAL ENGINEERING

CE 530 Experimental Hydraulics (1-6-3)
Experiments for model calibration and verification; flow characteristics of weirs, flumes, spillways, self-regulated siphons, roughened beds, and cylindrical piles; determination lift and drag on models; model study approaches to diffusion in transport problems; experiment in groundwater flow and well hydraulics.
Prerequisite: Graduate Standing

CE 531 Advanced Engineering Hydrology (3-0-3)
Introduction to the elements of the hydrologic cycle; frequency analysis of precipitation and runoff; relationship between rainfall and runoff; flood routing; watershed modeling and urban hydrology.
Prerequisite: Graduate Standing

CE 532 Hydrodynamics (3-0-3)
Kinematics of fluid; continuity: plane flow, axi-symmetric flow, stream flow functions, circulation, velocity potential; dynamics of frictionless fluids: Eulerian equations of motion, irrotational incompressible flow, some elementary symmetric and axisymmetric flow, rotational flow, equations in a moving coordinate system, flow past spheres and cylinders; two-dimensional complex variables and applications.
Prerequisite: Graduate Standing

CE 533 Groundwater Flow and Contaminant Transport (3-0-3)
Properties of porous media, fluid storage and flow in saturated media, transport equations in porous media, equation of motion, Darcy's law, continuity & conservation equation, well hydraulics, principle of superposition, transport of contaminants by advection, modeling of adventive transport.
Prerequisite: Graduate Standing

CE 534 Hydraulics of Closed Conduits (3-0-3)
Concept of water hammer and unsteady flow through conduits; method of characteristics; algebraic water hammer; flow through highly flexible tubing; transients caused by pumps and turbines; computer models; case studies.

Prerequisite: Graduate Standing

CE 535 Design of Dams and Hydraulic Structures (3-0-3)
Types of hydraulic structures; classification of dams; problems of foundation; selection of sites; feasibility studies; design of gravity, arch, earth and rockfill dams; barrages and dams on permeable foundation and their design criteria; spillway types; energy dissipation devices; syphon aqueducts; design criteria for transitions from trapezoidal to rectangular flumes.
Prerequisite: Graduate Standing

CE 536 GIS Applications in Water Resources (3-0-3)
Introduction to Geographic Information System (GIS) with applications in water resources; Spatial information in hydrology and water resources; Data models and data structure; Digital elevation models and their applications in water resources management; River and watershed networks; Flood hydrology modeling and flood plain mapping; Hydrologic/hydraulic models using GIS.
Prerequisite: Graduate Standing

CE 537 Water Resources and Environmental Systems Analysis (3-0-3)
Applications of system engineering techniques to water and environmental problems; optimization techniques, linear programming, integer programming, goal programming, non-linear programming, dynamic programming; multi-objective decision analysis; simulation methods.
Prerequisite: Graduate Standing

CE 538 Advanced Open Channel Flow (3-0-3)
Basic concepts of fluid flow; the energy and momentum principles in open channel flow; critical flow; flow resistance in uniform and non-uniform flow; normal depth analysis; flow profiles in gradually varied flow; rapidly varied flow; channel controls and channel transitions; flow of waves and equation of motion in unsteady flow; computer applications in open channel.
Prerequisite: Graduate Standing

CE 539 Coastal Engineering (2-3-3)
An introduction to the mechanics of coastal environment; linear wave theory, kinematics, dispersion, mass transport radiation stress, energy flux, current; shoaling, refraction, diffraction; real sea states; wind wave prediction; wave climate; wave loading; tides and tidal circulation; storm tides; limited laboratory experiments.
Prerequisite: Graduate Standing

CE 540 Computational Methods in Water Resources (3-0-3)
Numerical methods for solving the time-dependent Navier-Stokes equations in complex geometrics, numerical methods for hyperbolic equations: low-order and high-order finite volume methods, streamline/front-tracking methods, applications to groundwater flow and contamination.
Prerequisite: Graduate Standing

CE 541 Chemistry in Environmental Engineering (2-3-3)
Environmental aspects of physical, organic, and inorganic chemistry including applications in environmental engineering of the phenomena of precipitation, buffering capacity, chemical equilibria, and adsorption.
Prerequisite: Graduate Standing

CE 542 Microbiology in Environmental Engineering (2-3-3)
Role of microorganisms in wastewater treatment; aerobic and anaerobic digestion of municipal sludges, and degradation of water quality in drinking water systems; disinfection of wastewater and drinking water for removal of viruses, bacteria and protozoa that cause waterborne diseases.
Prerequisite: Graduate Standing

CE 543 Air Pollution Engineering (3-0-3)
Introduction to air pollution issues and effects, air pollution control regulations, measurements techniques, meteorology for air pollution engineers, basics of air pollution control, design of air pollution control systems for particulates and gases removal, air pollution dispersion modeling.
Prerequisite: Graduate Standing

CE 544 Unit Operations and Processes Laboratory (1-6-3)
Analytical methods utilized for assessment of water and wastewater quality; laboratory evaluation for the design of physical, chemical, and biological unit operations and processes in water and wastewater treatment.
Prerequisite: Graduate Standing

CE 546 Industrial Wastewater Treatment (3-0-3)
Introduction to industrial wastewater issues and treatment standards, pollution prevention and waste reduction, design of physico-chemical processes for industrial wastewater treatment including equalization, neutralization, API/CPI and solids separator, metal precipitation, flotation, membrane systems, adsorption, and air stripping, application of biological treatment to industrial wastewater treatment with special emphasis on effect of toxic pollutants on reactor design.
Prerequisite: CE 541

CE 547 Physical and Chemical Processes (3-0-3)
Theory and applications of physical and chemical processes in water treatment; coagulation; softening; desalting; stabilization; filtration; adsorption; fluoridation; gas transfer.
Prerequisite: CE 541

CE 548 Biological Processes (3-0-3)
Theory and applications of biological processes in wastewater treatment; kinetic models; aeration and oxygen transfer; suspended-growth and fixed-film processes; aerobic and anaerobic digestion; sludge thickening, dewatering and disposal.

Corequisite: CE 542

CE 549 Selected Topics in Environmental Engineering (2-3-3)
Study of the dynamic role of environmental engineering in maintaining environmental quality. A comprehensive study of any phase of environmental engineering.
Prerequisite: Graduate Standing

CE 591 Advanced Topics in Water Resources and Environmental Engineering (2-3-3)
Advanced topics selected from the broad area of water resources and environmental engineering to provide the student with knowledge of recent applications and developments in the specialty.
Prerequisite: Graduate Standing

CE 633 Mechanics of Heterogeneous Fluids in Porous Media (3-0-3)
Characteristics of porous media and fluid mixtures; capillarity; heterogeneous fluids in static systems; mechanical equilibrium; Brooks-Corey and Van Genuchten models; hysteresis; relative permeability; soil-water-air system; flux equation; tortuosity; Kozeny-Carman equation; generalized Darcy's equation; steady and unsteady two-phase flow; infiltration theory.
Prerequisite: CE 533

CE 635 Water Resources Planning (3-0-3)
Development of supply-demand relationships and projections; analysis of projects for water supply, flood control, irrigation, drainage or quality control; benefit-cost analysis; economic feasibility studies; multipurpose projects and cost allocation techniques.
Prerequisite: CE 531

CE 638 Stochastic Hydrology (3-0-3)
Introduction to probabilistic hydrology; random variables correlated in time and space; applications to rainfall, stream flow, groundwater, water use and storage; time series analysis; and stochastic data generation models.
Prerequisite: CE 531

CE 639 Risk Analysis in Water Resources and Environmental Systems (3-0-3)
Risk and uncertainty; random variables and random events; CDF's and PDF's; population moments, moments of non-linear functions of random variables, first order analysis of uncertainty; methods of estimating parameters of distribution functions; goodness of fit tests; ANOVA; risk analysis applied to applied to hydrology, hydraulics, groundwater, water resources, and environmental engineering systems.
Prerequisite: CE 531, MATH 560

CE 640 Advanced Contaminant Transport in Porous Media (3-0-3)
Advection with mixing, hydrodynamic dispersion, non-conservative solutes, field scale contaminant transport, groundwater contamination by LNAPLS and DNAPLS, containment and cleanup.
Prerequisite: CE 533

CE 641 Chemical Processes in Environmental Engineering (3-0-3)
Application of chemical equilibria, surface chemistry and kinetics to water and wastewater systems; reactor design and kinetics; chemistry and coagulation, corrosion, hardness reduction and disinfection; theory and applications of mass transfer in concurrent and countercurrent operations.
Prerequisite: CE 547

CE 642 Remediation of Contaminated Sites (3-0-3)
Characterizing contaminated sites with respect to contaminants and subsurface properties, physical, chemical and biological treatment processes, project planning and design, technology evaluation and selection.
Prerequisite: CE 533

CE 643 Membranes and Water and Wastewater Treatment (3-0-3)
Membrane material and types, separation processes, rejects versus transport, applications to desalination and water treatment, design of membrane systems. RO and ultrafiltration, Unconventional treatment technologies.
Prerequisite: CE 541

CE 645 Hazardous Waste Management (3-0-3)
Classification, chemistry, and toxicology of hazardous wastes will be presented; control technologies, regulatory policies and management strategies will be examined.
Prerequisite: CE 541

CE 646 Water Quality Modeling (3-0-3)
Evaluation and control of water quality in streams, lakes, and estuaries. Mathematical analyses of patterns of water movement and their relationship to water quality.
Prerequisite: CE 533, CE 541

CE 647 Municipal Solid Waste Management (3-0-3)
Problems, regulations, collection, handling, recycling and disposal of municipal solid wastes in the urban and rural sectors; integrated waste management system with resource recovery, composting, incineration, landfill disposal and their costs.
Prerequisite: CE 541

CE 648 Risk Assessment in Civil Engineering (3-0-3)
Introduction to risk assessment; Uncertainty modeling; Process/Techniques of risk assessment; Risk-based decision-making; Risk assessment database and software; Reliability and reliability-based design; Selected case studies and applications in Civil Engineering.

Prerequisite: CE 531

COMMON COURSES

CE 598 Masters Design Project (0-6-3)
Application of knowledge and skills acquired during the tenure of the graduate program in the solution of open-ended, advanced-level design problems from a technical, environmental and socio-economic viewpoint. Use of computer-aided engineering in a project environment will be emphasized. Students can work with senior engineers from industry on a specific design project. The project should be completed under the supervision of a faculty member and examined by a committee.
Prerequisite: Consent of Instructor

CE 599 Seminar M.S. (1-0-0)
Graduate students working towards the M.S. degree are required to attend the seminars given by faculty, visiting scholars, and fellow graduate students. Additionally, each student must present at least one seminar on a timely research topic. Among other things, this course is designed to give the student an overview of research in the department, and a familiarity with the research methodology, journals and professional societies in his discipline.
Corequisite: Graduate Standing

CE 600 Master of Engineering Report (0-6-3)
This will be prepared as an informative report based on a professional work related to analysis, design or construction of a facility that has particular significance or interest. It may also include collection of data or methodologies for design & construction or application of innovative technology. The report will be completed under the supervision of a faculty member and examined by a committee.
Prerequisite: Consent of Advisor

CE 606 Independent Research (3-0-3)
This course is intended to allow the student to conduct research in advanced problems in his MS research area. The faculty offering the course should submit a research plan to be approved by the Graduate Program Committee at the academic department. The student is expected to deliver a public seminar and a report on his research outcomes at the end of the course.
Prerequisite: Prior arrangement with an instructor

CE 610 MS Thesis (0-0-6)
The student has to undertake and complete a research topic under the supervision of a graduate faculty member in order to probe in-depth a specific problem in the research area.
Prerequisite: CE 599

CE 699 Seminar Ph.D. (1-0-0)
PhD students are required to attend Departmental seminars delivered by faculty,

visiting scholars and graduate students. Additionally, each PhD student should present at least one seminar on a timely research topic. PhD students should pass the comprehensive examination as part of this course. This course is a pre-requisite to registering the PhD Pre-dissertation CE 711. The course is graded as pass or fail. IC grade is awarded if the PhD Comprehensive exam is not yet passed.
Prerequisite: Graduate Standing

CE 701 Directed Research I (3-0-3)
This course is intended to allow the student to conduct research in advanced problems in his PhD research area. The faculty offering the course should submit a research plan to be approved by the Graduate Program Committee at the academic department. The student is expected to deliver a public seminar and a report on his research outcomes at the end of the course.
Prerequisite: Prior arrangement with an instructor

CE 702 Directed Research II (3-0-3)
This course is intended to allow the student to conduct research in advanced problems in his PhD research area. The faculty offering the course should submit a research plan to be approved by the Graduate Program Committee at the academic department. The student is expected to deliver a public seminar and a report on his research outcomes at the end of the course.
Prerequisite: Prior arrangement with an instructor

CE 711 PhD Pre-Dissertation (0-0-3)
This course enables the student to submit his PhD Dissertation Proposal and defends it in public. The student passes the course if the PhD Dissertation committee accepts the submitted dissertation proposal report and upon successfully passing the Dissertation proposal public defense. The course grade can be NP, NF or IP.
Prerequisite: PhD Candidacy
Corequisite: CE 699

CE 712 PhD Dissertation (0-0-9)
This course enables the student work on his PhD Dissertation as per the submitted dissertation proposal, submit its final report and defend it in public. The student passes this course if the PhD Dissertation committee accepts the submitted final dissertation report and upon successfully passing the Dissertation public defense. The course grade can be NP, NF or IP.
Prerequisite: CE 711