



**King Fahd University of Petroleum & Minerals**

**College of Engineering Sciences  
Civil & Environmental Engineering Department**

## **MEng in Civil Engineering**

**April 2016**

## DEGREE PLAN

Following are the Revised Degree Plans recommended for the MEng programs in various option areas:

### Degree Plan for Master of Engineering Program (Structures and Civil Engineering Materials)

<b>First Semester</b>		<b>CT</b>	<b>LB</b>	<b>CR</b>
CE 501	Concrete Materials	3	0	3
CE 506	Structural Mechanics	3	0	3
				<b>6</b>
<b>Second Semester</b>				
CE 521	Advanced Reinforced Concrete Design	3	0	3
CEM 520	Construction, Contracting and Administration	3	0	3
				<b>6</b>
<b>Third Semester</b>				
CE 523	Behavior and Design of Steel Structures	3	0	3
MATH 5xx	Either MATH 513 or MATH 560	3	0	3
				<b>6</b>
<b>Fourth Semester</b>				
CE xxx	CE Elective*	3	0	3
XX 5xx/6xx	Elective (in Business/Non-technical field)**	3	0	3
				<b>6</b>
<b>Fifth Semester</b>				
CE xxx	CE Elective*	3	0	3
CE xxx	CE Elective*	3	0	3
CE 600	Civil Engineering Project	0	6	3
				<b>9</b>
<b>Total Credits</b>				<b>33</b>

\* From any option

\*\* Graduate courses offered university wide, with consent of the Department

#### Notes:

- Each student is expected to submit his detailed degree plan according to the above generic degree plan for approval by the Department and the Deanship of Graduate Studies within the 8<sup>th</sup> week of the second semester of enrollment.
- Students are required to adhere to the regulations of degree plan. No relaxations will be given to any student, and courses taken in conflict of the above will not be counted towards the degree.
- At most two 400-level elective courses may be allowed with the approval of the advisor.
- The order of taking the courses can be different from above, but students must take the core courses before electives.

**Degree Plan for Master of Engineering Program  
(Transportation Engineering)**

<b>Course #</b>	<b>Title</b>	<b>Lt</b>	<b>Lb</b>	<b>Cr</b>
<b>First Semester</b>				
MATH 560	Applied Regression and Experimental Design	3	0	3
CE 575	Pavement Evaluation, Maintenance and Rehabilitation	2	1	3
				<b>6</b>
<b>Second Semester</b>				
CE 576	Geometric Design of Highways	2	1	3
CE 5xx/6xx	Transportation Elective	3	0	3
				<b>6</b>
<b>Third Semester</b>				
CEM 520	Construction, Contracting and Administration	3	0	3
XX 5xx/6xx	Elective (in Business/Non-technical field)**	3	0	3
				<b>6</b>
<b>Fourth Semester</b>				
CE xxx	CE Elective*	3	0	3
CE 5xx/6xx	Transportation Elective	3	0	3
				<b>6</b>
<b>Fifth Semester</b>				
CE xxx	CE Elective*	3	0	3
CE xxx	CE Elective*	3	0	3
CE 600	Civil Engineering Project	0	6	3
				<b>9</b>
	<b>Total Credit Hours</b>			<b>33</b>

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**Degree Plan for Master of Engineering Program  
(Geotechnical Engineering)**

<b>Course #</b>	<b>Title</b>	<b>Lt</b>	<b>Lb</b>	<b>Cr</b>
<b>First Semester</b>				
CE 550	Nature of Behavior of Soils	3	0	3
CE 561	Advanced Soil Mechanics	3	0	3
				<b>6</b>
<b>Second Semester</b>				
CE 552	Foundation Engineering	3	0	3
CE 553	Soil and Site Improvement	3	0	3
				<b>6</b>
<b>Third Semester</b>				
MATH 5xx	Either MATH 513 or MATH 560	3	0	3
CEM 520	Construction, Contracting and Administration	3	0	3
				<b>6</b>
<b>Fourth Semester</b>				
CE xxx	CE Elective*	3	0	3
CE xxx	CE Elective*	3	0	3
				<b>6</b>
<b>Fifth Semester</b>				
CE xxx	CE Elective*	3	0	3
XX 5xx/6xx	Elective (in Business/Non-technical field)**	3	0	3
CE 600	Civil Engineering Project	0	6	3
				<b>9</b>
	<b>Total Credit Hours</b>			<b>33</b>

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**Degree Plan for Master of Engineering Program  
(Water Resources & Environmental Engineering)**

Course #	Title	Lt	Lb	Cr
<b>First Semester</b>				
CE 541	Chemistry in Environmental Engineering	2	3	3
CE 533	Groundwater Flow and Contaminant Transport	3	0	3
				<b>6</b>
<b>Second Semester</b>				
CEM 520	Construction, Contracting and Administration	3	0	3
CE 531	Advanced Engineering Hydrology	3	0	3
				<b>6</b>
<b>Third Semester</b>				
MATH 5xx	Either MATH 513 or MATH 560	3	0	3
CE 547	Physical and Chemical Processes	3	0	3
				<b>6</b>
<b>Fourth Semester</b>				
CE xxx	CE Elective*	3	0	3
CE xxx	CE Elective*	3	0	3
				<b>6</b>
<b>Fifth Semester</b>				
XX 5xx/6xx	Elective (in Business/Non-technical field)**	3	0	3
CE xxx	CE Elective*	3	0	3
CE 600	Civil Engineering Project	0	6	3
				<b>9</b>
<b>Total Credit Hours</b>				<b>33</b>

\* From any option

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## **COURSE DESCRIPTIONS**

### **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.

*Prerequisite:* Graduate Standing

*Note:* Not to be taken for credits with ME 551

**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 Reinforced Concrete Behavior and 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**

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 & 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)**

Phenomenological 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 & 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.

*Co-requisite:* 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 the 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 foundations; analysis, design, and installation of pile foundations; capacity and settlement of piles and pile groups; drilled piers and caissons.

*Prerequisite:* CE 561 or Consent of the Instructor

### **CE 553 Soil and Site Improvement**

**(3-0-3)**

Behavior of natural soils; shallow and deep mechanical modifications; improvement by admixtures; grouting; hydraulic modifications; thermal and electrical treatments; modifications by inclusions and confinement; development of marginal lands; treatment of local problematic soils; landfills.

*Prerequisite:* CE 561 or Consent of the 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 pressure 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 the 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 liners; leachate collection and removal system; landfill cover and gas venting systems; design and stability of landfill elements; construction quality assurance and control 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 the 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 factors; site investigation; behavior of unsaturated soils; expansive soils; collapsing soils; sabkha soils; calcareous sediments; uncontrolled and deep fills; limestone 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 ENGINEERING & 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 & 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 advective 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; siphon 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 geometries, 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.

*Co-requisite:* 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 hydrology, hydraulics, groundwater, water resources, and environmental engineering systems.

*Prerequisite:* CE 531 and 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 & 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 and 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 the Advisor

### **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 the Advisor