Course Catalog - Fall 2004

Civil and Environmental Engineering

195 ***About Civil Engineering*** Credit: 0 hours.
(CEE 195) Civil engineering orientation course including historical developments, education requirements, relation to science, professional practice, and specialties within the profession

199 ***Undergraduate Open Seminar*** Credit: 1 to 5 hours.
(CEE 199) May be repeated.

201 ***Systems Engrg & Economics*** Credit: 3 hours.
(CEE 292) Introduction to the formulation and solution of civil engineering problems. Major topics are: engineering economy, mathematical modeling, and optimization. Techniques, including classical optimization, linear and nonlinear programming, network theory, critical path methods, simulation, decision theory, and dynamic programming are applied to a variety of civil engineering problems. Prerequisite: MATH 230; credit or concurrent registration in MATH 225

202 ***Engineering Risk & Uncertainty*** Credit: 3 hours.
(CEE 293) Identification and modeling of non-deterministic problems in civil engineering design and decision making. Development of stochastic concepts and simulation models, and their relevance to real design and decision problems in various areas of civil engineering Prerequisite: credit or concurrent registration in MATH 242 recommended

300 ***Behavior of Materials*** Credit: 4 hours.
(CEE 210) Same as TAM 324. See TAM 324.

310 ***Transportation Engineering*** Credit: 3 hours.
(CEE 220) An introduction to the design, planning, operation, management, and maintenance of transportation systems; integrated multi-modal transportation systems (highways, air, rail, etc.); layout of highways, airports, and railroads with traffic flow models, capacity analysis, and safety. Design of facilities and systems with life cycle costing procedures and criteria for optimization Prerequisite: TAM 251; credit or concurrent registration in CEE 202.

311 ***Engineering Surveying*** Credit: 4 hours.
(CEE 201) Introduction to surveying and photogrammetry. Prerequisite: CEE 202 credit or concurrent registration in CS 101.

312 ***Route Surveying*** Credit: 3 hours.
(CEE 205) Principles for the design and layout of routes; coverage includes horizontal and vertical alignment, route location, earthwork, computation, ground and photogrammetric survey methods, and special survey methods for highways, railroads, pipelines, tunnels and urban construction Prerequisite: CEE 311.

320 ***Construction Engineering*** Credit: 3 hours.
(CEE 216) Introduction to the construction processes: contracting and bonding, planning and scheduling, estimating and project control, productivity models, and construction econometrics. Prerequisite: CEE 201; credit or concurrent registration in CS 101 and CEE 202.

330 ***Environmental Engineering*** Credit: 3 hours.
(CEE 241) Considers the sources, characteristics, transport, and effects of air and water contaminants; biological, chemical, and physical processes in water; atmospheric structure and composition; unit operations for air and water quality control; solid waste management; and environmental quality standards. Prerequisite: CHEM 104.

350 ***Water Resources Engineering*** Credit: 3 hours.
(CEE 255) Quantitative aspects of water in the earth's environment and its engineering implications, including design and analysis of systems directly concerned with use and control of water; quantitative introduction to hydrology, hydraulic engineering, and water resources planning Prerequisite: CEE 202; credit or concurrent registration in TAM 335 and CEE 201.

360 ***Structural Engineering*** Credit: 3 hours.
(CEE 261) Basic topics in the analysis, behavior and design of trusses and framed structures under static loads; analysis topics include member forces in trusses, shear and moment diagrams, deflections, simple applications of the force method and slope-deflection; introduction to computer applications. Prerequisite: TAM 251.

380 ***Geotechnical Engineering*** Credit: 3 hours.
(CEE 280) Introduction to geotechnical engineering. Classification of soils, compaction in the laboratory and in the field, soil exploration, boring and sampling, permeability of soils, one-dimensional settlement analyses, strength of soil, introduction to foundations. Prerequisite: TAM 251

400 ***Welding and Joining Process*** Credit: 3 or 4 hours.
(CEE 375) Same as MSE 444. See MSE 444.

401 ***Concrete Materials*** Credit: 3 hours.
(CEE 314) Examines the influence of constituent materials (cements, aggregates and admixtures) on the properties

of fresh and hardened concrete; mix design handling and placement of concrete; and behavior of concrete under various types of loading and environment; test methods. Laboratory practice is an integral part of the course. Prerequisite: CEE 300.

405 ***Asphalt Materials, I*** Credit: 3 or 4 hours.

(CEE 321) Properties and control testing of bituminous materials, aggregates for bituminous mixtures, and analysis and design of asphalt concrete and liquid asphalt cold mixtures; structural properties of bituminous mixes; surface treatment design; and recycling of mixtures. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 310.

406 ***Pavement Design, I*** Credit: 3 or 4 hours.

(CEE 320) Analysis, behavior, performance, and structural design of pavements for highways and airfields; topics include climate factors, rehabilitation, life cycle design economics, and traffic loadings. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 310.

407 ***Airport Design*** Credit: 3 or 4 hours.

(CEE 334) Basic principles of airport facilities design to include aircraft operational characteristics, noise, site selection, land use compatibility, operational area, ground access and egress, terminals, ground service areas, airport capacity, and special types of airports. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: Senior standing in civil engineering.

415 ***Geometric Design of Roads*** Credit: 4 hours.

(CEE 322) Analysis of factors in developing a highway transportation facility; traffic estimates and assignment; problems of highway geometrics and design standards; planning and location principles; intersection design factors; street systems and terminal facilities; programming improvements; drainage design; structural design of surface; concepts of highway management and finance; and highway maintenance planning Prerequisite: CEE 310.

416 ***Traffic Capacity Analysis*** Credit: 3 or 4 hours.

(CEE 325) Study of fundamentals of traffic engineering; analysis of traffic stream characteristics; capacity of urban and rural highways; design and analysis of traffic signals and intersections; traffic control; traffic impact studies; and traffic accidents 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 310.

417 ***Urban Transportation Planning*** Credit: 4 hours.

(CEE 330) Same as UP 430. See UP 430.

420 ***Construction Productivity*** Credit: 3 or 4 hours.

(CEE 315) Introduction of the application of scientific principles to the measurement and forecasting of productivity in construction engineering. Conceptual and mathematical formulation of labor, equipment, and material factors affecting productivity 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 320.

421 ***Construction Planning*** Credit: 3 or 4 hours.

(CEE 316) Project definition; scheduling and control models; material, labor and equipment allocation; optimal schedules; project organization; documentation and reporting systems; and management and control 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 320.

422 ***Construction Cost Analysis*** Credit: 3 or 4 hours.

(CEE 318) Introduction to the application of scientific principles to costs and estimates of costs in construction engineering; concepts and statistical measurements of the factors involved in direct costs, general overhead costs, cost markups and profits; and the fundamentals of cost recording for construction cost accounts and cost controls 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 320.

430 ***Ecological Quality Engineering*** Credit: 2 hours.

(CEE 337) Examines the characteristics of rivers and lakes which affect the management of domestic and industrial wastewaters; includes assessment of chemical hazards, and introduction to surveillance and biomonitoring, and a review of regulations governing effluents Prerequisite: CEE 330.

431 ***Biomonitoring*** Credit: 3 hours.

(CEE 338) Discusses the theory and application of biomonitoring as a component of environmental management; reviews a range of techniques to analyze effluents and assess condition and trend in the environment, using biological and ecological systems; and emphasizes biomonitoring program design, selection and analysis of data, and interpretation of biomonitoring results Prerequisite: CEE 430.

432 ***Stream Ecology*** Credit: 3 hours.

(CEE 347) Description of physical, chemical, and biological characteristics in streams and rivers including an integrated study of the environmental factors affecting the composition and distribution of biota; emphasizes the application of ecological principles in aquatic ecosystem protection and management Same as IB 450. Prerequisite: CEE 430.

434 ***Environmental Systems, I*** Credit: 3 hours.

(CEE 339) Introduction to the concepts and applications of environmental systems analysis. Application of mathematical programming and modeling to the design, planning and management of engineered environmental systems, regional environmental systems, and environmental policy. Economic analysis, including benefit-cost analysis and management strategies. Concepts of tradeoff, non-inferior sets, single and multi-objective optimization. Practical application to case studies to convey an understanding of the complexity and data collection challenges of actual design practice Prerequisite: CEE 201 or GE 330; CEE 330.

437 ***Water Quality Engineering*** Credit: 3 hours.
(CEE 342) Fundamental theory underlying the unit processes utilized in the treatment of water for domestic and industrial usage, and in the treatment of domestic and industrial wastewaters. Prerequisite: CEE 330; credit or concurrent registration in TAM 335.

440 ***Solid and Hazardous Waste*** Credit: 3 hours.
(CEE 336) Investigation of the regulatory and technical issues affecting solid and hazardous waste management, with an emphasis on the principles governing the transport, fate, and remediation of solid and hazardous waste in the subsurface, including advection, dispersion, sorption, interphase mass transfer, and transformation reactions. Prerequisite: CEE 330.

442 ***Env Eng Principles, Physical*** Credit: 3 hours.
(CEE 340) Analysis of the physical principles which form the basis of many water and air quality-control operations; sedimentation, filtration, inertial separations, flocculation, mixing and principles of reactor design. Prerequisite: CEE 437.

443 ***Env Eng Principles, Chemical*** Credit: 4 hours.
(CEE 343) Application of principles of chemical equilibrium and chemical kinetics to air and water quality. Chemistry topics are thermodynamics, kinetics, acid/base chemistry, complexation, precipitation, dissolution, and oxidation/reduction. Many applications are also presented. Prerequisite: CEE 437.

444 ***Env Eng Principles, Biological*** Credit: 3 hours.
(CEE 346) Application of principles of biochemistry and microbiology to air and water quality, wastes, and their engineering management; biological mediated changes in water and in domestic and industrial wastewater. Prerequisite: CEE 443.

445 ***Air Quality Modeling*** Credit: 3 hours.
(CEE 345) Overview of practical and advanced approaches to air pollution modeling, including aspects of pollutant transport, transformation, and loss. Models considered include: Gaussian plume, chemical mass balance, chemical reaction, grid and trajectory. Evaluation of models and the development of efficient control strategies are also discussed Same as ATMS 425. Prerequisite: CEE 330 and credit or concurrent registration in TAM 335; or ATMS 401.

446 ***Air Quality Engineering*** Credit: 3 hours.
(CEE 349) Description and application of chemical and physical principles related to air pollutants, aerosol mechanics, attenuation of light in the atmosphere, air quality regulation, generation of air pollutants, methods to remove gaseous and particulate pollutants from gas streams, and atmospheric dispersion Prerequisite: CEE 330; credit or concurrent registration in TAM 335.

447 ***Atmospheric Chemistry*** Credit: 3 hours.
(CEE 348) Course will present current knowledge of the biochemical cycles of atmospheric trace gases, their interactions on global and regional scales, and their significance for the chemistry in the atmosphere. The important fundamental concepts that are central to understanding air pollutants, e.g., the formation of aerosols and the transformation and removal of species in the atmosphere, will be introduced Same as ATMS 420, and ENVS 450. Prerequisite: CHEM 104; either CEE 330 or ATMS 401.

449 ***Environmental Engineering Lab*** Credit: 3 hours.
(CEE 335) Combination of lecture and laboratory designed to provide exposure to the use of traditional analysis tools and techniques in analysis, control, and design of natural and engineered environmental systems including air, water, wastewater, solid and hazardous waste, and ecological systems 3 undergraduate hours. Prerequisite: CEE 437 or CEE 446.

450 ***Surface Hydrology*** Credit: 3 hours.
(CEE 350) Study of descriptive and quantitative hydrology dealing with the distribution, circulation, and storage of water on the earth's surface; discusses principles of hydrologic processes and presents methods of analysis and their applications to engineering and environmental problems Prerequisite: CEE 350.

451 ***Environmental Fluid Mechanics*** Credit: 3 hours.
(CEE 351) Incompressible fluid mechanics with particular emphasis on topics in analysis and applications in civil engineering areas; primary topics include principles of continuity, momentum and energy, kinematics of flow and stream functions, potential flow, laminar motion, turbulence, and boundary-layer theory Prerequisite: TAM 335.

452 ***Hydraulic Analysis and Design*** Credit: 3 hours.
(CEE 353) Hydraulic analysis and design of engineering systems: closed conduits and pipe networks; hydraulic structures, including spillways, stilling basins, and embankment seepage; selection and installation of hydraulic machinery Prerequisite: TAM 335.

453 ***Urban Hydrology and Hydraulics*** Credit: 3 hours.
(CEE 356) Hydraulic analysis and design of urban, highway, airport, and small rural watershed drainage problems; discussion of overland and drainage channel flows; hydraulics of storm-drain systems and culverts; determination of design flow; runoff for highways, airports, and urban areas; design of drainage gutters, channels, sewer networks, and culverts Prerequisite: CEE 350.

454 ***Groundwater*** Credit: 3 hours.
(CEE 357) Physical properties of groundwater and aquifers, principles and fundamental equations of porous media flow and mass transport, well hydraulics and pumping test analysis, role of groundwater in the hydrologic cycle, groundwater quality and contamination Prerequisite: CEE 350 and TAM 335.

460 ***Steel Structures, I*** Credit: 3 hours.
(CEE 263) Introduction to the design of metal structures; behavior of members and their connections; and theoretical, experimental, and practical bases for proportioning members and their connections 3 undergraduate hours. No graduate credit. Prerequisite: CEE 360

461 ***Reinforced Concrete, I*** Credit: 3 hours.
(CEE 264) Study of the strength, behavior, and design of reinforced concrete members subjected to moments, shear, and axial forces; extensive discussion of the influence of the material properties on behavior 3 undergraduate hours. No graduate credit. Prerequisite: CEE 360

462 ***Steel Structures, II*** Credit: 3 or 4 hours.
(CEE 363) Metal members under combined loads; connections, welded and bolted; moment-resistant connections; plate girders, conventional behavior, and tension field action. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 460.

463 ***Reinforced Concrete, II*** Credit: 3 or 4 hours.
(CEE 364) Study of the strength, behavior, and design of indeterminate reinforced concrete structures, with primary emphasis on slab systems; emphasis on the strength of slabs and on the available methods of design of slabs spanning in two directions, with or without supporting beams. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 461.

465 ***Design of Structural Systems*** Credit: 3 or 4 hours.
(CEE 365) The whole structural design process including definition of functional requirements, selection of structural scheme, formulation of design criteria, preliminary and computer-aided proportioning, and analysis of response, cost, and value. 3 undergraduate hours. 4 graduate hours. Prerequisite: Credit in either CEE 460 or 461 with concurrent registration in the other

467 ***Masonry Structures*** Credit: 3 or 4 hours.
(CEE 367) Introduction to analysis, design and construction of masonry structures. Mechanical properties of clay and concrete masonry units, mortar, and grout. Compressive, tensile, flexural, and shear behavior of masonry structural components. Strength and behavior of unreinforced bearing walls. Detailed design of reinforced masonry beams, columns, structural walls with and without openings, and complete lateral-force resisting building systems 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 461.

468 ***Prestressed Concrete*** Credit: 3 or 4 hours.
(CEE 368) Study of strength, behavior, and design of prestressed reinforced concrete members and structures, with primary emphasis on pretensioned, precast construction; emphasis on the necessary coordination between design and construction techniques in prestressing. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 461.

469 ***Wood Structures*** Credit: 3 or 4 hours.
(CEE 369) Mechanical properties of wood, stress grades and working stresses; effects of strength-reducing characteristics, moisture content, and duration of loading and causes of wood deterioration; glued-laminated timber and plywood; behavior and design of connections, beams, and beam-columns; design of buildings and bridges; other structural applications: trusses, rigid frames, arches, and pole-type buildings; and prismatic plates and hyperbolic paraboloids 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 460 or CEE 461

470 ***Structural Analysis*** Credit: 4 hours.
(CEE 361) Direct stiffness method of structural analysis; fundamentals and algorithms; numerical analysis of plane trusses, grids and frames; virtual work and energy principles; introduction to the finite element method for plane stress and plane strain. Prerequisite: CEE 360.

471 ***Structural Mechanics*** Credit: 3 or 4 hours.
(CEE 379) Beams under lateral load and thrust; beams on elastic foundations; virtual work and energy principles; principles of solid mechanics, stress and strain in three dimensions; static stability theory; torsion; computational methods. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: MATH 385 and TAM 251.

472 ***Structural Dynamics*** Credit: 3 or 4 hours.
(CEE 374) Analysis of the dynamic response of structures and structural components to transient loads and foundation excitation; single-degree-of-freedom and multi-degree-of-freedom systems; response spectrum concepts; simple inelastic structural systems; and introduction to systems with distributed mass and flexibility 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 360 , MATH 385, and TAM 212.

480 ***Foundation Engineering*** Credit: 3 hours.
(CEE 284) Analysis and design of foundations, bearing capacity and settlement of foundations; stability of excavations and slopes; ground movements due to construction; analysis and design of excavations, retaining walls, slopes and underground structures in soil and rock 3 undergraduate hours. No graduate credit. Prerequisite: CEE 380.

483 ***Soil Mechanics and Behavior*** Credit: 4 hours.
(CEE 383) Composition and structure of soil; water flow and hydraulic properties; stress in soil; compressibility behavior and properties of soils; consolidation and settlement analysis; shear strength of soils; compaction and unsaturated soils; experimental measurements Prerequisite: CEE 380.

484 ***Applied Soil Mechanics*** Credit: 4 hours.
(CEE 384) Application of soil mechanics to earth pressures and retaining walls, stability of slopes, foundations for structures, excavations; construction considerations; instrumentation Prerequisite: CEE 483.

490 ***Computer Methods*** Credit: 3 or 4 hours.
(CEE 391) Review of programming concepts; formulation and programming of numerical, data processing, and logical problems with applications from various branches of civil engineering; organization of programs and data; and development and use of problem-oriented programming languages in civil engineering Same as CSE 491. 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CS 101; senior or graduate standing in civil engineering.

491 ***Decision and Risk Analysis*** Credit: 3 or 4 hours.
(CEE 393) Development of modern statistical decision theory and risk analysis, and application of these concepts in civil engineering design and decision making; Bayesian statistical decision theory, decision tree, utility concepts, and multi-objective decision problems; modeling and analysis of uncertainties, practical risk evaluation, and formulation of risk-based design criteria, risk benefit trade-offs, and optimal decisions 3 undergraduate hours. 3 or 4 graduate hours. Prerequisite: CEE 202.

495 ***Professional Practice*** Credit: 0 hours.
(CEE 295) Series of lectures by outstanding authorities on the practice of civil engineering and its relations to economics, sociology, and other fields of human endeavor. 0 undergraduate hours. No graduate credit. Prerequisite: Junior standing

497 ***Independent Study*** Credit: 0 to 16 hours.
(CEE 397) Individual investigations or studies of any phase of civil engineering selected by the student and approved by the department 1 to 4 undergraduate hours, or 0 to 16 graduate hours Prerequisite: Senior or graduate standing; consent of instructor.

498 ***Special Topics*** Credit: 1 to 4 hours.
(CEE 398) Structured presentations of new and developing areas of knowledge in civil engineering offered by the faculty to augment the formal courses available Prerequisite: Individually identified for each offering under this course number; see Schedule.

500 ***Advanced Topics in Materials*** Credit: 1 to 4 hours.
(CEE 410) Lectures and discussions related to advanced topics in the science and technology of materials used in civil engineering construction May be repeated in the same or separate terms to a maximum of 16 graduate hours. Prerequisite: As specified for each section; see Schedule.

506 ***Pavement Design, II*** Credit: 4 hours.
(CEE 420) Development of models for and analysis of pavement systems; use of transfer functions relating pavement response to pavement performance; evaluation and application of current pavement design practices and procedures; analysis of the effects of maintenance activities on pavement performance; and economic evaluation of highway and airport pavements. Prerequisite: CEE 406.

508 ***Pavement Evaluation and Rehab*** Credit: 4 hours.
(CEE 421) Concepts and procedures for condition survey rating; evaluation by nondestructive testing (roughness, skid resistance, structural capacity); and destructive testing, maintenance strategies, and rehabilitation of pavement systems for highways and airfields. Prerequisite: CEE 406.

509 ***Transportation Soils*** Credit: 4 hours.
(CEE 424) Occurrence and properties of surficial soils, soil classification systems, soil variability; subgrade evaluation procedures, repeated loading behavior of soils; soil compaction and field control; soil moisture, soil temperature, and frost action; soil trafficability and subgrade stability for transportation facility engineering. Prerequisite: CEE 483.

515 ***Traffic Flow Theory*** Credit: 4 hours.
(CEE 425) Fundamentals of traffic flow, traffic flow characteristics, statistical distributions of traffic flow parameter, traffic stream models, car following models, continuum follow models, shock wave analysis, queuing analysis, traffic flow models for intersections, network flow models and control, traffic simulation. Prerequisite: CEE 416 and knowledge of probability and statistics.

516 ***Sys Method and Network Techniq*** Credit: 4 hours.
(CEE 416) Same as IE 512. See IE 512.

534 ***Surface Water Quality Modeling*** Credit: 4 hours.
(CEE 441) Mathematical modeling of the movement and fate of pollutants and other substances in streams, lakes and other natural water bodies. Development of one, two, and three dimensional differential conservation equations, one, two and three dimensional steady-state and transient solutions. Finite difference, finite element, and finite particle methods. Lagrangian and Eulerian formulations, diffusion and dispersion tensors, numerical

dispersion, and solution stability. Kinetic relationships describing important physical, chemical, and biochemical water constituent transformation phenomena. Field or laboratory experiment in model calibration and verification Same as CSE 564. Prerequisite: MATH 385, CEE 442, and CEE 451.

535 ***Environmental Systems, II*** Credit: 4 hours.

(CEE 439) Fundamental concepts of uncertainty, risk, and reliability applied to environmental and water resources decision making. Chance constraints, Markov and Monte Carlo modeling, geostatistics, unconditional and conditional simulation, genetic algorithms, neural networks, simulated annealing, and a review of relevant portions of basic probability and statistical theory. Many techniques are applied to a real-world environmental decision making problem initially developed in CEE 434. Prerequisite: CEE 202 and CEE 434.

536 ***Multiattribute Decision Making*** Credit: 4 hours.

(CEE 444) Same as GE 530. See GE 530.

537 ***Water Quality Control Proc, I*** Credit: 4 hours.

(CEE 440) Theory and basic design of processes used in water and wastewater treatment, including adsorption, ion exchange, chemical oxidation and reduction, disinfection, sedimentation, filtration, coagulation, flocculation, and chemical precipitation. Prerequisite: Credit or concurrent registration in CEE 442 and CEE 443.

538 ***Water Quality Control Proc, II*** Credit: 4 hours.

(CEE 442) Theory and its application for design and operation of processes used in water and wastewater treatment; emphasis is on biological treatment processes and related processes for gas transfer, sludge dewatering, sludge disposal, and solids separations. Prerequisite: CEE 442 and CEE 443; credit or concurrent registration in CEE 444.

540 ***Remediation Design*** Credit: 4 hours.

(CEE 445) Evaluation and design of alternative treatment processes for hazardous waste sites contaminated with organic and/or metal wastes. Group design project due at the end of the term. Prerequisite: CEE 440.

545 ***Aerosol Sampling and Analysis*** Credit: 4 hours.

(CEE 449) Studies principles of sampling for particles and gases in the field of air pollution; examines instrumental techniques relevant to the design of sampling systems used in process control, ambient air monitoring and laboratory experiments; methods of sample analysis and their limitations. Same as ATMS 535, ENVS 545, and ME 516. Prerequisite: MATH 385 and CEE 446.

546 ***Air Quality Control*** Credit: 4 hours.

(CEE 448) Application of principles describing the generation, separation, and removal of air contaminants from gas streams generated by stationary sources. Local field trips typically occur each term to see the application of the air quality control devices in the field. Same as ME 515. Prerequisite: CEE 442 or equivalent and CEE 446.

550 ***Hydroclimatology*** Credit: 4 hours.

(CEE 450) Application of deterministic and probabilistic concepts to simulate and analyze hydrologic systems; discussion of the theory and application of linear and nonlinear, lumped, and distributed systems techniques in modeling the various phases of the hydrologic cycle. Prerequisite: CEE 450.

551 ***Open-Channel Hydraulics*** Credit: 4 hours.

(CEE 451) Advanced hydraulics of free surface flow in rivers and open channels; discussion of theory, analytical and numerical solution techniques, and their applications to gradually and rapidly varied nonuniform flows, unsteady flow, and flow in open-channel networks. Prerequisite: CEE 451.

555 ***Mixing in Environmental Flows*** Credit: 4 hours.

(CEE 455) Physical processes involved in transport of pollutants by water; turbulent diffusion and longitudinal dispersion in rivers, pipes, lakes, and the ocean; diffusion in turbulent jets, buoyant jets, and plumes. Prerequisite: MATH 380 MATH 385, and TAM 335.

557 ***Groundwater Modeling*** Credit: 4 hours.

(CEE 457) Examines theory and application of numerical methods, finite differences and finite element, for solving the equations of groundwater flow and solute transport; transport of chemically reacting solutes; model calibration and verification. Same as CSE 565. Prerequisite: CEE 454; MATH 385.

559 ***Sediment Transport*** Credit: 4 hours.

(CEE 459) Physical processes of transportation and deposition of sediment particles in liquid bodies with particular emphasis on fluvial sediment problems; sediment in desilting basins; reservoirs and delta formation; erosion; stable channel design; and river morphology. Prerequisite: CEE 551.

560 ***Steel Structures, III*** Credit: 4 hours.

(CEE 465) Theories of ultimate behavior of metal structural members with emphasis on buckling and stability of members and frames; theory of torsion applied to beam torsion, lateral-torsional buckling, curved beams with emphasis on design criteria; post-buckling strength of plates and post-buckling versus column behavior. Prerequisite: CEE 462.

561 ***Reinforced Concrete, III*** Credit: 4 hours.

(CEE 466) In-depth study of the behavior of reinforced concrete members, including the relationships between behavior and building code requirements. Prerequisite: CEE 463.

563 ***Reinforced Concrete, IV*** Credit: 4 hours.
(CEE 467) Study of the strength and behavior of assemblages of reinforced concrete members, including a study of the applicability of traditional elastic design procedures to structures which exhibit inelastic behavior under the influence of both short and long term loadings. Prerequisite: CEE 561

570 ***Finite Element Methods*** Credit: 4 hours.
(CEE 478) Theory and application of the finite element method; stiffness matrices for triangular, quadrilateral, and isoparametric elements; two- and three-dimensional elements; algorithms necessary for the assembly and solution; direct stress and plate bending problems for static, nonlinear buckling and dynamic load conditions; displacement, hybrid, and mixed models together with their origin in variational methods. Same as CSE 551. Prerequisite: CEE 471 or TAM 551.

571 ***Plates and Shells*** Credit: 4 hours.
(CEE 473) Classical plate bending theory; emphasis on emthods of solution including series expansions, variational procedures, and finite element techniques applicable to plate-type structures commonly encountered in practice; consideration of inplane loads, large deflections, buckling, and anisotropy. Prerequisite: CEE 471.

572 ***Earthquake Engineering*** Credit: 4 hours.
(CEE 479) Study of the effects of earthquakes on constructed works and of the design of structures to resist earthquake motions; earthquake ground motions and mechanisms; response of structures to earthquake motion; behavior of materials, elements, assemblages and structures subjected to earthquake motion; principles of earthquake resistant design; and special topics. Prerequisite: CEE 472

574 ***Probabilistic Loads and Design*** Credit: 4 hours.
(CEE 477) Application of probabilistic methods in describing and defining loads on structures with emphasis on the random fluctuation in time and space. Introduction to random vibration methods and applications to dynamic response of structures under wind and earthquake loads. Computer simulation of structural loads and responses. Probability-based safety criteria and review of current methods of selection of design loads and load combinations Prerequisite: CEE 202 and CEE 472.

575 ***Fracture and Fatigue*** Credit: 4 hours.
(CEE 475) Fatigue and fracture behavior of steel structures and connections; fatigue and fracture mechanics theory and experimental data; assessment of behavior and current design specification practice. Prerequisite: CEE 462.

580 ***Excavation and Support Systems*** Credit: 4 hours.
(CEE 480) Classical and modern earth pressure theories and their experimental justification; pressures and bases for design of retaining walls, bracing of open cuts, anchored bulkheads, cofferdams, tunnels, and culverts. Prerequisite: Credit or concurrent registration in CEE 484.

581 ***Earth Dams*** Credit: 4 hours.
(CEE 481) Fundamentals of problems of slope stability; seepage in composite sections and anisotropic materials; methods of stability analysis; mechanism of failure of natural and artificial slopes; compaction; and field observations. Prerequisite: Credit or concurrent registration in CEE 484.

582 ***Consolidation of Clays*** Credit: 4 hours.
(CEE 482) Elastic solutions relevant to soil mechanics; permeability; general application of Terzaghi's theory of one-dimensional consolidation; advances in consolidation theories; mechanism of volume change; delayed and secondary compressibility and creep; theory of three-dimensional consolidation and solutions; radial flow and design of sand drains; and analysis and control of settlement. Prerequisite: CEE 483.

583 ***Shear Strength of Soils*** Credit: 4 hours.
(CEE 483) Physico-chemical properties of soils; fabric and structure of soil; mechanism of shearing resistance; residual shear strength of overconsolidated clays and clay shales; long-term shear strength of overconsolidated clays; Hvorslev shear strength parameters; and undrained shear strength of clays. Prerequisite: CEE 483 .

584 ***Geotechnical Case Histories*** Credit: 4 hours.
(CEE 484) Critical study of case histories of projects in geotechnical engineering; current practice in the design and construction of foundations, embankments, and waterfront structures. Prerequisite: CEE 484

585 ***Deep Foundations*** Credit: 4 hours.
(CEE 485) Ultimate capacities and load-deflection of piles and drilled shafts subjected to compressive loads, tensile loads, and lateral loads; effects of duration of load, soil-structure interaction; two and three dimensional analysis of pile groups with closely spaced piles; effects of installation; inspection of deep foundations and full-scale field tests. Prerequisite: CEE 484.

586 ***Rock Mechanics and Behavior*** Credit: 4 hours.
(CEE 486) Physical properties and classification of intact rock, theories of rock failure, state of stress in the earth's crust, stresses and deformations around underground openings assuming elastic, plastic, and time-dependent behavior; effect of geologic discontinuities on rock strength; and introduction to stability analyses in rock. Prerequisite: CEE 483; GEOL 550; TAM 451.

587 ***Applied Rock Mechanics*** Credit: 4 hours.
(CEE 487) Application of rock mechanics to engineering problems; shear strength of rock masses; dynamic and

static stability of rock slopes; deformability of rock masses; design of pressure tunnel linings and dam foundations; controlled blasting and blasting vibrations; tunnel support; machine tunneling; design and construction of large underground openings; and field instrumentation. Prerequisite: CEE 586.

588 ***Geotechnical Earthquake Engrg*** Credit: 4 hours.

(CEE 488) Seismic hazard analysis, cyclic response of soils and rock; wave propagation through soil and local site effects; liquefaction and post liquefaction behavior, seismic soil-structure of foundations and underground structures, seismic design of retaining walls, underground structures and tunnels. Construction and machine vibrations. Blasting Prerequisite: CEE 472 and CEE 484.

595 ***Seminar*** Credit: 0 to 1 hours.

(CEE 495) Discussion of current topics in civil and environmental engineering and related fields by staff, students, and visiting lecturers. May be repeated.

597 ***Independent Study*** Credit: 0 to 16 hours.

(CEE 497) Individual investigations or studies of any phase of civil engineering selected by the student and approved by the adviser and the staff member who will supervise the investigation. Prerequisite: Consent of instructor.

598 ***Special Topics*** Credit: 1 to 4 hours.

(CEE 498) Structured presentations of new and developing areas of knowledge in civil engineering at an advanced graduate level. Prerequisite: Individually identified for each offering under this course number; see Schedule.

599 ***Thesis Research*** Credit: 0 to 16 hours.

(CEE 499) May be repeated. Approved for S/U grading only.