

# Department of Civil and Environmental Engineering

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## Degrees Offered

- Master of Science, Civil Engineering (M.S.C.E.)
- Doctor of Philosophy, Civil Engineering (Ph.D.)

The Department of Civil and Environmental Engineering offers the degree of master's of science in civil engineering (M.S.C.E.). In conjunction with the Benjamin M. Statler College of Engineering and Mineral Resources, the master's of science in engineering (M.S.E.) and the doctor of philosophy degrees are available with emphases in civil engineering.

## Program Objectives

- Have the ability to work on multidisciplinary teams, have high technical competence, and have the ability to meet present and future challenges in a specialty area of civil and environmental engineering
- Have the ability to effectively plan and execute scientific research or other high-level investigations using the most current methods and techniques in the civil and environmental engineering fields
- Have the ability to effectively communicate the results of their research or investigations through writing and oral presentations
- Have the ability to contribute to the body of engineering knowledge and/or to economic growth by developing the science, the materials, and the technology necessary to deliver vital infrastructure services in the most cost effective manner while protecting the health, safety, and welfare of human society

## Program Outcomes

- Graduates will have an ability to function on teams involving multiple civil engineering specialties.
- Graduates will have an ability to apply advanced methodologies in their specialty area.
- Graduates will have an ability to effectively communicate technical information.
- Graduates will have an ability to design and conduct experiments, analyze and interpret data, and develop recommendations.
- Graduates will have an understanding of professional and ethical responsibility.
- Graduates will have an ability to understand the impact of engineering solutions in global and societal context.
- Graduates will have a recognition of the need to engage in life-long learning.
- Graduates will have an ability to use contemporary techniques, skills, and tools necessary for engineering practice in education, industry, and/or government.

## Student Learning Outcomes

- Graduates will meet the academic standards required by WVU for those in graduate school while completing courses pertinent to their specialty area and as specified in their plan of study.
- Graduates will conduct experimental or investigatory work necessary to satisfy the requirements of either the thesis option or report option for graduation.
- Graduates will write and orally defend a thesis, a report, or a dissertation.
- Graduates will serve in primary roles as graduate research assistants on research projects or on problem investigations sponsored by companies, associations, or government agencies looking for new methodology or science to resolve problems associated with the planning, design, construction, operation, and maintenance of the infrastructure or for related needs.

## Areas of Concentration

There are five major areas of interest of the faculty and graduate studies:

- Construction engineering and management, which includes construction project planning and cost control; construction operations; construction safety and health; sensing, analytics, simulation, and visualization for construction and infrastructure practices; integrated and automated construction; building information modeling; infrastructure planning; construction profitability; asset management and risk control
- Environmental and water resources, which includes wetland and natural stream restoration; water, waste water, and industrial waste treatment; site remediation; groundwater hydraulics, hydrology, sediment transport, fluid mechanics, water and health, and satellite remote sensing of hydrological processes
- Geotechnical engineering, which includes soil mechanics, foundations engineering, soil-structure interaction, geomechanics, geoenvironmental, groundwater and seepage, geosynthetics, contaminant transport, earthwork design, and waste by-product utilization
- Transportation engineering, which includes planning, design, construction, operations, and maintenance of transportation facilities/systems (roadways, railroads, airports, and public transportation) as well as related areas of infrastructure management and expert systems

- Structural engineering, which includes advanced structural mechanics, structural dynamics, bridge engineering, building design for static and dynamic loads, advanced materials for civil infrastructure, and nondestructive testing and evaluation

## Faculty

The Department of Civil and Environmental Engineering has a full-time faculty of twenty-three who are active in teaching, research, and professional commitments. Many of the faculty members are licensed professional engineers registered in one or more states and are involved in state, regional, and national professional organizations, serving on numerous technical committees. They are successful researchers and have published extensively in technical journals. The Civil and Environmental Engineering faculty produces graduates who can assume the problem solving, decision-making, and technical leadership roles of a professional engineer and who have the sound educational background for the continuing professional development the field requires.

Students tailor their program of study to pursue individual topics of interests with guidance from a faculty advisor. Opportunities abound within the master's and doctoral tracks for a research experience in which the student tackles an engineering problem individually with guidance from a faculty advisor. The graduate program in civil engineering was established with the aim of developing its students' abilities to use today's contemporary methods of engineering analysis and design to solve tomorrow's engineering problems.

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## FACULTY

### CHAIR

- Hema J. Siriwardane - Ph.D., P.E. (Virginia Polytechnic Institute and State University)  
Geomechanics/Geotechnical Engineering, Finite Element Method, Computer Applications

### PROFESSORS

- Hung-Liang (Roger) Chen - Ph.D. (Northwestern University)  
Structural Dynamics, Structural Experimentation, Dynamic Soil-Structure Interaction, Damage in Reinforced Concrete Structures, Nondestructive Evaluation, Concrete
- Hota GangaRao - Ph.D., P.E. (North Carolina State University)  
Maurice A. and Jo Ann Wadsworth Distinguished Professor, Director of the Constructed Facilities Center, Director of the NSF Center for Integration of Composites into Infrastructure, Mathematical Modeling of Engineering Systems, Bridge Engineering, Composite Material Characterization and Implementation
- Udaya B. Halabe - Ph.D., P.E. (Massachusetts Institute of Technology)  
Nondestructive Evaluation and In-Situ Condition Assessment of Structures and Materials, Elastic and Electromagnetic (Radar) Wave Propagation, Structural Analysis and Design, Structural Dynamics and Wind/Earthquake Resistant Design
- Lian-Shin Lin - Ph.D., P.E. (Purdue University)  
Physiochemical and Biological Treatment, Innovative Wastewater Technologies, Emerging Coaminants, Sustainable Development, Watershed Pollution
- David R. Martinelli - Ph.D. (University of Maryland)  
Transportation Engineering, Traffic Operations, Systems Analysis, Infrastructure Management
- Radhey Sharma - Ph.D. (University of Oxford)  
Sustainable Infrastructure, Geotechnical Engineering and Geoenvironmental, Energy Engineering
- Hema J. Siriwardane - Ph.D., P.E. (Virginia Polytechnic Institute and State University)  
Geomechanics/Geotechnical Engineering, Finite Element Method, Computer Applications
- John P. Zaniwski - Ph.D., (University of Texas)  
Asphalt Technology Professor, Pavement Materials, Design, Construction, Maintenance, Infrastructure Management

### ASSOCIATE PROFESSOR

- Karl Barth - Ph.D. (Purdue University)  
Jack H. Samples Distinguished Professor of Structures, Steel Structures, Bridge Design and Rehabilitation, Connections, Stability Analysis, Experimental Mechanics
- Leslie Clark Hopkinson - Ph.D. (Virginia Polytechnic Institute and State University)  
Surface Hydrology, Environmental Hydraulics, Ecological Engineering, River Mechanics
- John D. Quaranta - Ph.D., P.E. (West Virginia University)  
Geotechnical/Geo-Environmental Engineering, Soil Testing and Characterization, Soil and Mine Waste Dewatering, Geo-Synthetics, Soil and Groundwater Remediation

## ASSISTANT PROFESSORS

- Omar I. Abdul-Aziz - Ph.D. (University of Minnesota, Twin Cities)  
Ecological-Water Resources Engineering; Scaling of Hydro-Ecological and Biochemical Variables; Modeling of Stream Water Quality and Ecosystem Carbon; Fluid Mechanics; Hydrology
- Fei Dai - Ph.D. (Hong Kong Polytechnic University)  
Construction Engineering, Construction Management, Construction Information Technologies
- Kakan Day - Ph.D. (Clemson University)  
Intelligent Transportation Infrastructure Design and Analysis; Connected and Automated Vehicle Technology; Traffic Operations; Big Data Analytics for Transportation Data Management; Artificial Intelligence in Transportation.
- Seung Hong - Ph.D. (Georgia Institute of Technology)  
Hydraulic engineering, Sediment transport, Erosion control
- Antarpreet Jutla - Ph.D. (Tufts University)  
Water Resources, Hydrology & Human Health, Remote Sensing, Issues of Scales in Hydroclimatic Processes
- P.V. Vijay - Ph.D. (West Virginia University)  
Concrete Structures; P Composite Structures for Bridges, Buildings, and Pavements; Aging of Structures and Rehabilitation, Recycled Polymers for Infrastructure, Analytical Modeling
- Yoojung Yoon - Ph.D. (Purdue University)  
Infrastructure Asset Management, Risk Management in Construction, Project Management and Control, Construction Equipment Management
- Dimitra Pyrialakou - Ph.D. (Purdue University)  
Transportation Engineering, Transportation Planning and Evaluation, Public and Rail Transportation, Airport Operations, Transportation Econometrics, and Transportation Engineering Education.

## RESEARCH ASSISTANT PROFESSORS

- Ruifeng (Ray) Liang - Ph.D. (Institute of Chemistry, Chinese Academy of Sciences)

## PROFESSORS EMERITUS

- Ronald W. Eck - Ph.D. (Clemson University)
- Donald Gray - Ph.D. (Purdue University)
- W. Joseph Head - Ph.D. (Purdue University)
- Charles R. Jenkins - Ph.D. (Oklahoma State University)
- Larry D. Luttrell - Ph.D. (Cornell University)
- William A. Sack - Ph.D. (Michigan State University)

## ASSOCIATE PROFESSORS EMERITUS

- Robert N. Eli - Ph.D. (University of Iowa)
- Darrell R. Dean, Jr. - Ph.D. (Purdue University)

## ADJUNCT ASSOCIATE PROFESSOR

- Avinash Unnikrishnan - Ph.D. (University of Texas, Austin)  
Transportation Network Analysis and Planning, Freight Network Analysis and Logistics, Intelligent Transportation Systems

## LECTURER

- LiYaning (Maggie) Tang - Ph.D. (The Hong Kong Polytechnic University)  
Public-Private Partnership (PPP), Environmental impact assessment (EIA), Construction sustainability, Carbon emission footprint

## Admission

To be eligible for admission into the M.S.C.E. degree program, a candidate must fulfill either of the following:

- Hold or expect to receive a B.S.C.E. degree from either an accredited ABET curriculum or an internationally recognized program
- Have a superior academic record and a baccalaureate degree in another engineering field, mathematics, or science

Candidates with a baccalaureate degree in another field of engineering, mathematics, or science are also eligible for admission into the M.S.E. degree. Candidates are normally required to attain a baccalaureate level of proficiency in areas of emphasis of the department. An engineering technology (non-calculus based) degree is not sufficient qualification for admission into any of the graduate programs offered by the department.

To be eligible for admission into a doctorate of engineering program, a candidate is expected to hold or expect to receive a B.S. or an M.S. degree or equivalent in the following:

A discipline of engineering from an institution which has an ABET accredited program in that discipline which has an internationally recognized program in engineering, or mathematics and sciences (as specified by individual programs).

The other requirements for admission into the graduate programs of the department are summarized as follows:

- Grade point average of 3.0 or better (out of a possible 4.0) in all previous college work and must meet all other requirements below.
- Three reference letters; at least two of the three references should be from the institution the applicant last attended.
- International students must demonstrate proficiency in communicating in English (a minimum TOFEL score of 550, or iBT score of 79, or IELTS score of 6.5) (Students who have completed a recent four-year bachelor's degree in the the USA need not submit these scores.)
- All applicants are encouraged to submit GRE scores for fellowship and funding options. Applicants who have not received their undergraduate degree in the United States are required to submit GRE General Test scores with the Engineering Subject Test score being optional.

## Provisional Admission

An applicant who is not qualified for regular graduate student admission status, due either to insufficient grade-point average, incomplete credentials, or inadequate academic background, can be admitted as a provisional student. Requirements for attaining regular student status must be stated in the letter of admission. Provisional students must sign a contract, which lists these requirements in detail, no later than their first registration.

## Curriculum in Masters of Science in Civil Engineering

A candidate for the M.S. degree in civil engineering must comply with the rules and regulations as outlined in the WVU Graduate Catalog and the specific requirements of the Statler College and the Civil and Environmental Engineering Department.

## Program Requirements

All M.S. degree candidates are required to perform research and follow a planned program of study. The student's research advisor, in conjunction with the student's Advising and Examining Committee (AEC) will be responsible for determining the plan of study appropriate to the student's needs. The underlying principle of the planned program is to provide the students with the necessary support to complete their degree and prepare them for their career.

## Curriculum Requirements

A minimum cumulative GPA of 3.0 is required in all courses

### Course Requirements \*

A minimum of 60% of courses must be from 500 level or above

A minimum cumulative GPA of 3.0 is required in all coursework used for degree requirements

Any CE courses 500-799

15

Select the following based on degree path:

9

Any AEM, AGBI, BIOC, BIOL, BIOM, BIOS, CE, CHE, CHEM, CPE, CS, EE, ENVP, GEOL, IENG, IH&S, MAE, MATH, MINE, PNGE, PHYS, SAFM, SENG, STAT, or WMAN courses 400-799

Complete 1 of the following options:

6-12

### Thesis Option - 6 hours

CE 697 Research (6 hours)

Written Research Proposal

Thesis

Final Oral or Written Examination

### Problem Report Option - 9 hours

Complete 6 additional hours of coursework

CE 697 Research (3 hours)

Written Research Proposal

Formal written report or professional report/paper

Final Oral or Written Examination

### Coursework Option - 12 hours \*\*

Complete 12 additional hours of coursework

Final Oral or Written Examination

Total Hours

30-36

\* Students who do not hold a baccalaureate degree in civil engineering are required to take a set of undergraduate civil engineering courses above and beyond the minimum coursework requirements.

\*\* Although rarely permitted, this option is open to students with practical engineering experience or those who have demonstrated an ability to organize and develop a project and write a technical report. Approval to pursue this option must be obtained from the student's AEC, the graduate program coordinator, and the department chairperson.

## Final Examination

M.S. students following the thesis or problem report option must prepare a written research proposal. The proposal must be approved by the student's AEC at least one semester prior to the final oral examination.

All students, regardless of option, are required to pass a final oral or written examination, administered by their AEC, covering the thesis or problem report and/or related course material.

## Suggested Plan of Study

The plan below illustrates the Thesis Option. It is important for students to take courses in the order specified as much as possible; all prerequisites and concurrent requirements must be observed. A typical M.S.C.E degree program that completes degree requirements in two years is as follows.

### First Year

| Fall              | Hours Spring        | Hours |
|-------------------|---------------------|-------|
| CE Course         | 3 CE Course         | 3     |
| CE Course         | 3 Additional Course | 6     |
| Additional Course | 3                   |       |
|                   | 9                   | 9     |

### Second Year

| Fall      | Hours Spring | Hours |
|-----------|--------------|-------|
| CE Course | 3 CE Course  | 3     |
| CE 697    | 3 CE 697     | 3     |
|           | 6            | 6     |

Total credit hours: 30

## Curriculum in Doctor of Philosophy – Civil Engineering

A candidate for the Ph.D. degree with a major in civil engineering must comply with the rules and regulations as outlined in the WVU Graduate Catalog and the specific requirements of the Statler College and the Civil and Environmental Engineering Department.

### Program Requirements

The doctor of philosophy degree with a major in civil engineering is administered through the college's interdisciplinary Ph.D. program. The research work for the doctoral dissertation must show a high degree of originality on the part of the student and must constitute an original contribution to the art and science of civil engineering.

All Ph.D. degree candidates are required to perform research and follow a planned program of study. The student's research advisor, in conjunction with the student's Advising and Examining Committee (AEC) will be responsible for determining the plan of study appropriate to the student's needs. The underlying principle of the planned program is to provide the students with the necessary support to complete their degree and prepare them for their career.

### Curriculum Requirements

A minimum cumulative GPA of 3.0 is required in all courses

A minimum cumulative GPA of 3.0 is required in all coursework used for degree requirements

#### Course Requirements\*

Any AEM, AGBI, BIOC, BIOL, BIOM, BIOS, CE, CHE, CHEM, CPE, CS, EE, ENVP, GEOL, IENG, IH&S, MAE, MATH, MINE, PNGE, PHYS, SAFM, SENG, STAT, or WMAN courses 500-799 18

Research 24

CE 797 Research

#### Examinations

Qualifying Exam

Candidacy Exam

## Final Exam

Total Hours

42

- \* Students who do not hold a baccalaureate degree in civil engineering are required to take a set of undergraduate civil engineering courses above and beyond the minimum coursework requirements.  
A minimum of forty-two hours of coursework and thirty hours of independent research beyond a bachelor's degree, or eighteen hours of coursework and twenty-four hours of independent research beyond an M.S. degree are required.

## Graduate Committee

For the Ph.D. program, the student, research advisor, academic advisor, and department chairperson appoint the student's AEC. Each committee must consist of at least five members, with at least three members from CEE, and at least one from outside the department. By the end of the Ph.D. student's second semester, the student, with the advice and consent of the academic advisor, graduate coordinator, and members of the student's AEC, submits a plan of study, initiated in CEE, to the dean.

## Examinations

### QUALIFYING EXAM

All students must take and pass a written qualifying examination. Normally, the qualifying examination is given no later than one semester after completion of eighteen credit hours toward the doctoral degree. This examination is designed to assess the basic competency of students in the civil engineering field to determine whether or not they have sufficient knowledge to undertake independent research.

### CANDIDACY EXAMINATION

In order to be admitted to candidacy, the student must pass a candidacy exam, which is designed to evaluate the student's overall ability to engage in high-level research. After passing the qualifying examination, the student must submit to the AEC a written research proposal of his/her planned dissertation work and successfully defend it in an oral examination. The research proposal must be approved by the student's AEC. A student who has successfully completed all coursework, passed the qualifying examination, and successfully defended the research proposal, and receives the college's approval becomes a candidate for a Ph.D. degree in CE. Thereafter, the student will officially be engaged in dissertation research. At the completion of the dissertation research, the candidate must prepare a dissertation and defend it orally at the final defense conducted by the AEC.

A student who has successfully completed all coursework, passed the qualifying examination, and successfully defended the research proposal is defined as one who is a candidate for the Ph.D. degree.

### FINAL EXAMINATION

At the completion of the dissertation research, candidates must prepare a dissertation and pass the final oral examination (defense) administered by their AEC.

In order to complete the Ph.D. requirements, a student must pass a final oral examination on the results embodied in the dissertation. This examination is open to the public and, in order to evaluate critically the student's competency, may include testing on material in related fields, as deemed necessary by the AEC. In addition, since the Ph.D. degree is primarily a research degree that embodies the results of an original research proposal and represents a significant contribution to scientific literature, the student must submit a manuscript on this research to the AEC.

## Suggested Plan of Study

It is important for students to take courses in the order specified as much as possible; all prerequisites and concurrent requirements must be observed. A typical doctoral degree program that completes degree requirements in three years beyond an M.S. degree is as follows.

### First Year

| Fall      | Hours Spring | Hours |
|-----------|--------------|-------|
| CE Course | 3 Course     | 3     |
| CE Course | 3 Course     | 3     |
| CE 797    | 3 CE 797     | 3     |
|           | 9            | 9     |

### Second Year

| Fall   | Hours Spring | Hours |
|--------|--------------|-------|
| Course | 3 Course     | 3     |
| CE 797 | 6 CE 797     | 6     |
|        | 9            | 9     |

**Third Year**

| <b>Fall</b> | <b>Hours Spring</b> | <b>Hours</b> |
|-------------|---------------------|--------------|
| CE 797      | 9 CE 797            | 9            |
|             | 9                   | 9            |

Total credit hours: 54

**Major Learning Outcomes****CIVIL ENGINEERING**

## Program Objectives

- Have the ability to work on multidisciplinary teams, have high technical competence, and have the ability to meet present and future challenges in a specialty area of civil and environmental engineering
- Have the ability to effectively plan and execute scientific research or other high-level investigations using the most current methods and techniques in the civil and environmental engineering fields
- Have the ability to effectively communicate the results of their research or investigations through writing and oral presentations
- Have the ability to contribute to the body of engineering knowledge and/or to economic growth by developing the science, the materials, and the technology necessary to deliver vital infrastructure services in the most cost effective manner while protecting the health, safety, and welfare of human society

## Program Outcomes

- Graduates will have an ability to function on teams involving multiple civil engineering specialties.
- Graduates will have an ability to apply advanced methodologies in their specialty area.
- Graduates will have an ability to effectively communicate technical information.
- Graduates will have an ability to design and conduct experiments, analyze and interpret data, and develop recommendations.
- Graduates will have an understanding of professional and ethical responsibility.
- Graduates will have an ability to understand the impact of engineering solutions in global and societal context.
- Graduates will have a recognition of the need to engage in life-long learning.
- Graduates will have an ability to use contemporary techniques, skills, and tools necessary for engineering practice in education, industry, and/or government.

## Student Learning Outcomes

- Graduates will meet the academic standards required by WVU for those in graduate school while completing courses pertinent to their specialty area and as specified in their plan of study.
- Graduates will conduct experimental or investigatory work necessary to satisfy the requirements of either the thesis option or report option for graduation.
- Graduates will write and orally defend a thesis, a report, or a dissertation.
- Graduates will serve in primary roles as graduate research assistants on research projects or on problem investigations sponsored by companies, associations, or government agencies looking for new methodology or science to resolve problems associated with the planning, design, construction, operation, and maintenance of the infrastructure or for related needs.

**COURSES****CE 511. Pavement Design. 3 Hours.**

PR: CE 451 or consent. Effects of traffic, soil, environment, and loads on the design and behavior of pavement systems. Design of pavement systems. Consideration of drainage and climate. Pavement performance and performance surveys. (3 hr. rec.).

**CE 515. Flexible Pavements. 3 Hours.**

Design, construction and mathematics of flexible pavements, including material characterization, mix design, construction methods, pavement design and evaluation, and maintenance procedures.

**CE 520. Groundwater Dynamics. 3 Hours.**

PR: Consent. Introduction to groundwater, formulation of equations for saturated and unsaturated flow, analytical solutions for steady and transient cases, transport of pollutants, and numerical techniques. (3 hr. lec.).

**CE 522. Free Surface Hydrodynamics. 3 Hours.**

PR: CE 322 or consent. The dynamics of liquid flow with a free surface under the influence of gravity; open channel hydraulics, wave motion, and buoyancy effects. (3 hr. lec.).

**CE 524. Groundwater Engineering. 3 Hours.**

PR: CE 322 or consent. Introduction to the nature, hydrology, mechanics, technology, and quality of groundwater. Well solutions in confined, leaky, and unconfined aquifers. Modeling concepts and public-domain computer programs.

**CE 526. Environmental Systems Modeling. 3 Hours.**

Theory and practice of systems thinking to understand the complexities of the hydrological cycle, analysis of hydrological time series for detection of trends and frequencies, stochastic and deterministic models for system dynamics, issues of equifinality and uncertainty.

**CE 530. Probability, Reliability, and Statistical Methods in Engineering Design. 3 Hours.**

PR: Consent. Accounting for influence of uncertainty and reliability in analysis and design of Civil Engineering systems.

**CE 531. Pedestrian/Bike Transportation. 3 Hours.**

Planning, design, operation and maintenance of pedestrian and bicycle facilities, including multi-use trail, and in-depth examination of policies, programs and design principles to encourage non-motorized travel.

**CE 533. Geometric Design of Highways. 3 Hours.**

PR: Consent. The theory and practice of geometric design of modern highways, horizontal and vertical alignment, cross-slope, design speed, sight distances, interchanges, and intersections. Critical analysis of design specifications. (2 hr. lec., 3 hr. lab.).

**CE 534. Introduction to Traffic Engineering. 3 Hours.**

PR: CE 332 or consent. The purpose, scope, and methods of traffic engineering. Laboratory devoted to conducting simple traffic studies, solving practical problems, and designing traffic facilities. (2 hr. lec., 3 hr. lab.).

**CE 538. Highway Safety Engineering. 3 Hours.**

PR: CE 431 or consent. Relationship between human, vehicular, and roadway factors which impact safety; functional requirements of highway safety features; legal aspects; accident analysis; evaluation of highway safety projects. (3 hr. lec.).

**CE 539. Traffic Engineering Operations. 3 Hours.**

PR: CE 534. Theory and practice of application of traffic engineering regulations; traffic control concepts for urban street systems and freeways; freeway surveillance and incident management; driver information systems; traffic control system technology and management. (3 hr. lec.).

**CE 540. Environmental Chemistry and Biology. 3 Hours.**

PR: CE 322 or consent. Study of physical and chemical properties of water. Theory and methods of chemical analysis of water, sewage, and industrial wastes. Biological aspects of stream pollution problems. (2 hr. lec., 3 hr. lab.).

**CE 542. Physicochemical Treatment. 3 Hours.**

PR: CE 347 or consent. Engineering topics on water and wastewater treatment based on pollutant's physical and chemical characteristics will be presented, including human health concerns related to water, regulations, reactor theory, transport phenomena, and various treatment technologies.

**CE 543. Water Quality Modeling and Analysis. 3 Hours.**

PR: CE 347 or consent. Theories, methodologies and data analyses will be presented for water quality modeling in surface and groundwater, and for determining water quality distributions, trends, and compliance with regulatory standards.

**CE 546. Principles of Biological Waste Treatment. 3 Hours.**

PR: CE 540 or consent. Examination of biological treatment systems related to microbiology and function. Models used to describe system behavior and kinetics are developed. Laboratory and field experiments are performed to understand the relation between operation and design. (2 hr. lec., 3 hr. lab.).

**CE 547. Applied Wetlands Ecology and Management. 3 Hours.**

The management and ecology of wetland vegetation, soils, hydrology, and wildlife. (Offered in fall of odd years. Also listed as WMAN 547 and PLSC 547.).

**CE 549. Solid and Hazardous Waste Management. 3 Hours.**

PR: Consent. Patterns and problems of solid waste storage, transport, and disposal. Examinations of various engineering alternatives with appropriate consideration for air and water pollution control and land reclamation. Analytical approaches to recovery and reuse of materials. (2 hr. lec., 3 hr. lab.).

**CE 550. Soil Properties and Behavior. 3 Hours.**

PR: CE 451 or consent. Soil mineralogy and the physicochemical properties of soils and their application to an understanding of permeability, consolidation, shear strength, and compaction. Prediction of engineering behavior of soils in light of physicochemical concepts. (3 hr. lec.).

**CE 551. Soil Testing. 3 Hours.**

PR: CE 351 or consent. Experimental evaluation of soil properties and behavior. Emphasis is placed on the proper interpretation of experimental results and application of such results to practical problems. (1 hr. lec., 6 hr. lab.).

**CE 552. The Finite Element Method. 3 Hours.**

PR: Graduate standing in CE or MAE or consent. Introductory treatment of theoretical basis of finite element method, mathematical formulation, different types of elements, stress analysis in solids, applications, and computer implementation.

**CE 553. Advanced Finite Element Methods. 3 Hours.**

PR: Consent. Formulation procedures and applications of finite element methods to two- and three-dimensional problems, techniques for nonlinear analysis, computer implementation, applications in field problems, flow, and dynamics.



**CE 561. Statically Indeterminate Structures. 3 Hours.**

PR:CE 461 or consent. Force and displacement methods of analysis; energy principles and their application to trusses, frames, and grids; effects of axial forces; influence lines for frames, arches, and trusses; secondary stress analysis. (3 hr. lec.).

**CE 563. Introduction to Structural Dynamics. 3 Hours.**

PR:CE 561 PR: CE 561. General theory for dynamic response of systems having one or several degrees of freedom. Emphasis on the application of dynamic response theory to structural design. (3 hr. lec.).

**CE 564. Nondestructive Material and Structural Evaluations. 3 Hours.**

PR: Consent. Nondestructive evaluation (NDE) using techniques based on mechanical and electromagnetic wave propagation; theory and applications of various NDE techniques including infrared thermography, dynamic characterization, seismic reflection and refraction, ultrasonics, acoustic emission, and radar. (3 hr. lec.).

**CE 566. Advanced Materials for Infrastructure. 3 Hours.**

PR:CE 462 and CE 463. Introduction to principles of material science; material structure, characterization at coupon and component level, practical information on fiber-reinforced shapes; establishment of failure analysis and standardization. (3 hr. lec.).

**CE 567. Prestressed Concrete. 3 Hours.**

PR:CE 461 and CE 462 or consent. Behavior and design of prestressed concrete members. Materials, bending, shear, torsion, methods of prestressing, prestress losses, deflections, compression members, composite members, and indeterminate structures. (3 hr. lec.).

**CE 591A-Z. Advanced Topics. 1-6 Hours.**

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

**CE 593A-Z. Special Topics. 1-6 Hours.**

A study of contemporary topics selected from recent developments in the field.

**CE 594A-Z. Seminar. 1-6 Hours.**

Seminars arranged for advanced graduate students.

**CE 693A-C. Special Topics. 1-6 Hours.**

A study of contemporary topics selected from recent developments in the field.

**CE 695. Independent Study. 1-6 Hours.**

Faculty supervised study of topics not available through regular course offerings.

**CE 697. Research. 1-15 Hours.**

PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project, or a dissertation. (Grading may be S/ U.).

**CE 721. Environmental Fluid Mechanics. 3 Hours.**

PR: Consent. Equations of motion including buoyancy and Coriolis force; mechanics of jets and plumes; diffusion, dispersion, and mixing in rivers, lakes, reservoirs, and estuaries. (3 hr. lec.).

**CE 722. Deterministic Hydrology. 3 Hours.**

PR: Consent. An in-depth treatment of the dynamics of the accumulation of runoff, including the formulation of the unsteady surface flow equations and the unsteady saturated-unsaturated subsurface flow equations. Both analytical and numerical solutions are presented with applications. (3 hr. lec.).

**CE 732. Transportation Systems Analysis. 3 Hours.**

PR: Consent. Systematic examination of the interaction between transport technology, activity systems, and traffic flows. Quantitative analysis of the relationship among vehicle cycles, networks, congestion, choice behavior, cost functions, and resulting travel-market equilibration. (3 hr. lec.).

**CE 744. Industrial and Advanced Waste Treatment. 3 Hours.**

PR or Conc: CE 540 or consent. Basic physical and chemical unit operations used in industrial and advanced waste treatment; applications for waste water reclamation and reuse; study of industrial wastes from standpoint of process, source, and treatment. (2 hr. lec., 3 hr. lab.).

**CE 751. Advanced Mechanics of Soils. 3 Hours.**

PR: CE 351 and CE 551 and MAE 640 or consent. Stress invariants, stress history and stress path, elastic and quasi-elastic models for soils; soil plasticity, failure theories for soils; critical state soil mechanics, and determination of construction parameters. (3 hr. lec.).

**CE 752. Advanced Foundation Analysis. 3 Hours.**

PR: CE 451 or consent. Study of soil-structure interaction. Applications of principles of soil mechanics and numerical methods for analysis and design of geotechnical structures: strip footings, axially and laterally loaded piles, braced excavations, sheet pile walls, tunnel lining, and buried pipes and culverts. (3 hr. lec.).

**CE 753. Advanced Earthwork Design. 3 Hours.**

PR: CE 453 or consent. Application of the principles of theoretical soil mechanics to the design of embankments of earth and rock. In-depth study of compaction theory, and stability of natural and man-made slopes by limit equilibrium and deformation considerations. (3 hr. lec.).

**CE 754. Groundwater and Seepage. 3 Hours.**

PR: Consent. Flow of groundwater through soils and its application to the design of highways and dams and to construction operations. Emphasis is placed on both the analytical and classical flow net techniques for solving seepage problems. (3 hr. lec.).

**CE 756. Soil Dynamics. 3 Hours.**

PR: CE 550 and consent. Consideration of the simple damped oscillator, wave propagation in elastic media, dynamic field and laboratory tests, dynamic soil properties, and foundation vibrations. Introduction to geotechnical aspects of earthquake engineering. (3 hr. lec.).

**CE 760. Finite Element Methods in Structural Analysis. 3 Hours.**

PR: CE 561 or consent. Relationships of elasticity theory; definitions and basic element operations; direct and variational methods of triangular and rectangular elements related to plane stress, plane strain, and flat plates in bending; variational principles in global analysis. (3 hr. lec.).

**CE 761. Bridge Engineering. 3 Hours.**

PR: CE 561 or consent. Statically indeterminate trusses, continuous trusses; steel and concrete arches; long-span and suspension bridges; secondary stresses. (3 hr. lec.).

**CE 763. Behavior of Steel Members. 3 Hours.**

PR: CE 463 or consent. Elastic behavior of steel members subjected to axial load, bending, and torsion. Elastic and inelastic response of beams, columns, and beam-columns to load and the resulting design implications. Comparison with standard steel codes and specifications. (3 hr. lec.).

**CE 765. Structural Design for Dynamic Loads. 3 Hours.**

PR: CE 563 or consent. Nature of dynamic loading caused by earthquakes and nuclear weapons blasts; nature of dynamic resistance of structural elements and structural systems; criteria for design of blast-resistance and earthquake-resistant structures; simplified and approximate design methods. (3 hr. lec.).

**CE 767. Behavior of Reinforced Concrete Members. 3 Hours.**

PR: CE 462 or consent. Studies of actual member behavior; members in flexure, combined flexure, shear, and torsion; bond and anchorage; combined axial load and flexure; slender columns; deep beams; derivation of current code provisions. (3 hr. lec.).

**CE 768. Behavior and Design of Fiber Reinforced Polymer Members. 3 Hours.**

PR: Consent. Studies of fiber reinforced polymer (FRP) composite member behavior including rebars and wraps for concrete, under flexure, axial, shear forces, and combined effects; design, durability, and rehabilitation of FRP members and systems including field applications.

**CE 790. Teaching Practicum. 1-3 Hours.**

PR: Consent. Supervised practice in college teaching of civil engineering. Note: This course is intended to insure that graduate assistants are adequately prepared and supervised when they are given college teaching responsibility. It will also present a mechanism for students not on assistantships to gain teaching experience. (Grading will be S/U.).

**CE 791A-Z. Advanced Study. 1-6 Hours.**

PR: Consent. Investigation of advanced topics not covered in regularly scheduled courses.

**CE 792A. Directed Study. 1-6 Hours.**

Directed study, reading and/or research.

**CE 793. Special Topics. 1-6 Hours.**

A study of contemporary topics selected from recent developments in the field.

**CE 794. Seminar. 1-6 Hours.**

Special seminars arranged for advanced graduate students.

**CE 795. Independent Study. 1-9 Hours.**

Faculty supervised study of topics not available through regular course offerings.

**CE 796. Graduate Seminar. 1 Hour.**

PR: Consent. Each graduate student will present at least one seminar to the assembled faculty and graduate student body of his or her program.

**CE 797. Research. 1-15 Hours.**

PR: Consent. Research activities leading to thesis, problem report, research paper or equivalent scholarly project or dissertation. (Grading may be S/U.).

**CE 798. Thesis or Dissertation. 1-6 Hours.**

PR: Consent. This is an optional course for programs that wish to provide formal supervision during the writing of student reports (698), or dissertations (798). Grading is normal.

**CE 799. Graduate Colloquium. 1-6 Hours.**

PR: Consent. For graduate students not seeking coursework credit but who wish to meet residency requirements, use the University's facilities, and participate in its academic and cultural programs. Note: Graduate students who are not actively involved in coursework or research are entitled, through enrollment in their department's 699/799 Graduate Colloquium to consult with graduate faculty, participate in both formal and informal academic activities sponsored by their program, and retain all of the rights and privileges of duly enrolled students. Grading is S/U; colloquium credit may not be counted against credit requirements for masters programs. Registration for one credit of 699/799 graduate colloquium satisfies the University requirement of registration in the semester in which graduation occurs.

**CE 900. Professional Development. 1-6 Hours.**

Professional development courses provide skill renewal or enhancement in a professional field or content area (e.g., education, community health, geology). The continuing education courses are graded on a pass/fail grading scale and do not apply as graduate credit toward a degree program.