CEGR 6251: ANALYSIS AND DESIGN OF DEEP FOUNDATIONS

Proposed and to be taught by:
Dr. Miguel A. Pando, Associate Professor of Civil & Environmental Engineering

Graduate Catalog – Information and Description
CEGR 6251. Analysis and Design of Deep Foundations. (3). Prerequisites: CEGR 3278 - Geotechnical Engineering I or consent of the instructor, graduate student status. Methodologies for analysis and design of deep foundations including different construction layouts and configurations (e.g., single and group piles), different installation techniques (e.g., driven, drilled, ACIP, etc.), different loading conditions (e.g., axial compression, axial tension, lateral, general loading, etc), different design approaches (e.g., allowable stress design – ASD, and load and resistance factor design - LRFD), among other topics; New emerging technologies, construction and inspection aspects and their implications on deep foundation design, and other topics. (Fall)

# Credit Hours: 3

Frequency: Offered every fall semester

Prerequisites: CEGR 3278 - Geotechnical Engineering I or consent of the instructor, graduate student status.

Course Objectives
The primary objective of this course is to gain an understanding of the analysis and design of deep foundations. Another objective is to critically assess project design considerations and geotechnical site conditions to select and design a suitable deep foundation system. Another objective is to learn deep foundation modeling software that is commonly used in geotechnical engineering practice.

By the end of the course, students will be able to:
1. Identify different deep foundation systems including their characteristics, advantages, limitations, and applications.
2. Appraise civil engineering project requirements and conditions in relation to the selection of appropriate deep foundation system alternatives for a project.
3. Design and interpret pile load tests.
4. Perform analysis and design of driven piles including driveability analyses (WEBAP), prepare pile driving recommendations, and be familiar with PDA and CAPWAP.
5. Perform analysis and design of drilled shafts.
6. Perform analysis and design of micropiles and other specialty deep foundations (ACIP, fundex, etc).
7. Utilize deep foundation design software (e.g., Driven, A-pile, LPILE, Group, FB-Pier, etc).
8. Design deep foundations for uplift, negative skin friction effects, scour, seismic loading, and other special design considerations.

Instructional Method: Lecture
Evaluation and Grading

<table>
<thead>
<tr>
<th>Item</th>
<th>Percentage of Final Grade</th>
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<tbody>
<tr>
<td>Quizzes (2 to 4)</td>
<td>10%</td>
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<tr>
<td>Homeworks</td>
<td>20%</td>
</tr>
<tr>
<td>Team Paper and Presentation</td>
<td>20%</td>
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<tr>
<td>Midterm Test</td>
<td>20%</td>
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<tr>
<td>Final Exam</td>
<td>30%</td>
</tr>
</tbody>
</table>

Final grade:
- A: 90% 100%
- B: 80% 89.9%
- C: 70% 79.9%
- U: Below 70%

Course Textbook

There is no single course textbook. The course material will consist of course handouts and references which will be posted in the course Moodle page (Transferring to Moodle 2 in Progress).

Some useful references for this course which will be posted include:

Important Course Policies

Classroom Expectations

This syllabus contains the policies and expectations I have established for CEGR 6090/INES8090 – Analysis and Design of Deep Foundations (Deep Foundations). Please read the entire syllabus carefully before continuing in this course. These policies and expectations are intended to create a productive learning atmosphere for all students. Unless you are prepared to abide by these policies and expectations, you risk losing the opportunity to participate further in the course.

Classroom Environment

I will conduct this class in an atmosphere of mutual respect. I encourage your active participation in class discussions. Each of us may have strongly differing opinions on the various topics of class discussions. The conflict of ideas is encouraged and welcome. The orderly questioning of the ideas of others, including mine, is similarly welcome. However, I will exercise my responsibility to manage the discussions so that ideas and arguments can proceed in an orderly fashion. You should expect that if your conduct during class discussions seriously disrupts the
atmosphere of mutual respect I expect in this class, you will not be permitted to participate further.

**Academic Integrity**
All students are required to read and abide by the Code of Student Academic Integrity. Violations of the Code of Student Academic Integrity, including plagiarism, will result in disciplinary action as provided in the Code. Definitions and examples of plagiarism are set forth in the Code. The Code is available from the Dean of Students Office or online (http://legal.uncc.edu/policies/up-407).

You have the responsibility to know and observe the requirements of the UNC Charlotte Code of Student Academic Integrity. This code forbids cheating, fabrication or falsification of information, multiple submissions of academic work, plagiarism, abuse of academic materials, and complicity in academic dishonesty. This includes falsifying attendance records.

**Advanced Notice about Use of Plagiarism Detection Program**
As a condition of taking this course, papers that the instructor in good faith suspects are in whole or in part plagiarized may be subject to submission for textual similarity review to Turnitin.com for the detection of plagiarism. Such works will be included as source documents in the Turnitin.com reference database solely for the purpose of detecting plagiarism of such papers. No student papers will be submitted to Turnitin.com without a student’s written consent and permission (Please fill out and sign Consent Form provided). If a student does not provide such written consent and permission, the instructor may: (i) require a short reflection paper on research methodology; (ii) require a draft bibliography prior to submission of the final paper; or (iii) require the cover page and first cited page of each reference source to be photocopied and submitted with the final paper.

**Attendance Policy**
Attendance is extremely important and expected. It is also your responsibility to obtain missed information when you are absent.

**Class Etiquette**
You will be asked to leave and will be counted absent if you:
- Do not arrive on time.
- Eat in classroom.
- Read newspapers or magazines.
- Do homework in class.
- Unauthorized use of your laptop.
- Use your cell phone or listen to a music device or text messages.
- Are disruptive or disrespectful.

**About Cell Phones and Smart Phones:** The use of cell phones, smart phones, or other mobile communication devices is disruptive, and is therefore prohibited during class. Except in emergencies, those using such devices must leave the classroom for the remainder of the class period.
**Minimum Time Expectations for this 3-credit Graduate Course**

This 3 credit course requires 3 hours of direct faculty classroom instruction and about 6 hours of out-of-class student work each week for approximately 15 weeks. Out-of-class work may include but is not limited to: REQUIRED READING, LIBRARY RESEARCH, WRITTEN ASSIGNMENTS, AND STUDYING FOR QUIZZES AND EXAMS. Please ensure you budget enough hours per week to study and do out-of-class work for this course.

**Late Assignments**

All assignments are expected to be submitted during class time on their assigned date. *Late homeworks will not be accepted.*

Requests for exception to this policy due to medical or other emergency require appropriate documentation (e.g., doctor’s note). This course will utilize a *“Stuff Happens” Card* to allow students one exception for the late submission of one assignment. You may turn in the work up to 24 hours after the due date using this card. After 24 hours you will not be able to submit later assignment.

**Attendance to examinations**

Students are required to attend all examinations. If a student is absent from an examination for a justifiable reason acceptable to the professor, he or she will be given a special examination. Otherwise, he or she will receive a grade of zero in the examination missed.

**Course notifications**

Make sure you check the *Moodle* site for the course periodically and check your university e-mail address.

**Mid-term Unsatisfactory Grades**

You will receive plenty of feedback at regular intervals in this course to allow you to assess your progress. Remember there is no TA in this course so all the grading will be done by me. If you are uncertain how well you are doing please feel free to come and see me during office hours or by appointment.

**Course Outline**

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Syllabus. Introduction, Deep foundation definitions, Axial load transfer process</td>
</tr>
<tr>
<td>2</td>
<td>Overview of driven piles and drilled shafts, construction methods and considerations.</td>
</tr>
<tr>
<td>3</td>
<td>Static methods driven piles</td>
</tr>
<tr>
<td>4</td>
<td>Static methods drilled shafts</td>
</tr>
<tr>
<td>5</td>
<td>Software DRIVEN, SPT97</td>
</tr>
<tr>
<td>6</td>
<td>Settlement of single piles, and pile groups</td>
</tr>
<tr>
<td>7</td>
<td>Settlement of pile groups (continued); Software FB-Pier</td>
</tr>
<tr>
<td>8</td>
<td>Uplift of piles. Note: 10/11 No Class – Student Recess (Fall break)</td>
</tr>
<tr>
<td>9</td>
<td>Negative skin friction</td>
</tr>
<tr>
<td>10</td>
<td>Mid-term exam; and Driven piles allowable stresses</td>
</tr>
<tr>
<td>11</td>
<td>Driven piles: Dynamic formulae, Wave Equation, Analysis; Software</td>
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</tbody>
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| 12 | GRLWEAP; PDA  
Driven piles: CAPWAP; Pile load tests  
Lateral loaded piles. P-y curves, Software LPILE and FB-Pier.  
General loading conditions.  
Specialty deep foundations: micropiles, ACIP, Fundex, etc.  
LRFD design of deep foundations.  
Last Class: Final term papers due and presentations (during class period)  
Final Exam (all-inclusive – duration: 2.5 hours; 13:00 – 15:30)
| (*) Schedule subject to change based on potential project site visits and guest lectures. |
CEGR 6253 Design of Waste Containment Systems

Proposed and to be taught by:
Dr. Vincent Ogunro, Associate Professor of Civil & Environmental Engineering

Graduate Catalog – Information and Description
CEGR 6253. Design of Waste Containment Systems. (3). Prerequisites: Consent of the instructor, graduate student status. Types and function of containment systems; Selection of effective containment system and its design; Design and analysis of landfills, grout curtains and slurry walls; Degradation mechanisms and monitoring of containment systems. (Fall)

# Credit Hours: 3

Frequency: Offered every fall semester

Prerequisites
- An introductory course in soil mechanics or geology
- Proficiency in simple computational methods.

Course Objectives
At the conclusion of this course, students should be able to:
- Apply relevant policies and specifications to the design of waste containment systems.
- Analyze containment system performance requirements.
- Develop approaches to gather required data, select the potentially effective containment systems and measure their performance.
- Understand the functions of different components of a containment system, and formulate numerical methods for assessing their functional capacity.
- Apply the concepts learned to numerically analyze the stability and contaminant transport through components of systems such as landfills, slurry walls, grout curtains, surface impoundments, tanks and cryogenic barriers.

Textbook and References
Considering that this course involves some techniques that have been developed only within the past few years, no single textbook will suffice. Reference materials are drawn from a significant number of recent technical guidance documents of agencies such as the U.S. Environmental Protection Agency (U.S.EPA) and the Department of Energy (U.S.DOE); and from open technical literature. Additional reading assignments will be given from the following text.

Instructional Method: Lecture

Grading Scheme
- Term paper .............................................10%
- Homework .............................................10%
- Midterm Exam .......................................40%
Course Content

1. Regulations And Policies That Pertain To Systems Design:
   - U.S. EPA Regulations And Policies On Waste Containment
   - Design Factors, Containment Decision Support Systems
   - Policies And Programs Of Other Agencies On Waste Containment
   - Technical Issues And Related Disciplines

2. Types And Functions Of Containment Systems:
   - Waste Containment Structures As Multi-Component Systems
   - Configurations Of The Most Common Containment Systems
   - Qualitative And Quantitative Relationships Between Risk, Pollutant Release And Design Aspects
   - Factor Of Safety And Probabilistic Design Approaches
   - Fundamental Concepts Of Risk, Hazard And Reliability As They Apply To Waste Containment Systems

3. Selection Of Potentially Effective Containment System:
   - Site Characterization
   - Categories Of Required Data And Their Sources (Hydrological Data, Hydrogeological Data, Geotechnical Data And Waste Data)
   - Measures Of Performance Effectiveness

4. Design And Analysis Of Landfills:
   - General Configuration And Approach
   - Design Of Cover Systems: general functions and design configurations of cover systems; design standards; cover erosivity analysis; analysis of sliding stability of cover systems; drainage layer evaluation and design; assessment of long-term settlement effects; geomembrane and geotextile applications; assessment of planar stresses in geomembranes analysis of the stability of cover soils above geomembranes
   - Design And Analysis Of Linner Systems: review of simple advection relationships; analysis of simple transit without retardation; analysis of simple transit with suction including the green-ampt wetting front model; analysis of simple transit with retardation
   - The One-Dimensional Advection Dispersion Equation: general numerical configuration and its application to barrier systems; analysis of the most common one-dimensional transport models, including solutions of relevant differential equations; approximate solutions for severely damaged barriers

5. Design And Analysis Of Grout Curtains And Slurry Walls:
   - Introduction To Rheological Properties Of Grouts: practical significance of rheological parameters; analogy between grout permeation of soils and grout flow in pipes; introduction to grouting methods; monitoring of grout performance
   - Types Of Slurry Walls And Their Performance Requirements: stability and flow computations for slurry walls; some slurry wall case histories

6. Other Containment Systems:
7. Degradation Mechanisms And Improvement And Monitoring Of Containment Systems:

- Waste Containment System Deterioration Mechanisms: introduction to structural and material textural changes in barriers; mineral crystallization, dissolution and leaching; approaches to improvement of barrier systems; containment attenuation processes and their enhancement; use of admixtures in barriers; monitoring techniques and technologies for waste containment systems.
CEGR 6254: Experimental Soil Mechanics

Proposed and to be taught by:
Dr. Miguel A. Pando, Associate Professor of Civil & Environmental Engineering

Graduate Catalog - Information and Description
CEGR 6254. Experimental Soil Mechanics. (3). Prerequisites: CEGR 3278 - Geotechnical Engineering I or consent of the instructor, graduate student status. Experimental methods, with emphasis on laboratory tests, to determine engineering soil properties and investigate soil behavior; i) classification tests (i.e., used to identify soil classification and identify general engineering behavior type); and ii) assessment of engineering properties, such as permeability, shear strength, stiffness, and compressibility; Primary lab tests to be covered in this course are: consolidation, direct shear, static triaxial, cyclic triaxial, cyclic simple shear, resonant column, and other advanced geotechnical laboratory tests; Also includes discussion on field sampling and testing, reconstituted samples, laboratory instrumentation and measurement techniques. (Spring)

# Credit Hours: 3

Frequency: Offered every spring semester

Objectives: Students are expected to be able to perform standard and advanced geotechnical laboratory tests, reduce and interpret test results and data, design experimental programs for applied and research problems, and write publication quality reports.

Outcomes: After attending this course students will be able to:
- Select, perform, and interpret adequate geotechnical tests for different soil types and design conditions,

Instructional Method: Lecture
This course meets at a specified time every week. However, some weeks you will have to coordinate to work outside these times to complete lab assignments or homeworks.

Most weeks we will start with a short review lecture. The objective of these initial lectures is to cover the main theory, but most weeks which involve standard undergraduate lab tests you are expected to do independent readings. The short lecture period will be followed by independent or guided lab sessions or experiments at the various geotechnical laboratories in EPIC. Please make sure that you indicate whether you have access to the main geotech labs in EPIC with your UNCC ID Card. If not we will need to request access for you (please check this the first week of classes).

Textbook and Other Resources
No specific text is required in this class. Will receive handouts, pdf copies of presentations, articles, etc. A useful textbook, but not required is: Bardet, J.P. (1997), Experimental Soil Mechanics, Prentice Hall, 583 p.
However, students are expected to download the U.S. Army Corps of Engineers Laboratory Soils Testing (see link below for USACOE manual). Course materials and handouts will be posted in the Moodle site assigned for this course. Handouts, ASTM Standards, data reduction sheets and other pertinent information can be found on this web page as well.

Other Useful References:

1) USACOE Laboratory Soil Testing Manual:  
http://140.194.76.129/publications/eng-manuals/em1110-2-1906/toc.htm  
2) ASTM Standards available online from UNCC library.  
- Know the proper soil specimen handling and preparation procedures for geotechnical testing.  
- Know the critical techniques required to conduct and present results of consolidation, permeability, and shear strength tests.  
- Know techniques to eliminate and reduce critical testing errors.

Grading:

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<tbody>
<tr>
<td>Homeworks</td>
<td>15 %</td>
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<tr>
<td>Lab reports</td>
<td>40 %</td>
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<tr>
<td>Quizzes</td>
<td>5 %</td>
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<tr>
<td>Project</td>
<td>20 %</td>
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<tr>
<td>Final Exam</td>
<td>20 %</td>
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<tr>
<td>Total</td>
<td>100 %</td>
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Honor Code: The UNCC Code of Academic Integrity will be enforced.  
http://www.legal.uncc.edu/policies/ps-105.html

Assignments and Lab Reports:  
The assignments must be submitted in letter report format, similar to the fashion that test results are submitted by an engineering firm to a client (See page 3)). They will be graded based on technical content and accuracy, and also on the quality of the writing.

Project:  
The project for this semester will entail a geotechnical report for a small industrial facility. We will be using the field data from the drilling demonstration. Students will prepare a geotechnical report that must include the sections typically included in a geotechnical report (including, project description and scope, site location, geology, field testing, lab testing, soil conditions, engineering recommendations (foundations, earth work, etc), and other sections you consider necessary for this project. This project will count for 20% of the grade of this course.

Final Exam:  
All inclusive final examination that will focus primarily on theory and background of the different tests covered throughout the semester.

Additional notes concerning Lab Test Reports (individual and group reports)  
Besides the transmittal memo/letter; and particularly for the group lab reports, the report shall include the following sections (prepared in ASCE conference proceeding style):
Introduction
The introduction section sets the stage as to why we are doing this experiment or research. Problem statement. Example: (1) CRS tests provide an alternative to conventional tests for finding parameters to calculate magnitude & rate of settlement. But are the results compatible? or (2) What is the effect of stress path? (3) What is the effect of gradient on coefficient of permeability?

Purpose and Scope
This section states objectives and "what was done to achieve this objective". Example: The purpose of this permeability test was to determine values for k, and evaluate the effects of gradient and flow direction on k values. These objectives were achieved by performing a double burette (ASTM D5084) test using various gradients and flow directions.

The introduction, purpose and scope, should tell the reader WHY (problem), objective, and WHAT/ HOW experiment was done.

Literature Review
For this section, present a brief review of those references that you will refer to in data analysis, or background you feel the reader should have to understand the report. However, omit BASICS! Example: Carpenter and Stephenson (1885) observed that k decreased as i increased, which is contrary to Darcy's Law. Do Not explain Darcy's Law.

Material (Soil), Test Equipment, and Procedure
A brief description on soil type, i.e., classification, visual description, grain-size curves. Specimen preparation- Compacted, undisturbed, pluviated, water contents, densities
Test equipment & Procedure - Refer to ASTM or USACOE specs wherever possible, and where necessary note exceptions.

Presentation and Analysis of DATA
Make use of summary tables and graphs to present results and make "points" that will be in analysis of data. Place raw data in appendix. Alibis go here. Back-up each spread-sheet with example hand calculations.

Conclusions
1. Be concise
2. Each conclusion should be backed-up in data analysis section
3. For every purpose, there must be a conclusion

References
Use ASCE style.

Course Outline
- Measurement techniques:
  - Common lab equipment and instrumentation
  - Electronic transducers,
  - calibration,
- data acquisition systems.

- Classification and Index tests (Week 2): (Prior to Week 2 please review undergraduate notes and relevant references, and ASTM Standards)
  - Moisture content
  - Particle size distribution (sieving, sedimentation theory, hydrometer)
  - Atterberg limits
  - Specific Gravity
  - Sample density
  - Visual classification and descriptions.

- Chemical tests:
  - pH
  - Sulphate content, Organic content, Carbonate content, Chloride content, Others.

- Drilling and sampling techniques:
  - Drilling Demonstration
  - "Undisturbed specimens" from thin walled tubes
  - "Undisturbed specimens" from block samples
  - Reconstituted samples (e.g., compacted, air or water pluviated, sedimentation, etc.)

- Compaction tests:
  - Definitions, theory
  - Compaction procedures (e.g., Standard and Modified Proctor, etc).
  - Field tests
  - Discussion (Suction, crushing of particles, other factors).

- Permeability tests:
  - Definitions, theory
  - Indirect methods
  - Direct methods (constant head and falling head, using triaxial device)

- Direct shear tests:
  - Definitions, theory
  - ASTM D3080 methodology
  - Other shear tests (simple shear, ring shear, etc.)

- Triaxial testing:
  - Introduction, conventional apparatus, modern setup, strain
  - Unconfined compression
  - Backpressure saturation techniques
  - UU, CU, CD, and advanced stress paths
  - Recent advances: frictionless ends, local strain and/or pore pressure measurements.

- Compressibility tests:
  - Introduction, consolidation theory
  - Oedometer test as per ASTM D 2435
  - Constant strain rate consolidation (CRS test)

- Cyclic triaxial
- Cyclic simple shear.
- Resonant column testing and other advanced tests.
CEGR 6255 Soil Stability and Earth Structures

Proposed and to be taught by:
Dr. Miguel A. Pando, Associate Professor of Civil & Environmental Engineering

Graduate Catalog – Information and Description
CEGR 6255. Soil Stability and Earth Structures. (3). Prerequisites: CEGR 3278 - Geotechnical Engineering I or consent of the instructor, graduate student status. Soil and rock slope stability including the aspects of analysis, design, and stabilization within a geotechnical framework; Concepts related to seepage analysis of isotropic and anisotropic soil structures to relate the influence of groundwater conditions in slope stability problems; Presentation of slope stability analysis procedures based on limit equilibrium principles and stress-deformation analyses; Stability considerations of natural slopes and human-made soil structures; Computer software for seepage and slope stability analysis is explained. (Spring)

# Credit Hours: 3

Frequency: Offered every spring semester

Prerequisites: CEGR 3278 - Geotechnical Engineering I or consent of the instructor, graduate student status. Students are expected to have knowledge in geotechnical engineering principles, geology, and fluid mechanics. Completion of the graduate course on shear strength of soils or equivalent is recommended.

Course Objectives
By the end of this course, the students will be able to assess the stability of natural and man-made soil slopes and identify possible mitigation techniques or schemes for unstable slopes. The student will be able to analyze seepage and ground water for slope stability problems.

Specific objectives of the course include:
- Student should be able draw seepage flow nets for isotropic and anisotropic soils.
- Student should be able perform seepage analyses for slopes and dams using a finite element commercial software (e.g., Seep/W or equivalent).
- Student should be able analyze the stability of a soil slopes and embankment dams using limit equilibrium analyses and finite element analyses. This includes static and dynamic analyses as well as stability and deformation assessment under different design conditions (e.g., short term, long term, rapid draw down, seismic, etc).
- Student should be aware of different stabilization techniques that can be used for unstable slopes.

Instructional Method: Lecture
Evaluation and Grading
The following grade distribution is suggested:
- Assignments and Quizzes = 20%
- Project = 25%
- Midterm exam = 25%
- Final Exam = 30%

Final grade:
A: 90%  -  100%
B: 80%  -  89.9%
C: 70%  -  79.9%
U: Below 70%

Final Exam: TBD as per academic calendar and registrar final exam schedule.

Course Textbook:
There is no single course textbook. The course material will consist of course handouts and references which will be posted in the course Moodle 2 page. Instruction will be supplemented by references listed in supplementary handouts provided by instructors and by assigned lesson readings.

Useful textbooks (complimentary but not required):

Important Course Policies

Classroom Expectations
This syllabus contains the policies and expectations I have established for CEGR 6090/INES8090 – Slope Stability and Earth Structures. Please read the entire syllabus carefully before continuing in this course. These policies and expectations are intended to create a productive learning atmosphere for all students. Unless you are prepared to abide by these policies and expectations, you risk losing the opportunity to participate further in the course.

Classroom Environment
I will conduct this class in an atmosphere of mutual respect. I encourage your active participation in class discussions. Each of us may have strongly differing opinions on the various topics of class discussions. The conflict of ideas is encouraged and welcome. The orderly questioning of the ideas of others, including mine, is similarly welcome. However, I will exercise my responsibility to manage the discussions so that ideas and argument can proceed in an orderly fashion. You should expect that if your conduct during class discussions seriously disrupts the atmosphere of mutual respect I expect in this class, you will not be permitted to participate further.
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- Do homework in class.
- Unauthorized use of your laptop.
- Use your cell phone or listen to a music device or text messages.
- Are disruptive or disrespectful.

About Cell Phones and Smart Phones: The use of cell phones, smart phones, or other mobile communication devices is disruptive, and is therefore prohibited during class. Except in emergencies, those using such devices must leave the classroom for the remainder of the class period.

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TENTATIVE LIST OF TOPICS (*)

<table>
<thead>
<tr>
<th>Topics</th>
<th>Contact hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Introduction</td>
<td></td>
</tr>
<tr>
<td>Course objectives and scope, introduction to slope stability problem.</td>
<td>1.25</td>
</tr>
<tr>
<td>2. Overview of slope stability problem: approach, considerations,</td>
<td>1.25</td>
</tr>
<tr>
<td>limitations, etc</td>
<td></td>
</tr>
<tr>
<td>3. Review of Seepage applied to slope stability problems</td>
<td>2.5</td>
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<tr>
<td>4. Review of Shear Strength of soils and rocks for slope stability</td>
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<td>problems</td>
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<td>5. Limit equilibrium analysis for slope stability problems:</td>
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<td>General considerations, limit equilibrium versus deformation,</td>
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<td>philosophy of factor of safety.</td>
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<td>6. Infinite slope analyses</td>
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<td>Dry, parallel and inclined seepage.</td>
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<td>7. Wedge model analysis</td>
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<td>8. Conventional limit equilibrium methods</td>
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<tr>
<td>Circular failure surfaces, Swedish method, ordinary method of slices,</td>
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<tr>
<td>modified Swedish, Bishop method, modified Bishop method, Janbu,</td>
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and modified Janbu.

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<td>9.</td>
<td>Software, searching techniques, simplified stability charts</td>
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<td><strong>TEST 1</strong></td>
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<td>10.</td>
<td>Advanced limit equilibrium methods</td>
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<td>Spencer, Morgenstern-price, others</td>
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<td>11.</td>
<td>Detailed guidelines to select shear strength parameters, water effects</td>
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<td>12.</td>
<td>Deformation analysis of slopes and dams:</td>
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<td>Limitations of limit equilibrium analyses. Deformations, strain compatibility, and finite element analyses</td>
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<td>13.</td>
<td>Back-analysis</td>
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<td>Principles of back-analysis, learning from slope failures, variability and uncertainty of back-analysis models</td>
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<td>14.</td>
<td>Landslides in tropical climates</td>
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<td>15.</td>
<td>Special Considerations for Design of Earth dams and Embankments</td>
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<td>16.</td>
<td>Seismic Stability of Slopes</td>
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<td><strong>Total contact hours:</strong></td>
<td><strong>45</strong></td>
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(*): Schedule subject to change based on potential project site visits and guest lectures.
APPENDIX B
Civil and Environmental Engineering

- M.S. in Civil Engineering
- M.S. in Engineering
- Ph.D. in Infrastructure and Environmental Systems (see the Infrastructure and Environmental Systems heading)

Department of Civil and Environmental Engineering
http://cee.uncc.edu

Graduate Program Director
Dr. Srinivas S. Pulugurtha

Graduate Program Student Services Specialist
Adrienne Threatt

Graduate Faculty
James E. Ambur, GE, Associate Professor
James D. Bowen, Associate Professor
Shen-en Chen, P.E., Professor
John L. Daniels, P.E., Interim Department Chair and Associate Professor
Wei Fan, P.E., Associate Professor
Janos I. Gergely, S.E., P.E., Associate Professor
Edd Hauser, Professor
Hilary L. Inyang, Duke Energy Distinguished Professor
Rajaram Janardhanan, Professor
Martin R. Kane, P.E., Associate Professor
Olya Keen, Assistant Professor
Milind Khire, P.E., Professor
Sara McMillan, Assistant Professor
David Naylor, P.E., Lecturer
Vincent O. Ogunro, Associate Professor
Miguel A. Pando, Associate Professor
Youngjin Park, Faculty Associate
Srinivas S. Pulugurtha, P.E., Associate Professor
William Saunders, P.E., Lecturer
Brett Q. Tempest, Assistant Professor
Kimberly A. Warren, Associate Professor
David C. Weggel, P.E., Associate Professor
Matthew J. Whelan, Assistant Professor
Jy S. Wu, P.E., P.H., Professor
David Young, P.E., Professor

P.E. = Professional Engineer
P.H. = Professional Hydrologist
S.E. = Structural Engineer
Programs of Study
The Department of Civil and Environmental Engineering (CEE) provides opportunities for discipline-specific and multidisciplinary graduate-level education in Civil and Environmental Engineering and closely related areas. Advanced coursework and research are used to enhance professional development, improve technical competency, and initiate a life-long learning experience. The Department has ongoing collaborative research and student exchange programs with several international institutions.

The Department offers graduate studies leading to a master’s degree (MSCE or MSE) in five areas of concentration:

1) Environmental and water resources engineering
2) Geo-environmental engineering
3) Geotechnical engineering
4) Structural engineering and structural materials
5) Transportation engineering

Doctoral studies leading to the Ph.D. in Infrastructure and Environmental Systems (INES) are available in an interdisciplinary, inter-college program. See the Infrastructure and Environmental Systems heading for details.

MASTER OF SCIENCE IN CIVIL ENGINEERING (MSCE) AND MASTER OF SCIENCE IN ENGINEERING (MSE)

Admission Requirements
In addition to the general requirements for admission to the Graduate School, the Department of Civil and Environmental Engineering seeks the following from applicants to the Master’s programs in Civil Engineering:

- An earned undergraduate degree in Civil Engineering for the MSCE master’s program or a closely related field for the MSE master’s program
- An undergraduate GPA of 3.0 or better
- A satisfactory score from the Aptitude Portion of the GRE
- Three letters of recommendation
- An acceptable TOEFL score as required by UNC Charlotte for international students
- And any other appropriate credentials as required by the Graduate School

Additional Admission Requirements
- Admission to the MSE program may require completion of certain deficiencies as specified by each area of concentration
- Admission to the Early-Entry Program requires a minimum GPA of 3.2, completion of at least 75 hours toward the BSCE degree, and acceptance by the Graduate School to the MSCE or MSE programs at UNC Charlotte.
Early-Entry Program
Undergraduate students at UNC Charlotte with outstanding academic performance, and satisfying the requirements described above, may be admitted to the Early-Entry Program to pursue graduate study while completing the undergraduate degree requirements. Early-Entry students are dually enrolled with both undergraduate and graduate status, may request two graduate Civil Engineering (CEGR) courses to be applied to both their graduate and undergraduate programs (double-counting), and may complete up to 15 credits toward their MS degree prior to graduating with their BSCE degree.

Application Deadline
Applications for admission must be submitted online directly to the Graduate School. They may be submitted any time prior to their published application deadlines. To be considered for assistantships and tuition grants for the following academic year, students should apply by February 15 because the Department makes the first round of award decisions by March 15. However, the Department will continue to evaluate applications for admission provided the application is complete for admission consideration as determined by the Graduate School.

Assistantships
Research and teaching assistantships are available from the Department on a competitive basis to highly qualified applicants/students.

Tuition Grants
Tuition grants including Non-Resident Tuition Differentials and Resident Tuition Aids are available on a competitive basis for both out-of-state and in-state students, respectively.

Degree Requirements
A minimum of 30 approved graduate credit hours is required for graduation. At least half of the approved graduate credit hours must be in courses numbered 6000 or above. A student may fulfill the 30-hour requirement by pursuing one of the three study options: (a) 24 hours of coursework plus 6 hours of thesis, (b) 27 hours of coursework plus 3 hours of research project, or (c) 30 hours of coursework and a comprehensive examination. Each student is limited to one individual study within the 30-hour requirement.

Track Descriptions/Requirements
Required core courses for the various tracks are listed below, as well as additional recommended courses for each study track.

Environmental and Water Resources Engineering

Environmental Engineering
CEGR 5142 Water/Wastewater Engineering (3)
CEGR 5143 Solid Waste Management (3)
CEGR 6141 Water Quality Modeling (3)

Water Treatment Engineering
CEGR 6243 Physical Processes in Environmental Systems (3)
CEGR 6245 Chemical and Biological Processes in Environmental Systems (3)
Water Resources
CEGR 6141 Water Quality Modeling (3)
CEGR 6146 Advanced Groundwater Analysis (3)
CEGR 6147 Watershed Modeling (3)
CEGR 6149 Watershed Analysis (3)
CEGR 6173 Environmental Aquatic Chemistry (3)

Environmental Management
CEGR 5237 Environmental Risk Management (3)
Natural Disasters (3)
ISO Management Systems (3)
Environmental Impact Assessment (3)
EMGT 6902 Legal Issues in Engineering Mgmt (3)
or EMGT 6950 Engineering System Integration (3)

Geo-Environmental Engineering
Required core courses:
CEGR 5145 Groundwater Resources Engineering (3)
CEGR 6253 Design and Analysis of Waste Containment Systems (3)
Soil and Groundwater Remediation (3)

Geotechnical Engineering
Required core courses:
CEGR 5145 Groundwater Resources Engineering (3)
CEGR 5270 Earth Pressures and Retaining Structures (3)
CEGR 5278 Geotechnical Engineering II (3)
CEGR 6268 Advanced Soil Mechanics (3)
CEGR 6251 Analysis and Design of Deep Foundations Engineering (3)
CEGR 6254 Experimental Soil Mechanics (3)

Additional recommended courses:
CEGR 5264 Landfill Design and Site Remediation (3)
CEGR 5271 Pavement Design (3)
CEGR 5272 Design with Geosynthetics (3)
CEGR 5273 Soil Improvement (3)
CEGR 5274 Site Characterization (3)
CEGR 6146 Advanced Groundwater Analysis (3)
CEGR 6252 Soil Dynamics and Earthquake Engineering (3)
Soil Improvement and Site Characterization (3)

Structural Engineering or Structural Materials
Required core courses:
CEGR 5108 Finite Element Analysis and Applications (3)
CEGR 5222 Structural Steel Design II (3)
CEGR 5224 Advanced Structural Analysis (3)
CEGR 5226 Reinforced Concrete Design II (3)
CEGR 6129 Structural Dynamics (3)

Additional recommended courses for the two tracks in Structural Engineering are:

**Structural Analysis and Design:**
CEGR 5121 Prestressed Concrete Design (3)
CEGR 5123 Bridge Design (3)
CEGR 6124 Masonry Design (3)
CEGR 6126 Analysis of Plates and Shells (3)
CEGR 6127 Fracture Mechanics and Fatigue (3)
CEGR 6128 Structural Optimization (3)
CEGR 5125 Forensic Engineering (3)
CEGR 5223 Timber Design (3)

**Structural Materials**
CEGR 6127 Fracture Mechanics and Fatigue (3)
MEGR 6141 Theory of Elasticity I (3)
CEGR 5125 Composite Materials (3)
CEGR 6125 Structural Strengthening (3)

**Transportation Engineering**
Required core courses:
CEGR 5161- Advanced Traffic Engineering (3)
CEGR 5162 Transportation Planning (3)
CEGR 5185 Geometric Design (3)
CEGR 6161- Traffic Control and Operation (3)
And one of the following:
GEOG 6100- Quantitative Methods in Geography (3)
MATH 6102- Linear Algebra (3)
MATH 6172- Advanced Applied Mathematics II (3)

**Note:** Undergraduate students who have taken any of the courses listed above, or equivalent material, as part of their undergraduate program need not take the corresponding 5000-level graduate courses. Instead, they may choose other graduate courses as part of their master's degree plan of study. Courses without designated course numbers are currently being offered as Special Topic classes with appropriate course numbers yet to be provided.

**Admission to Candidacy Requirements**
Each student is required to submit a Plan of Study to the Graduate Program Director before completing 18 hours of graduate credits. The Plan of Study will streamline coordination of the required coursework and research work between the student and his/her advisor before submitting the Admission to Candidacy.
Upon completion of a substantial amount of graduate work, each student must file an Admission to Candidacy form to the Graduate School by the filing date, typically at the beginning of the semester for graduation specified in the University Academic Calendar.

Application for Degree
Students preparing to graduate must submit an online Application for Degree by the filing date specified in the University Academic Calendar. If a student does not graduate in the semester identified on the Application for Degree, then the student must update his/her Admission to Candidacy and submit a new Application for Degree for graduation in a subsequent semester.

Transfer Credit
The Department accepts the transfer of graduate courses (6 credits maximum) taken at another institution or from UNC Charlotte prior to admission to the master’s program in Civil Engineering.

Electives
With advisor approval, a maximum of two graduate courses (outside CEGR or within CEGR) in a study area different from the student’s focus area may be incorporated into the 30-hour requirement. A student with a non-CEGR background is encouraged to fulfill the 30-hour requirement by taking all CEGR courses.

Advising
Each student is assigned an initial advisor. Upon developing a program of study, the student shall be supervised by his/her graduate advisor and a program committee.

Program Committee
The Program Committee shall consist of at least three UNC Charlotte graduate faculty members. A graduate faculty member (CEGR or non-CEGR) from outside the student’s major area-of-study may serve as a member of the Program Committee. The student’s CEE graduate advisor shall chair the committee.

Capstone Experiences
Students pursuing a master’s degree in Civil and Environmental Engineering have three options to complete the 30-credit hour program. Students may elect to complete 24 credit hours of coursework plus 6 credit hours of thesis; 27 credit hours of coursework plus 3 credit hours of a directed project; or 30 credit hours of coursework plus a written comprehensive examination. All three options require the formation of a program committee as described above. The thesis and project options require students to submit a written thesis or project report, and orally defend their work before their program committee.

A student’s comprehensive exam may be taken once all core courses are completed, and at least 18 hours of graduate coursework are either completed or in progress. Core courses taken at the graduate level may be included in the 18 hours. The student’s graduate advisor and the examining committee will coordinate the examination (typically offered once in the Fall semester and once in the Spring semester), preparing the exam with the assistance of members of the student’s program committee. The exam will measure the student’s mastery of theories and
applications in core courses and/or in the selected area of specialization within the discipline. Students will have only two attempts to pass the examination. All students passing the written examination will be assessed farther on their oral communication effectiveness.

Research Opportunity/Experience
Students in Civil and Environmental Engineering enjoy a curriculum with opportunities for interdisciplinary research, study abroad, and active participation in a growing research program. Programs of study can be tailored to suit individual needs and interests. The CEE website (http://cee.uncc.edu) provides current areas of research conducted by the Civil and Environmental Engineering faculty.

Program Learning Outcomes
Students completing master’s degree will demonstrate abilities to analyze and evaluate advanced topics in engineering, and to communicate technical information effectively. Achievement of these outcomes will prepare students to function professionally in their chosen careers.

Program learning outcomes for doctoral students are described in the “Infrastructure and Environmental Systems” section of this Catalog.

COURSES IN CIVIL AND ENVIRONMENTAL ENGINEERING (CEGR)

CEGR 5090. Special Topics in Civil Engineering. (1-4) Study of specific new areas emerging in the various fields of civil engineering. May be repeated for credit. (On demand)

CEGR 5108. Finite Element Analysis and Applications. (3) Prerequisites: CEGR 4224 and permission of department. Finite element method and its application to engineering problems. Application of displacement method to plane stress, plate strain, plate bending and axisymmetrical bodies. Topics include: dynamics, fluid mechanics, and structural mechanics. (Fall)

CEGR 5121. Prestressed Concrete Design. (3) Prerequisites: CEGR 3225, CEGR 4224, and permission of department. Analysis and design of prestressed components and systems, including materials and systems for prestressing, loss of prestress, flexural and shear design in accordance with current building codes, analysis of indeterminate prestressed systems, and control of camber, deflection and cracking. (Spring) (Alternate years)

CEGR 5123. Bridge Design. (3) Prerequisites: CEGR 3221, CEGR 3225, and permission of department. Review of bridge design codes and loading; superstructure and substructure design of short, intermediate, and long span bridges constructed of steel and concrete; earthquake design; segmental and cable-stayed bridges. (Spring) (Alternate years)

CEGR 5125. Forensic Engineering. (3) Prerequisite: CEGR 3122 and permission of department. Structural Analysis I, or consent of the instructor, graduate student status. Evaluation of structural and construction failures through review of case studies, types and causes of failures, and relevant methods of failure investigation; analysis of failures occurring in a variety of structures, involving a variety of materials, and resulting from a variety of causes;
development, expression, and defense of opinions and conclusions, orally and in writing, with an understanding of the impact on the legal process surrounding a failure claim. (Fall, alternate years)

CEGR 5126. Codes, Loads, and Nodes. (3). Prerequisite: CEGR 3122 and permission of department, Structural Analysis I, with a grade C or better, graduate student status. Building systems and components; code requirements according to the latest ASCE Standard 7 pertaining to buildings and other structures; gravity load analysis including dead, live, roof live and snow loads; lateral load analysis focusing on wind and seismic forces, and applied to the main lateral load resisting systems; software applications using the SAP2000 tool, with 2-D and 3-D models loaded with gravity and lateral loads. (Fall)

CEGR 5127. Green Building and Integrative Design. (3). Prerequisite: CEGR 3122 and permission of department, Structural Analysis I, or consent of the instructor, graduate student status. Course topics prepare students to function in multidisciplinary design teams working to produce buildings, sites, and coupled environmental-infrastructure systems with resilience and sustainability as design priorities. Focus areas include civil engineering aspects of energy use, material use, emissions generation and design strategies for integrated design. (On demand)

CEGR 5128. Matrix Methods of Structural Analysis. (3) Prerequisite: permission of department. Derivation of the basic equations governing linear structural systems. Application of stiffness and flexibility methods to trusses and frames. Solution techniques utilizing digital computer. (On demand)

CEGR 5141. Process Engineering. (3) Prerequisites: CEGR 3141 and permission of department. Applications of material and energy balance principles to the study of chemical, biological and environmental engineering processes. Overview of applied biotechnology, engineering thermodynamics and kinetics. (Fall)

CEGR 5142. Water/Wastewater Engineering. (3) Prerequisites: CEGR 3141 and permission of department. Analysis and design of water and wastewater treatment processes including physical, chemical and biological treatment. Computer-aided design of treatment systems. (Spring)

CEGR 5143. Solid Waste Management. (3) Prerequisites: CEGR 3141 and permission of department. Solid waste management, sources, generation rates, processing and handling, disposal, recycling, landfill closures, and remedial actions for abandoned waste sites. (Spring) (Alternate years)

CEGR 5144. Engineering Hydrology. (3) Prerequisites: CEGR 3143 and permission of department. A quantitative study of the various components of the water cycle, including precipitation, runoff, ground water flow, evaporation and transpiration, and stream flow. Hydrograph analysis, flood routing, frequency and duration, reservoir design, and computer applications. (Fall) (Alternate years)
CEGR 5145. Groundwater Resources Engineering. (3) Prerequisites: CEGR 3143 and permission of department. Overview of hydrological cycle. Principles of groundwater flow and well hydraulics, Regional groundwater flow and flow nets. Water chemistry and contamination. Applications of groundwater modeling. (Fall)

CEGR 5146. Advanced Engineering Hydraulics. (3) Prerequisites: CEGR 3143 and permission of department. Problems of liquids as applied in civil engineering; open channel flow; dams and spillways; water power; river flow and backwater curves; pipe networks, fire flow, sewage collection, groundwater, computer applications. (On demand)

CEGR 5161. Advanced Traffic Engineering. (3) Prerequisites: CEGR 3161 and permission of department. Analysis of basic characteristics of drivers, vehicles and roadway that affect the performance of road systems. Stream flow elements, volume, density, speed. Techniques of traffic engineering measurements, investigations and data analysis, capacity analysis. Intersections, accidents, parking. (Fall)

CEGR 5162. Transportation Planning. (3) Prerequisites: CEGR 3161 and permission of department. Urban transportation; travel characteristics of urban transportation systems; analysis of transportation-oriented studies; analytic methods of traffic generation, distribution, modal split and assignment; traffic flow theory. (Spring)

CEGR 5171. Urban Public Transportation. (3) Prerequisites: CEGR 3161 and permission of department. Planning, design, and operation of bus, rail, and other public modes. Relationship between particular modes and characteristics of urban areas. Funding, security and other administrative issues. (On demand)

CEGR 5181. Human Factors in Traffic Engineering. (3) Prerequisites: CEGR 3161 and permission of department. Study of the driver's and pedestrian's relationship with the traffic system, including roadway, vehicle and environment. Consideration of the driving task, driver and pedestrian characteristics, performance and limitations with regard to traffic facility design and operation. (Alternate years)

CEGR 5182. Transportation Environmental Assessment. (3) Prerequisite: permission of department. A study of the environmental impact analysis and assessment procedures for transportation improvements. Route location decisions. Noise, air quality, socio-economic, and other impacts. (On demand)

CEGR 5183. Traffic Engineering Studies. (3) Prerequisites: CEGR 3161 and permission of department. Introduction to the traffic engineering studies most used by traffic engineers including data collection techniques, statistical analysis procedures, report writing and presentation. One hour of lecture and three hours of laboratory per week. (Fall) (Alternate years)

CEGR 5184. Highway Safety. (3) Prerequisites: CEGR 3161 and permission of department. Engineering responses at the state and local levels to the problem of highway safety. Extent of the highway safety problem, elements of traffic accidents, common accident countermeasures,
collection and analysis of accident data, evaluation of safety-related projects and programs, and litigation issues. *(Fall) (Alternate years)*

**CEGR 5185. Geometric Design of Highways.** *(3)* Prerequisites: CEGR 3161 and permission of department. Theory and practice of geometric design of highways including intersections, interchanges, parking and drainage facilities. Driver ability, vehicle performance, safety and economics are considered. Two hours of lecture and three laboratory hours per week. *(On demand)*

**CEGR 5222. Structural Steel Design II.** *(3)* Prerequisites: CEGR 3221 and permission of department. Analysis and design of structural steel components and systems with emphasis on theories necessary for a thorough understanding of the design of complete structures. Compression members affected by local buckling, beams with lateral-torsional buckling, continuous beams and beam-columns are covered. Welded and bolted connections. Current AISC Specifications used. *(Spring)*

**CEGR 5223. Timber Design.** *(3)* Prerequisite: CEGR 3122. Structural Analysis I, or consent of the instructor, graduate student status and permission of department. Principles of Timber Design. Principles of timber design. Design of simple timber structures subjected to gravity loads and lateral forces. Computation of design loads; formulation of structural systems; design/analyze structural components and connections; structural system analysis of timber structures. Analysis of light commercial and residential structures. *(Fall)*

**CEGR 5224. Advanced Structural Analysis.** *(3)* Prerequisites: CEGR 3122 and permission of department. A continuation of CEGR 3122. Methods to determine deflections in structural members, including moment area, conjugate beam, virtual work, and Castiglione’s theorem. Analyze statically determinate and indeterminate structures, including approximate method, slope deflection, moment distribution, and matrix stiffness methods. Project to compare analysis techniques and introduce use of structural analysis computer programs. *(Fall)*

**CEGR 5226. Reinforced Concrete Design II.** *(3)* Prerequisites: CEGR 3225 and permission of department. Analysis and design of reinforced concrete components and systems with emphasis on the fundamental theories necessary for a thorough understanding of concrete structures. Concentrically loaded slender columns, slender columns under compression plus bending, Wall footings and column footings. Analysis of continuous beams and frames. Total design project involving the analysis and design of a concrete structure. Current ACI Specifications used. *(Spring)*

**CEGR 5234. Hazardous Waste Management.** *(3)* Prerequisites: CEGR 3141 and permission of department. Integration of scientific and engineering principles with legislation, regulation and technology in the management of hazardous wastes. Study of thermal, chemical, physical and biological systems and processes used in the treatment of hazardous wastes and the remediation of hazardous waste sites. *(On demand)*

**CEGR 5235. Industrial Pollution Control.** *(3)* Prerequisite: permission of department. Source and characterization of industrial wastewaters. Fundamentals of chemical and physical treatment
processes. Biological treatment technologies. Waste minimization and reduction technologies. Sludge handling and toxicity reduction. Implementation of field or laboratory treatability study. *(On demand)*

**CEGR 5237. Environmental Risk Management.** (3) Prerequisite: permission of department. Review of legislation and requirements pertaining to spills and releases of chemicals to the environment. Fundamentals of fires, explosions, toxic emissions and dispersion, hazardous spills, and other accidents. Study of techniques for accident prevention and spill control, and hazardous and risk assessment. *(On demand)*

**CEGR 5241. Chemical Processes in Water and Wastewater Treatment.** (3) Prerequisites: CHEM 1252, CEGR 3141, and permission of department. Chemical principles involved in the treatment of water and wastewaters; principles of chemical equilibrium relevant to natural water systems; the nature and effect of chemical interactions of domestic and industrial waste effluents on natural water systems. *(On demand)*

**CEGR 5243. Topics in Environmental Health.** (3) Prerequisites: CEGR 3141, CEGR 4142, and permission of department. Study of contemporary environmental health problems and practices as they relate to groundwater pollution, food and water-borne diseases, radiological health, occupational health and risk assessment. Provides an introduction to epidemiology and toxicology, and a historical review of federal environmental policy and legislative action. *(On demand)*

**CEGR 5262. Traffic Engineering.** (3) Prerequisites: CEGR 3161 and permission of department. Operation and management of street and highway systems. Traffic control systems, traffic flow theory, and highway capacity. Evaluation of traffic engineering alternatives and the conduct of traffic engineering studies. *(Spring)*

**CEGR 5264. Landfill Design and Site Remediation.** (3) Prerequisites: CEGR 3258, CEGR 3278, and permission of department. Principles of waste disposal and sanitary landfill siting including design, construction, operation and maintenance. Site assessment of underground storage tank leaks; site remediation, and clean up technologies using choice and economic analysis and computer applications. *(Spring, Alternate years)*

**CEGR 5270. Earth Pressures and Retaining Structures.** (3) Prerequisites: CEGR 3122, CEGR 3278, CEGR 4278, and permission of the department. Co-requisite: CEGR 4278 can be a co-requisite. Lateral earth pressure theory and the effects of wall friction, external loads, groundwater, and layered soils; design procedures and construction details associated with selected rigid and modular gravity/semi-gravity walls; mechanically stabilized earth walls, and externally supported structural walls. *(Fall)*

**CEGR 5271. Pavement Design.** (3) Prerequisites: CEGR 3161, CEGR 3278, and permission of department. Pavement design concepts and considerations; engineering properties of pavement materials including soils, bases, asphalt concrete, and Portland cement concrete; design of flexible and rigid pavements including shoulders and drainage; computer applications for pavement analysis and design. *(On demand)*
CEGR 5272. Design with Geosynthetics. (3) Prerequisites: CEGR 3258, CEGR 3278, CEGR 4278, and permission of department. Co-requisite: CEGR 4278 can be a co-requisite. Introduction to geosynthetic materials, properties, laboratory test procedures, and functions; geosynthetic design methods used for geotechnical, transportation hydraulic, and geo-environmental applications (roadways, walls, slopes, foundation soils, landfills, and dams); the incorporation of geosynthetics for soil reinforcement, separation, filtration, drainage and containment. (Spring)

CEGR 5273. Soil Improvement. (3) Prerequisites: CEGR 3278 - Geotechnical Engineering I or consent of the instructor. Graduate student status and permission of department. Engineering principles of soil improvement as they relate to applications in both geotechnical and geo-environmental engineering; innovative techniques to improve soils to meet technical and economic requirements. (Spring)

CEGR 5274. Site Characterization. (3) Prerequisites: CEGR 3278 - Geotechnical Engineering I or consent of the instructor. Graduate student status and permission of department. Site investigation and site assessment technologies employed in geotechnical and environmental engineering; Site investigation planning and various geophysical methods including: seismic measurements, ground penetrating radar, electrical resistivity, and electromagnetic conductivity; Drilling methods for soil, gas and ground water sampling; decontamination procedures; and long term monitoring methods: Conventional and state-of-the-art in situ methods for geotechnical and environmental site characterization: standard penetration test, vane shear test, dilatometer test, pressure meter test and cone penetration tests. Modern advances in cone penetrometer technology, instrumented with various sensors (capable of monitoring a wide range of physical and environmental parameters: load, pressure, sound, electrical resistivity, temperature, pH, oxidation reduction potential, chemical contaminants). (Fall)

CEGR 5278. Geotechnical Engineering II. (3) Prerequisites: CEGR 3258, CEGR 3278, and permission of department. Design of shallow and deep foundations, including structural considerations; lateral earth pressure theories; design of rigid and flexible earth retaining structures; advanced aspects of slope stability analysis; and computer applications. (Spring)

CEGR 5892. Individualized Study and Projects. (1-6) Prerequisite: permission of department. Individual investigation and exposition of results. May be repeated for credit. (On demand)

CEGR 5991. Graduate Research in Civil Engineering. (1-6) Prerequisite: permission of department. Independent study of a theoretical and/or experimental problem in a specialized area of civil engineering. May be repeated for credit. (On demand)

CEGR 6090. Special Topics in Civil Engineering. (1-6) Prerequisite: permission of department. Directed study of current topics of special interest. May be repeated for credit. (On demand)
CEGR 6122. Advanced Topics in Structural Steel. (3) Prerequisites: CEGR 4222 and permission of department. Theory of plastic behavior of steel structures; current topics in structural steel. (On demand)

CEGR 6124. Masonry Design. (3) Prerequisites: CEGR 3225 and permission of department. Introduction of masonry materials and systems, engineering and materials properties and testing procedures. Design of reinforced and un-reinforced masonry (clay and concrete) walls, beams, and columns for vertical, wind, and seismic loads. Analysis and design of masonry structures and introduction to computer applications. (Spring) (Alternate years)

CEGR 6125. Structural Strengthening. (3) Prerequisite: CEGR 3221, CEGR 3225, and permission of department—Structural Steel Design I and CEGR 3225—Reinforced Concrete Design I, with a grade C or better, graduate student status. Code requirements for the evaluation of existing structures; analysis of existing structures; performance based design of buildings and bridges; strengthening/retrofit techniques for concrete, structural steel, masonry and timber elements, such as beams, columns, shear/bearing/retaining walls, and slabs; studies of actual strengthening projects using innovative techniques and materials. (Spring)

CEGR 6126. Analysis of Plates and Shells. (3) Prerequisite: CEGR 4224 and permission of department. Analysis of rectangular and circular plates using classical as well as numerical methods; orthotropic and continuous plates; plate buckling. Analysis of thin shells and shells of revolution with and without bending; membrane theory of cylindrical shells; symmetric and unsymmetrical loading; pipes, tanks, and pressure vessels; computer applications. (On demand)

CEGR 6127. Fracture Mechanics and Fatigue. (3) Prerequisites: CEGR 3221 and permission of department. Introduction to fracture mechanics and fatigue, including Griffith Theory, plane strain-stress conditions, critical stress intensity factors, factors influencing fracture toughness, fracture mechanics design principles, fatigue performance, and fatigue initiation and propagation. (On demand)

CEGR 6128. Structural Optimization. (3) Prerequisites: CEGR 4224 and permission of department. Introduction to optimization concepts; reformulation of common structural analysis and design problems to an optimization format; optimization of constrained, unconstrained, linear, and nonlinear problems by classical and numerical techniques; and computer applications. (On demand)

CEGR 6129. Structural Dynamics. (3) Prerequisites: CEGR 3122 and permission of department. Methods for dynamic analysis of single and multiple degree of freedom systems. Topics include: free vibrations, dynamic response of simple structures under time dependent loads (e.g., harmonic, periodic, impulsive, general dynamic loading), support motion, frequency domain analysis, response spectra, earthquake engineering. (Spring)

CEGR 6141. Water Quality Modeling. (3) Prerequisite: permission of department. Mathematical modeling of water quality in receiving streams including: generation of point and nonpoint sources of pollution; formulation of transport equations for contaminants in stream and
estuarine water; and prediction of the fate, persistence and transformation of chemical pollutants in aquatic ecosystems. Computer model simulation and case studies. (On demand)

CEGR 6142. Bioenvironmental Engineering. (3) Prerequisites: CEGR 3141 and permission of department. Theoretical principles and design of aerobic and anaerobic biological unit processes for renovating waters and wastewaters. Activated sludge, aerated and facultative lagoons, rotating biological contractors, trickling and anaerobic filters. (On demand)

CEGR 6144. Environmental Biotechnology. (3) Prerequisite: permission of department. Application of biotechnology to the management of environmental problems. Study of bioprocess principles, bioremediation of waste disposal sites, cell immobilization technology and innovative biotechnologies. (On demand)

CEGR 6145. Waste Incineration. (3) Prerequisite: permission of department. Fundamentals of incineration of hazardous/solid wastes. Thermochemical applications and equipment design. Computer modeling of the incineration process and air quality control. (On demand)


CEGR 6147. Watershed Modeling. (3) Prerequisite: Permission of department. Characterization of non-point source pollution; modeling of flow and pollutant transport in storm runoff. Watershed modeling in a GIS environment including applications of SWIMM, BASINS, HEC-HMS, HEC-RAS, and NRCS models. (Spring)

CEGR 6148. Water Conservation. (3) Prerequisite: permission of department. Principles and issues concerning water conservation and methods for effecting water conservation, including residential, industrial, commercial, and agricultural water conservation; water rates, audits and reuse/reclamation as they relate to water conservation; and case studies. (On demand)

CEGR 6149. Watershed Analysis. (3) Prerequisite: permission of department. Study of NPS problems in urban and non-urban watersheds and from highway runoff. Estimate of sediment yield and design of BMPs including sediment control structures. Introduction to monitoring and modeling of hydrologic systems. Watershed modeling in a GIS environment. (Fall)

CEGR 6161. Traffic Control and Operation. (3) Prerequisites: CEGR 5161 and permission of department. Traffic control theory and application; traffic regulation, laws and ordinances; speed control, intersection control, flow control and parking control; design and application of control devices, investigation, evaluation techniques; statistical analysis; administration. (Spring)

CEGR 6162. Computer Applications for Transportation Engineers. (3) Prerequisites: CEGR 3161 or consent of the instructor. Apply analytical techniques using traffic simulation and transportation planning software to evaluate various transportation facilities. Emphasis on practical applications.
computer applications and software packages such as HCS, SYNCHRO/SimTraffic, and VISSIM; 4-Step planning process using TransCAD; Build mathematical models. (Spring, alternate years)

CEGR 6163. GIS for Civil Engineers. (3) Prerequisites: CEGR 2101 - Engineering Drawing, AutoCAD, or consent of the instructor; graduate student status and permission of department. Apply Geographic Information System (GIS) tools to solve Civil Engineering problems: add layers, label, & symbolize features, create maps in ArcMap, generate tables & spatial databases, address matching, query & join tables, perform spatial overlays, generate buffers, and conduct spatial analysis. Civil Engineering case studies. (Fall, alternate years)

CEGR 6164. Traffic Safety. (3) Prerequisites: CEGR 3161 - Introduction to Transportation Engineering or consent of the instructor; graduate student status and permission of department. Crash data elements and source of data; Crash site reconstruction; Quantifying risk; Safety evaluation process: Problem definition, high crash locations, ranking and prioritization, understanding causal factors, countermeasure selection, before-after evaluation; Crash prediction Modeling; Economic appraisal; Safety conscious planning. (Fall, alternate years)

CEGR 6165. Urban Systems Engineering. (3) Prerequisites: CEGR 3202 and permission of department. Survey of economic, political, sociological and technological factors affecting modern growth; a planning process and its role in solving selected urban problems with emphasis on engineering contributions. (On demand)

CEGR 6171. Air Quality Control. (3) Prerequisite: permission of department. Study of various types of air pollutants, their sources, nature and effects. Examination of air quality criteria, standards and monitoring. Analysis of feasibility, applicability and efficiency of diverse systems of control. Evaluation of goal and research needs in the future. (On demand)

CEGR 6172. Air Dispersion Modeling. (3) Prerequisite: permission of department. Atmospheric pollution problems, federal regulations, boundary layer meteorology, dispersion theory, Gaussian model, plume rise formulas, air toxics, and computer modeling of point area, line and mobile sources. (On demand)

CEGR 6173. Environmental Aquatic Chemistry. (3) Prerequisites: CHEM 3111, CHEM 3141, or equivalent; and permission of department. Concepts of chemical equilibrium applied to natural aquatic systems. Topics include: acid-base reactions, buffer systems, mineral precipitation, coordinate chemistry, redox reactions, adsorption phenomena and chemical-equilibria computer programs. (Spring) (Alternate years)

CEGR 6181. Traffic Flow Theory. (3) Prerequisites: CEGR 5161 and permission of department. Logical foundations and mathematical representation of traffic flow; interrelation between microscopic and macroscopic equations of motion for highway traffic; stochastic properties of traffic at low and moderate densities. Car-following theories of traffic flow at high densities. Applications of queuing theory. (On demand)
CEGR 6182. Transportation Systems Analysis. (3) Prerequisites: CEGR 5161 and permission of department. Issues, concepts and methods of transportation systems engineering and planning. Decision making in transportation management. The application of analytical methods to the development and evaluation of transport systems. (On demand)

CEGR 6243: Physical Processes in Environmental Systems. (3) Prerequisites: CEGR 3141, CEGR 3143, MATH 2171, graduate student status and permission of department. Environmental Engineering Processes. Physical Processes in Environmental Systems. Physical processes that describe the behavior of materials in natural and engineered environmental systems including transport, diffusion/dispersion, volatilization, sorption/desorption, flocculation, filtration, and sedimentation. (Fall)

CEGR 6244: Chemical Fate and Transport. (3) Prerequisites: CEGR 3141 and permission of department. Fate of chemicals in the environment and transport processes within and between phases. Environmental chemo-dynamics. Volatilization, dissolution and adsorption from an equilibrium perspective. Evaluation of mass transfer kinetics across environmental compartments. (On demand)

CEGR 6245: Chemical and Biological Processes in Environmental Systems. (3) Prerequisites: CHEM 1251, CEGR 3141, and permission of department. Chemical and biological processes that describe the behavior of materials in natural and engineered environmental systems. Chemical processes to be covered may include acid-base reactions, equilibrium partitioning, pH buffering, precipitation/dissolution, complex formation, adsorption, oxidation-reduction, coagulation, and adsorption. Fundamentals of biological theories to be covered may include kinetics, bioenergetics, genetics, and cellular functions. (Fall)

CEGR 6251. Analysis and Design of Deep Foundations. (3) Prerequisites: CEGR 3278 and permission of department. Geotechnical Engineering I or consent of the instructor. Graduate student status. Methodologies for analysis and design of deep foundations including different construction layouts and configurations (e.g., single and group piles), different installation techniques (e.g., driven, drilled, ACIP, etc.), different loading conditions (e.g., axial compression, axial tension, lateral, general loading, etc.), different design approaches (e.g., allowable stress design - ASD, and load and resistance factor design - LRFD), among other topics. New emerging technologies, construction and inspection aspects and their implications on deep foundation design, and other topics. (Fall)

CEGR 6252. Soil Dynamics and Earthquake Engineering. (3) Prerequisites: CEGR 3122, CEGR 3278, and permission of department. Review of the dynamics of single and multi degree of freedom systems. Earthquake mechanism, distribution, magnitude, intensity, ground shaking, site effects, prediction, and response spectra. Soil liquefaction; aseismic design of foundations; seismic codes; and machine foundation design. (On demand)

CEGR 6253. Design and Analysis of Waste Containment Systems. (3) Prerequisites: permission of department; consent of the instructor; graduate student status. Types and function of containment systems; Selection of effective containment system and its design; Design and
analysis of landfills, grout curtains and slurry walls; Degradation mechanisms and monitoring of containment systems. (Fall)

CEGR 6254. Experimental Soil Mechanics. (3). Prerequisites: CEGR 3278 – Geotechnical Engineering I or consent of the instructor, graduate student status and permission of department. Experimental methods, with emphasis on laboratory tests, to determine engineering soil properties and investigate soil behavior; i) classification tests (i.e., used to identify soil classification and identify general engineering behavior type); and ii) assessment of engineering properties, such as permeability, shear strength, stiffness, and compressibility; Primary lab tests to be covered in this course are: consolidation, direct shear, static tri-axial, cyclic tri-axial, cyclic simple shear, resonant column, and other advanced geotechnical laboratory tests. Also includes discussion on field sampling and testing, reconstituted samples, laboratory instrumentation and measurement techniques. (Spring)

CEGR 6255. Soil Stability and Earth Structures. (3). Prerequisites: CEGR 3278 – Geotechnical Engineering I or consent of the instructor, graduate student status and permission of department. Soil and rock slope stability including the aspects of analysis, design, and stabilization within a geotechnical framework; Concepts related to seepage analysis of isotropic and anisotropic soil structures to relate the influence of groundwater conditions in slope stability problems; Presentation of slope stability analysis procedures based on limit equilibrium principles and stress-deformation analyses; Stability considerations of natural slopes and human-made soil structures; Computer software for seepage and slope stability analysis is explained. (Spring)

CEGR 6261. Traffic Signal Control Systems. (3) Prerequisites: CEGR 6161 and permission of department. Study of control systems for isolated intersections, arterial streets, closed networks, and freeways. Emphasis on computer models; state-of-the-art detection, control, and communications equipment and software; and intelligent vehicle/highway systems. (Fall)

CEGR 6268. Advanced Soil Mechanics. (3) Prerequisites: CEGR 3258, CEGR 3278, and permission of department. One and two-dimensional consolidation, layered strata effects, and creep; seepage in layered strata, flow net, and seepage forces; shear strength parameters, effective and total stress paths, and application for slope stability evaluation; principles of critical state soil mechanics; computer applications. (Fall)

CEGR 6892. Individualized Study and Projects. (1-6) Prerequisite: permission of department. Individual investigation or exposition of results for the 3-hour MS project. May be repeated for credit. (Fall, Spring, Summer)

CEGR 6990. Industrial Internship. (1-3) Prerequisite: Completion of nine hours of graduate coursework. Full- or part-time academic year internship in engineering complementary to the major course of studies and designed to allow theoretical and course-based practical learning to be applied in a supervised industrial experience. Each student’s program must be approved by their graduate program director and requires a mid-term report and final report to be graded by the supervising faculty. Graded on a Pass/Unsatisfactory basis. Credit hours gained from
Internship shall not be part of the minimum credit hours requirement for graduation. *(On demand)*

**CEGR 6991. Graduate Master Thesis Research.** (1-6) Prerequisite: permission of department. Individual investigation culminating in the preparation and presentation of a thesis. May be repeated for credit. *(Fall, Spring, Summer)*

**CEGR 8090. Special Topics.** Directed study of current topics of special interest. *(See the Infrastructure and Environmental Systems heading for details.)*