CE 413 – DESIGN OF CONCRETE STRUCTURES
FALL 2013

This course studies the design of reinforced concrete members in accordance with the ACI Building Code. At the end of the course, students should be able to design simple reinforced concrete structures for gravity and wind loadings. Students are required to demonstrate proficiency in the analysis and design of flexural members, compression members, one-way and two-way slab systems, and footings, and systems comprised of such members. Students will also be proficient in designing for shear, meeting serviceability requirements, and satisfying reinforcing cover, spacing, and development length requirements. The course also provides a brief introduction to concrete mix design and concrete testing procedures.

Prerequisite: To take CE 413 you must have completed ES 230 – Strength of Materials.

Professor: Anne Raich, Ph.D. 322 ACE raicha@lafayette.edu
330-5590 http://sites.lafayette.edu/raicha

Lecture: MWF 3:10 pm – 4:00 pm, AEC 306
Office Hours: Tues. 11:00 am - noon; Tues. & Thurs. 2:30 pm - 4:30 pm
Other times, if the door to my office is open, feel free to stop by and ask questions

Textbook: McCormac, J.C. and Brown, R.H. (2013) Design of Reinforced Concrete, 9th Ed., Wiley Publishers, ISBN 978-1-118-12984-5
Note: There is a cheaper eBook version available from the Wiley website

Exam I: Thursday, October 3rd, 2013 (Evening Exam – 7:00 pm to 9:00 pm)
Exam II: Thursday, November 7th, 2013 (Evening Exam – 7:00 pm to 9:00 pm)
Final Exam: T.B.D.

Notes: For all exams you will be able to bring one page of handwritten notes. The use of other notes or books during the exam will not be permitted. The final exam is comprehensive.

Grade Distribution:				
	Homework (~7):	15%	Exam I:	15%
	Team Project:	20%	Exam II:	20%
	Concrete Lab:	5%	Final Exam:	25%

Final Grading Scale: $A \geq 92$; $92 > A- \geq 90$; $90 > B+ \geq 87$; $87 > B \geq 82$; $82 > B- \geq 80$; $80 > C \geq 70$; $70 > D \geq 60$; $F < 60$

Expected Workload:
The types of assignments in this course range from individual homework assignments to laboratory work to team project work. The main purpose of individual homework is to help you learn the fundamentals of reinforced concrete analysis and design. The lab work will provide the opportunity to gain hands-on experience designing, mixing concrete and testing concrete to determine its properties. The team project provides the opportunity to apply your knowledge in designing the primary structural elements of a 3-story building. The amount of out-of-class work will vary each week. Several out-of-class laboratory work sessions will be arranged with teams of 3 to 4 students. The first lab session for each team is scheduled during the second or third week of the course. This lab will be around 1-1/2 hours long and will involve mixing a batch of concrete according to a developed mix design, performing slump and density tests, and casting test cylinders. Additional 30-minute lab sessions will follow at 3-days, 7-days, 14-days and 28-days after the initial pour date in order to perform compressive strength, elastic modulus and split tensile strength tests.

Learning Objectives:
Specific learning objectives are defined for each topic that identify the knowledge and skills the student is expected to have learned and mastered. Full understanding of a learning objective is accomplished through in-class and out-of-class work (i.e. notes, discussion, labs, readings, homework & project work) and exams will test that students have acquired the identified knowledge and skills. The scheduled topics listed below may be changed during the semester.

Attendance and Participation:
Regular and on-time class attendance *is required,* although no grade is assigned for attendance**.** Class participation is expected and provides an opportunity to ask *your* questions, which helps all students learn the course material more thoroughly. You are responsible for all material covered in class, even if absent for authorized activities.

Class	Date		Tentative Topic (Subject to Change)	Class Reading
1	M	8/26	Introduction/Reinforced Concrete Structural Systems	1.1 – 1.10
2	W	8/28	Material Properties of Concrete and Reinforcing Steel	1.11 – 1.19
3	F	8/30	Concrete Mix Design	Handout/Lab HW
4	M	9/2	ACI Design Philosophy/ Design Loads *Set Out-of-Class Lab Times*	1.21-1.27 & 3.1-3.3 & 4.1
5	W	9/4	Flexural Behavior of Beams	2.1 - 2.3
6	F	9/6	Beams - Uncracked/Cracked Section Behavior	Handout & 2.1 – 2.6
7	M	9/9	Beams - Ultimate Strength/Equivalent Stress Block/Balanced	3.3 - 3.11
8	W	9/11	Beams - Section Analysis	3.6 - 3.11
9	F	9/13	Beams - Section Analysis - Multiple Layers and Over-Reinforced	5.7
10	M	9/16	Continuous Beams - T-Section Analysis	5.1 – 5.3
11	W	9/18	Cont. Beams & Frames- Infl. Lines/Load Patterns/ACI Moment Coeffs	14.1 – 14.3 & 14.5 - 14.7
12	F	9/20	Cont. Beams & Frames – Computer Modeling and Analysis	Handout
13	M	9/23	Flexural Members – Beam Design	4.1 - 4.6
14	W	9/25	Flexural Members - Use of Design Aids and Code Requirements	4.1 - 4.8 & 4.10
15	F	9/27	Flexural Members – T-Section Design	5.4 - 5.6
16	M	9/30	Flexural Members – T- and L-Section Design	5.4 - 5.6
17	W	10/2	Flexural Members – Doubly Reinforced/Compression Reinforcement	5.8 & 5.10
THURSDAY		**10/3**	**EXAM I** (Evening Exam 7:00 pm – 9:00 pm)	
18	F	10/4	One-way Slabs & Joists *Discuss Project Details*	4.7
19	M	10/7	One-way Slabs & Joists	Handout
20	W	10/9	Reinforcement Detailing - Development Lengths	7.1 – 7.5
21	F	10/11	Reinforcement Detailing - Bar lengths, cutoffs, splices	7.8 – 7.13; 14.11
	M	10/14	*Fall Break – No Class*	
22	W	10/16	Reinforcement Detailing - Hooks, Detailing Requirements	7.5, 7.13, & 7.17
23	F	10/18	Reinforcement Detailing – Continuity and Integrity	Handout
24	M	10/21	Flexural Members – Shear	8.1 – 8.7
25	W	10/23	Shear Reinforcement of Beams	8.8 – 8.11
26	F	10/25	Shear Reinforcement of Beams	8.8 – 8.11
27	M	10/28	Shear Reinforcement of Beams - Design	
28	W	10/30	Shear Reinforcement of Beams – Design & Detailing	8.17
29	F	11/1	Serviceability - Deflection	6.1 – 6.8
30	M	11/4	Serviceability – Deflection and Crack Control	6.8 – 6.14
31	W	11/6	Short Column Behavior & Analysis	9.1 – 9.11
THURSDAY		**11/7**	**EXAM II** (Evening Exam 7:00 pm – 9:00 pm)	
32	F	11/8	Short Column Behavior & Analysis/Interaction Diagrams	10.1 – 10.7
33	M	11/11	Short Columns – Interaction Diagrams	10.1 – 10.7 & Handout
34	W	11/13	Short Columns – Interaction Diagrams & Design	10.6 – 10.10 & 8.13
35	F	11/15	Short Columns – Biaxial Bending/Design	10.8, 10.9 & 7.7, 7.14
36	M	11/18	Behavior of Two-Way Slab Floor Systems	16.1 – 16.8
37	W	11/20	Two-Way Slab Floor Systems - Direct Design Method	16.5 – 16.8
38	F	11/22	Two-Way Slab Floor Systems - Direct Design Method/Interior	16.9 & 16.11
39	M	11/25	Two-Way Slab Floor Systems - Direct Design Method/Exterior	16.11 & 16.14
	W & F	11/27 & 11/29	*Holiday Break – No Class*	
40	M	12/2	Two-Way Slab Floor Systems – Detailing & Shear	16.5
41	W	12/4	Footings – Flexural Design	12.1 – 12.6
42	F	12/6	Footings – Shear Design	12.6, 12.12, 12.14 &12.16
FINAL: TBA				

"It's like if you plant something in the concrete and if it grows and the rose petal has got all kinds of scratches and marks, you ain't gonna say "damn, look at all the scratches and marks on the rose that grew from the concrete..", you are gonna be like "Damn, a ROSE grew from the CONCRETE?" – Tupac Shakur

Academic Integrity Statement**:** "Students are expected to be honorable, ethical, and mature in every regard"
Just as ethical conduct is an essential part of the engineering profession, academic integrity is essential to ensure a fair and positive learning environment. No form of scholastic misconduct will be tolerated. Academic dishonesty includes cheating, fabrication, falsification, plagiarism, copying homework from other students (even if you have received their permission) or from a solution, etc. It is the student's responsibility to comply with the *Lafayette College Student Handbook* (http://studentlife.lafayette.edu/resources/) and to be familiar with the *Principles of Intellectual Honesty* (http://fye.lafayette.edu/academics/). Violations will be handled in accordance with the Procedural Standards in Disciplinary Proceedings outlined in the *Student Handbook*.

> *"I give you two examinations, one in trigonometry and one in honesty. I hope you pass them both, but if you must fail one, let it be trigonometry for there are many good people in this world today who cannot pass an examination in trigonometry, but there are no good people in the world who cannot pass an examination in honesty" - Vanderbilt Univ. past-Chancellor Madison Sarratt*

Homework Policy:
Homework will be collected at the beginning of class on the date due. Late homework will be accepted **only** by making a **prior** arrangement with the instructor either during office hours or by email, subject to Lafayette College Dean's Excuse Policy outlined in section 7.3.2 of the Faculty Handbook under the heading Class Attendance

- This class emphasizes developing professional problem solving skills and applying these skills to design reinforced concrete structural elements and systems. All homework should be submitted on engineering paper (one side only) in a professional manner, which includes neat handwriting and organization. Therefore, neatness, clarity, and the ease that others have in understanding your work ('calcs') is critical and will be considered as part of your grade. The following should be provided in the homework:
  - Provide a description of the problem being solved and the assumptions made.
  - Provide clearly drawn sketches that include dimensions and necessary labels
  - Clearly identify the design or analysis steps and calculations made. Check your units and assumptions.
  - Provide a summary of your final answers and assess whether your answers seem reasonable.
- Unless otherwise stated, all homework in this class is expected to be individual work. Copying the work of others, including homework, is in violation of the College's Principles of Intellectual Honesty, which can be accessed at http://fye.lafayette.edu/academics/. You may discuss the homework assignments with other students. All work submitted, however, must be your own and it is your responsibility to properly acknowledge the source of ideas and facts received from others, including other students. A student who commits academic dishonesty is subject to a range of penalties, including suspension or expulsion. The primary purpose of homework is to facilitate learning about structural behavior and mechanics not just using equations to get the correct answer.
- Discussions about re-grading of homework or exams are not conducted in person or by email. If you would like to request re-grading, attach a signed statement to your work that details where you feel you lost points and submit it to the professor within one week after the homework or exam has been returned.

Team Project Information:

- The team project will involve the design and analysis of a reinforced concrete structure. The objective of this project is to allow students to take their knowledge gained concerning the design of individual elements (beams, slabs, columns, reinforcement) and apply it to the design of a system composed of these elements. This design project requires the consideration of alternative solutions and the selection of a final design.
- Teams are made up of 3 or 4 students. Your team must submit a member list to Prof. Raich by Friday, Oct. 4th. After that date, you will be placed on a team. The 1st team task is to develop a company name, logo & letterhead.
- In this term project, you will be designing beams, slabs, joists, columns, and footings for a three-story building. These are the main structural components in any reinforced concrete building. Therefore, acquiring these design skills should be a priority since they are highly-sought out by structural consulting firms and government agencies. What you learn in this course is what many professional structural engineers do on a daily basis. Your team's work on each project task will be evaluated with the expectation that an 'A' means that I think that you could be hired to do this particular task for a living under the direction of a licensed professional engineer.
- More details concerning the team project design tasks, requirements, specifications, and reporting requirements will be presented and discussed later in the semester and will also be made available on the course website. Project task submittals will include a cover letter, AutoCAD design drawings, full calculations and an invoice for hours worked by the project team. The due dates for each project task will be posted at that time.

Reasons for the Emphasis on Clear Calculations on Your Homework and Team Project Submittals (PCA, Ken Hover)

1. When you work for an engineering firm your calculations are not your personal property but are the legal property of that firm (including what you may consider to be scratch notes or rough drafts).
2. When another engineer needs to make a modification to your work, your 'calcs' will be his or her starting point.
3. Should the owner in the future decide to make an addition or change building occupancy or loads, your 'calcs' will be needed.
4. If you get promoted, transferred to another office, or win the lottery, another engineer may have to pick up where you left off, and if your 'calcs' are not clear, that other engineer may have to start all over, meaning that all your time (and salary) were wasted.
5. You may be called away for a number of weeks or months or the project may be delayed for an extended period. By the time you get back to the project the clarity of your calculations will determine whether you can figure out what you have already done or whether you have to start all over again.
6. The project owner has the right to pass the engineer's calculations on to another engineer for review and comment and again the starting point will be your 'calcs'.
7. Should your firm ever need to defend the correctness of your work in a court of law, your calculations are likely to be subpoenaed (i.e., a court order that demands that your firm turn-over your calculations), and further clarification or annotation will not be permitted. The lawyers, judge, jury and 'experts' will judge the correctness of your work based on your calculations. Your original calculations, without modifications, may become 'Exhibit A'. If the calculations are sloppy or unprofessional, the judge and jury are likely to assume (mistakenly, perhaps) that you are likewise a sloppy and unprofessional engineer. If your calculations contain an error, the opposition's expert witness WILL catch it and the lawyer for the opposition will make sure everyone knows about it.

How Clear Calculations Work in Practice (PCA, Ken Hover)

Hand calculations are required for homework and project task submittals. The only exception is when you use Excel spreadsheets to perform analysis or design. Do your calculations neatly, by hand, in pencil, the very first time. If you need to make changes go back and cross-out or line-out previous work, adding notes that explain the reason for the changes, and move on. Put your name and the date on every page, and number every page. If done neatly and sequentially from the start you will not need to re-copy your calculations for submittal, which should be avoided due to mistakes that can occur during the copying process. Do NOT type your calculations in an attempt to make them neater. This can lead to mistakes and misinterpretation. Your calculations should include hand-drawn sketches and free-body diagrams. Although, AutoCAD drawings will be required for the final design drawings in each project task submittal, these drawings do not take the place of clear hand-drawn sketches in your calculations.

Clear Calculations Extend to the Format of Excel Spreadsheets for Analysis and Design (PCA, Ken Hover)

Many routine multi-step design calculations turn out to be not particularly difficult. Using Excel spreadsheets is an excellent way to save time while performing the required calculations and design code checks. Although you are mainly interested in the output of the spreadsheet you create, others will need to also understand how to use it and how to interpret the results provided. Therefore, you need to provide enough clear text, headings, colors, fonts, boxes, arrows, descriptions, hints, controls etc. in your spreadsheet so that non-developers can still use it easily and with confidence (if they have to check everything then no time is saved).

Final Clear Calculations Point – Billable Project Hours (PCA, Ken Hover)

During the semester, each team project task submittal will include a professional engineering services invoice. Each invoice will show the number of hours the each team member worked for that project task. Direct costs will be computed as the hours worked multiplied by hourly rate for each engineer. Indirect costs will be computed as a multiple of the direct costs. Indirect costs include office-space, computers, software, administrative staff, bonuses, benefits, sick and vacation time, continuing education, liability insurance, company vehicles, birthday cakes, microwaves, telephones, toilet paper, and pens and papers for all the hand written calculations, among many other things. We will discuss how to prepare the invoices when the first project task is assigned. Although submitting an invoice as a professional engineer pays off in actual dollars, your team's invoice payoff will be the pride you have in your professionally performed analysis and design calculations.

Software Used for this Class:

The CEE Lab computers have SAP 2000 installed, which you can use to complete the homework assignments and project. Information on SAP 2000 is available on-line as part of the Computers and Structures official webpage.

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Students with Disabilities**:** The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation or require assistance with academic concerns/accommodations, please contact the Office of the Dean of the College, 200 Scott Hall (610-330-5080).

ABET Student Outcomes Addressed:

(a) Ability to apply knowledge of mathematics, science, and engineering to solve engineering problems.
(c) Ability to design a system, component or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(e) Ability to identify, formulate, and solve civil engineering problems
(f) Understanding of professional and ethical responsibility
(g) Ability to communicate effectively in written form
(i) Recognition of the need to engage in life-long learning including continuing education
(k) Ability to use the techniques, skills, and modern engineering tools necessary for civil engineering practice

CE 413 Course Student Learning Objectives

Goal: Provide the opportunity for students to learn concepts and design principles of reinforced concrete structures.

1) Gain an understanding of how structural system elements (beams, slabs, columns, footings) behave under various loading conditions. (3a & 3e)
2) Gain an understanding of how the design strength is calculated for structural system elements (beams, slabs, columns, footings). (3a & 3e)
3) Provide opportunities for students to develop their computer modeling and analysis skills to determine axial, shear and moments in beams and columns in structural systems. (3k)
4) Apply methods of providing structural safety and selecting appropriate design loads for structural systems. (3a & 3c)
5) Understand the professional responsibilities of structural engineers regarding analysis, design and application of code requirements. (3c & 3f)
6) Gain a working knowledge of concrete mix design and concrete testing methods to determine compressive strength, tensile strength, and stress-strain behavior including determining the modulus of elasticity. (3c & 3k)
7) Analyze and design reinforced concrete beams, columns, slabs, and footings considering both strength and serviceability requirements. (3c & 3e)
8) Recognize design inadequacies or potential design errors in their own work and in the work of others. (3e, 3f & 3i)
9) Gain experience working on project teams and communicating details of conceptual designs and design solutions to others in memos, reports and design drawings. (3g)
10) Gain the basic knowledge of reinforced concrete design required to take advanced courses in graduate school or begin self-study and to fully contribute to the analysis and design work undertaken by structural consulting firms. (3i)

"The student work in this course is in full compliance with the federal definition of a four credit hour course. See the Lafayette College Office of the Registrar webpage for the full policy and practice statement."

Due Dates for HW and Project Parts

Class	Date		Tentative Topic (Subject to Change)	Class Reading
1	M	8/26	Introduction/Reinforced Concrete Structural Systems	1.1 – 1.8
HW1	W	8/28	Material Properties of Concrete and Reinforcing Steel	1.9 – 1.20
	F	8/30	Concrete Mix Design	Handout/Lab HW
Concrete Mix	M	9/2	ACI Design Philosophy/ Design Loads *Set Out-of-Class Lab*	1.21 - 1.27
HW2	W	9/4	Flexural Behavior of Beams	2.1 - 2.2
	F	9/6	Beams - Uncracked/Cracked Section Behavior	Handout & 2.1 – 2.10
	M	9/9	Beams - Ultimate Strength/Equivalent Stress Block/Balanced	3.1 - 3.6
	W	9/11	Beams - Section Analysis	3.7 - 3.11
HW3	F	9/13	Beams - Section Analysis - Multiple Layers and Over-Reinforced	5.7 – 5.8
	M	9/16	Continuous Beams - T-Section Analysis	5.1 – 5.3
	W	9/18	Cont. Beams & Frames- Infl. Lines/Load Patterns/ACI Moment	14.7
HW4	F	9/20	Cont. Beams & Frames – Computer Modeling and Analysis	Handout
	M	9/23	Flexural Members – Beam Design	4.1 - 4.6
	W	9/25	Flexural Members - Use of Design Aids and Code Requirements	4.1 - 4.6
	F	9/27	Flexural Members – T-Section Design	5.4 - 5.6
HW 5	M	9/30	Flexural Members – T- and L-Section Design	5.4 - 5.6
	W	10/2	Flexural Members – Doubly Reinforced/Compression Reinforcement	5.8
THURSDAY		**10/3**	**EXAM I** (Evening Exam 7:00 pm – 9:00 pm)	
	F	10/4	One-way Slabs & Joists *Project Details*	4.7
HW6	M	10/7	One-way Slabs & Joists	Handout
	W	10/9	Reinforcement Detailing - Development Lengths	7.1 – 7.5
A1	F	10/11	Reinforcement Detailing - Bar lengths, cutoffs, splices	7.8 – 7.13
	M	10/14	*Fall Break – No Class*	
	W	10/16	Reinforcement Detailing - Hooks, Detailing Requirements	
LAB	F	10/18	Reinforcement Detailing – Continuity and Integrity	Handout
	M	10/21	Flexural Members – Shear	8.1 – 8.7
	W	10/23	Shear Reinforcement of Beams	8.8 – 8.11
A2	F	10/25	Shear Reinforcement of Beams	8.8 – 8.11
	M	10/28	Shear Reinforcement of Beams - Design	
	W	10/30	Shear Reinforcement of Beams – Design & Detailing	
	F	11/1	Serviceability - Deflection	6.1 – 6.14
A3	M	11/4	Serviceability – Deflection and Crack Control	6.1 – 6.14
	W	11/6	Short Column Behavior & Analysis	9.1 – 9.11
THURSDAY		**11/7**	**EXAM II** (Evening Exam 7:00 pm – 9:00 pm)	
	F	11/8	Short Column Behavior & Analysis/Interaction Diagrams	9.1 – 9.11
	M	11/11	Short Columns – Interaction Diagrams	10.1 – 10.7 & 7.7
B1&B2	W	11/13	Short Columns – Interaction Diagrams & Design	10.8 – 10.10 & 8.13
	F	11/15	Short Columns – Biaxial Bending/Design	
	M	11/18	Behavior of Two-Way Slab Floor Systems	16.1 – 16.10
	W	11/20	Two-Way Slab Floor Systems - Direct Design Method	16.11
C1	F	11/22	Two-Way Slab Floor Systems - Direct Design Method/Interior	
	M	11/25	Two-Way Slab Floor Systems - Direct Design Method/Exterior	
	W & F	11/27 & 11/29	*Holiday Break – No Class*	
	M	12/2	Two-Way Slab Floor Systems – Detailing & Shear	
	W	12/4	Footings – Flexural Design	12.1 – 12.6
D1	F	12/6	Footings – Shear Design	12.12

E1 is Extra Credit

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