

THE UNIVERSITY OF WESTERN ONTARIO
FACULTY OF ENGINEERING
DEPARTMENT OF CIVIL and ENVIRONMENTAL ENGINEERING

CEE 9549a - Advanced Design and Behaviour of Concrete Structures
Course Outline – Fall 2016

- OBJECTIVES:** The objectives of this course are for the student to become able to:
1. recognise that design criteria in CSA Standard CAN/CSA A23.3 concerning the behaviour and design of reinforced concrete members and structures are simple applications of the fundamentals of statics and applied mechanics;
 2. document decisions made during the design process in coherent and legible design calculations;
 3. design structural reinforced concrete members and systems that are safe, serviceable, and economical.

PREREQUISITES: CEE 2220a, CEE 2221b, CEE 2202a, CEE 3340a, CEE 3341b, CEE 3347a, CEE 3358b, or their equivalent, by permission of the Instructor.

CO-REQUISITES: NONE.

ANTIREQUISITES: NONE.

TOPICS: Basic flexural theory and strain compatibility solutions. Serviceability criteria for members and structures. Shear design using truss models, compression field theory, and the modified compression field theory. Strut-and-tie models for detailing corbels, beams with dapped ends, and joints. Column analysis and design including slender columns in frames. Design of two-way slab systems to resist flexure and shear. Bond and development of reinforcement.

CONTACT HOURS: 3 lecture hours/week (personal study - 18 hours).

INSTRUCTOR: Dr. Aiham Adawi, P. Eng., SEB 3095, email: aadawi2@uwo.ca
Admin. Support: Kristen Edwards, SEB3009.

TEXT: NONE.

LECTURE NOTES: It is strongly recommended that prepared lecture notes be brought to each lecture. They can be downloaded from the course OWL site.

COMPUTING: Assignments may require the use of structural analysis software.

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REFERENCE: MacGregor, J. G. and Bartlett, F. M. (2000): *Reinforced Concrete: Mechanics and Design (1st Canadian Edition)*. Prentice-Hall Canada Inc. (Purchase Optional)

LABORATORY: There is no formal laboratory component of this course.

**SPECIFIC LEARNING
OBJECTIVES:**

1. Behaviour and Strength of Sections in Flexure: At the end of this segment, the student should be able to:
 - a) Compute moment-curvature relationships for reinforced concrete sections subjected to bending or combined bending and axial loads using the basic conditions of equilibrium, compatibility, and force-deformation relationships.
 - b) Recognise the impact of the response of concrete in uniaxial compression on the stress-strain diagram, and on the response for biaxial and triaxial stress states.
 - c) Summarise the additional assumptions necessary to develop a simplified flexural theory for reinforced concrete.
 - d) Compute the flexural capacity of T-beams, isolated unsymmetrical beams, and beams with compression reinforcement.
 - e) Apply simple truss-based models to determine appropriate transverse reinforcing for T-beam flanges.

2. Serviceability of Concrete Structures: At the end of this segment, the student should be able to:
 - a) Distinguish between the different methods used to determine the tensile strength of concrete, and the strengths obtained using the different methods.
 - b) Distinguish between structural and non-structural cracks, and assess whether the extent of flexural cracking is unserviceable according to current standards.
 - c) Recognise the potential limit states associated with deflections due to differential settlement, beam or slab bending, prestressing, or column deflections in tall buildings.
 - d) Compute long-term deflections due to creep and shrinkage of concrete structures.

3. Columns: At the end of this segment, the student should be able to:
 - a) Classify columns as “short” or “long”, and characterize the column behaviour based on this classification.
 - b) Distinguish between the axial response of short tied and spiral columns,

and determine the geometry of the spiral reinforcement necessary to obtain the desired response.

- c) Construct interaction diagrams for columns from first principles.
- d) Determine the capacity of a column subjected to biaxial bending.
- e) Compute the resistance of a slender column using approximate analyses involving moment magnifiers, or the design criteria presented in A23.3.
- f) Distinguish between material failures and stability failures, recognizing the impact of tangent and secant stiffnesses, non-uniform end moments, and sustained loads on stability failures.
- g) Analyse columns in sway and non-sway frames.

4. Shear Strength of Reinforced Concrete:

- a) Explain from first principles and experimental evidence the behaviour of beams without web reinforcement, and the transfer of forces after inclined cracking in beams with and without web reinforcement.
- b) Design beams to resist shear using section design methods or whole member design methods.
- c) Distinguish between shear design using Compression Field Theory (A23.3-84), Modified Compression Field Theory (A23.3-94) or Simplified Modified Compression Field Theory (A23.3-04).

5. Bond, Development and Anchorage of Reinforcement:

- a) Derive the relationships between bar force and bond, average bond stress in a beam, and an approximate development length equation.
- b) Appreciate the basis of, and apply, detailing rules for flexural steel resisting positive and negative moment.

6. Discontinuity Regions, Strut-and-Tie Models:

- a) Identify B and D regions in concrete structures and analyse D regions using strut-and-tie methods.
- b) Layout plastic trusses, size compression struts and nodal regions, and check the anchorage of tension ties.
- c) Correlate the mechanics of bottle-shaped compression regions and strut-and-tie models for opening and closing corners to the observed behaviour of these regions.

7. Two-Way Slabs:

- a) Classify slab systems as one-way or two-way and determine the static equilibrium of either classification.

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- b) Carry out preliminary design of two-way slabs, including layout, thickness, flexural reinforcement.
- c) Check shear at interior, edge and corner columns.

UNITS: SI units will be used in lectures and examinations.

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| EVALUATION: | Final Examination* | 50% |
| | Assignments | <u>50%</u> |
| | Total | 100% |

* Students must pass the final examination to pass this course. (Students who fail the final examination will be assigned the aggregate mark or 58%, whichever is smaller).

ASSIGNMENTS: Four or five assignments will be circulated during the term – some may appear in more than one part. Assignments should be turned in class as explained on assignment sheet. The penalty for late submission is 10% per working day late – if you need an extension, please indicate this in an email message before the assignment is due.

- CHEATING:** University policy states that cheating is a scholastic offence. The commission of a scholastic offence is attended by academic penalties that might include expulsion from the program. If you are caught cheating, there will be no second warning. For further information on scholastic offences, please see: http://grad.uwo.ca/current_students/graduate_regulations/section_10.htm
- ENGLISH:** In accordance with Senate and Faculty Policy, students may be penalised up to 10% of the marks on all assignments, tests and examinations for the improper use of English. Additionally, poorly written work with the exception of final examinations may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.
- CONDUCT:** Students are expected to arrive at lectures on time, and to conduct themselves during class in a professional and respectful manner that is not disruptive to others. Late comers may be asked to wait outside the classroom until being invited in by the Instructor. Please turn off your cell phone before coming to a class or exam. On the premises of the University or at a University-sponsored program, students must abide by the Student Code of Conduct: <http://www.uwo.ca/univsec/board/code.pdf>
- CONSULTATION:** Students are encouraged to discuss problems with their instructor at the end of the lecture, or during individual consultations arranged by appointment.
- SICKNESS OR OTHER PROBLEMS:** Students should immediately consult with the Department of Civil and Environmental Engineering if they are ill or have any other problems that could affect their performance in the course. Where appropriate, the problems should be documented (see attached). The student should seek advice from the Instructor concerning the recovery of work missed. Failure to notify the Department of illness or any other matter that could affect academic performance immediately (or as soon as possible thereafter) will have a negative effect on any appeal.
- NOTICE:** Students are responsible for regularly checking their email and notices posted outside the Civil and Environmental Engineering Department Office.

**INSTRUCTIONS FOR STUDENTS UNABLE TO WRITE TESTS
OR EXAMINATIONS OR SUBMIT ASSIGNMENTS AS SCHEDULED**

If, on medical or compassionate grounds, you are unable to write term tests or final examinations or complete course work by the due date, you should follow the instructions listed below. You should understand that academic accommodation will not be granted automatically on request. You must demonstrate to your department (or the Undergraduate Services office if you are in first year) that there are compelling medical or compassionate grounds that can be documented before academic accommodation will be considered. Different regulations apply to term tests, final examinations and late assignments. Read the instructions carefully. (see the 2016 Western [Academic Calendar](#)).

A. GENERAL REGULATIONS & PROCEDURES

1. Check the course outline to see if the instructor has a policy for missed tests, examinations, late assignments or attendance.
2. Bring your request for academic accommodation to the attention of the Chair of the department (or the Undergraduate Services office if you are in first year) prior to the scheduled time of the test or final examination or due date of the assignment. If you are unable to contact the relevant person, leave a message with the appropriate department (or Undergraduate Services office, if you are in first year). The addresses, telephone and fax numbers are given at the end of these instructions. Documentation must be provided as soon as possible.
3. If you decide to write a test or an examination you should be prepared to accept the mark you earn. Rewriting tests or examinations or having the value of a test or exam reweighted on a retroactive basis is not permitted.

B. TERM TESTS

1. If you are unable to write a term test, inform your instructor and the Chair of your Department (or the Undergraduate Services Office if you are in first year) prior to the scheduled date of the test. If the instructor is not available, leave a message for him/her at the department office and inform the Chair of the Department (or the Undergraduate Services Office if you are in first year).
2. Be prepared to provide supporting documentation to the Chair and the Undergraduate Services Office (see next page for information on documentation).
3. Discuss with the instructor if and when the test can be rescheduled. **N.B.** The approval of the Chair (or the Undergraduate Services Office if you are in first year) is required when rescheduling term tests.

C. FINAL EXAMINATIONS

1. If you are unable to write a final examination, contact the Undergraduate Services Office **PRIOR TO THE SCHEDULED EXAMINATION TIME** to request permission to write a Special Final Examination. If no one is available in the Undergraduate Services Office, leave a message clearly stating your name & student number (please spell your full name).
2. Be prepared to provide the Undergraduate Services Office with supporting documentation (see next page for information on documentation) the next day, or as soon as possible (in cases where students are hospitalized). The following circumstances are not considered grounds for missing a final examination or requesting special examinations: common cold, sleeping in, misreading timetable and travel arrangements.
3. In order to receive permission to write a special examination, you must obtain the approval of the Chair of the Department **and** the Associate Dean and in order to apply you must sign a "Recommendation for a Special Examination Form" available in the Undergraduate Services Office. The Undergraduate Services Office will then notify the course instructor(s) and reschedule the examination on your behalf.

N.B. It is the student's responsibility to check the date, time and location of the special examination.

D. LATE ASSIGNMENTS

1. Advise the instructor if you are having problems completing the assignment on time (**prior** to the due date of the assignment).
2. Be prepared to provide documentation if requested by the instructor (see reverse side for information on documentation).
3. If you are granted an extension, establish a due date. The approval of the Chair of your Department (or the Associate Dean if you are in first year) is not required if assignments will be completed prior to the last day of classes.
4.
 - i) Extensions beyond the end of classes must have the consent of the instructor, the department Chair and the Associate Dean. Documentation is mandatory.
 - ii) A Recommendation of Incomplete Form must be filled out indicating the work to be completed and the date by which it is due. This form must be signed by the student, the instructor, the department Chair and the Associate Dean.

SHORT ABSENCES

If you miss a class due to a minor illness or other problems, check your course outlines for information regarding attendance requirements and make sure you are not missing a test or assignment. Cover any readings and arrange to borrow notes from a classmate.

EXTENDED ABSENCES

If you are absent more than one week or if you get too far behind to catch up, you should consider reducing your workload by dropping one or more courses. (Note drop deadlines listed below). You may want to seek advice from the academic counsellor in your Department or the counsellors in the Undergraduate Services Office if you are in first year.

DOCUMENTATION

If you consulted an off-campus doctor or Student Health Services regarding your illness or personal problem, you must provide the doctor with a Student Medical Certificate to complete at the time of your visit and then bring it to the Department (or the Undergraduate Services Office if you are in first year). **This note must contain the following information: severity of illness, effect on academic studies and duration of absence.**

In Case of Serious Illness of a Family Member: Provide a Student Medical Certificate to your family member's physician to complete and bring it to the Department (or the Undergraduate Services Office if you are in first year).

In Case of a Death: Obtain a copy of the death certificate or the notice provided by the funeral director's office. You must include your relationship to the deceased and bring it to the Department (or the Undergraduate Services Office if you are in first year).

For Other Extenuating Circumstances: If you are not sure what documentation to provide, ask the Departmental Office (or the Undergraduate Services Office if you are in first year) for direction.

Note: Forged notes and certificates will be dealt with severely. To submit a forged document is a scholastic offence (see below).

ACADEMIC CONCERNS

You need to know if your instructors have a policy on late penalties, missed tests, etc. This information may be included on the course outlines. If not, ask your instructor(s).

You should also be aware of attendance requirements in some courses. You can be debarred from writing the final examination if your attendance is not satisfactory.

If you are in academic difficulty, check out the minimum requirements for progression in the calendar. If in doubt, see your academic counsellor.

Calendar References: Check these regulations in your 2016 Western Academic Calendar available at www.westerncalendar.uwo.ca.

[Absences Due to Illness](#) - page 117

[Academic Accommodations for Students with Disabilities](#) - page 118

[Academic Accommodations for Religious Holidays](#) - page 119

[Incomplete Standing](#) - page 104

[Scheduling of Term Assignments](#) – page 97

[Scholastic Offences](#) - page 113

[Special Examinations](#) - page 132

Note: These instructions apply to all students registered in the Faculty of Engineering regardless of whether the courses are offered by the Faculty of Engineering or other faculties in the University.

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| <u>Drop Deadlines:</u> | First term half course (i.e. "A" or "F"): | November 5, 2016 |
| | Full courses and full-year half courses (i.e. "E", "Y" or no suffix): | November 30, 2016 |
| | Second term half or second term full course (i.e. "B" or "G"): | March 7, 2017 |

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| Undergraduate Services Office: | SEB 2097 | telephone: (519) 661-2130 | fax: (519) 661-3757 |
| Dept. of Chemical and Biochemical Engineering: | TEB 477 | telephone: (519) 661-2131 | fax: (519) 661-3498 |
| Dept. of Civil and Environmental Engineering: | SEB 3005 | telephone: (519) 661-2139 | fax: (519) 661-3779 |
| Dept. of Electrical and Computer Engineering, Software Engineering Mechatronics Engineering | TEB 279 | telephone: (519) 661-3758 | fax: (519) 850-2436 |
| Dept. of Mechanical and Materials Engineering: | SEB 3002 | telephone: (519) 661-4122 | fax: (519) 661-3020 |