Civ E 779 – Nonlinear Analysis of Structures (Winter Term 2025/26)

Instructor: Ali Imanpour (imanpour@ualberta.ca)

Workload: 3 credits

Schedule:

Lecture	Tuesday	14:00 – 16:50 PM	(NREF 2-122)

Recommended Prerequisites: Civ E 660 (Advanced Structural Analysis) and Civ E 665 (Introduction to Finite Element Method)

Office hours: Tuesday 12:00 – 13:00, ICE 7-263 or by appointment via email

Course Description:

The four-credit course is offered by the Department of Civil and Environmental Engineering in the winter semester to graduate students in Structural Engineering. The course gives basis on nonlinear structural modelling and advanced structural analysis methods. Computer simulation of steel and reinforced concrete components and their energy dissipation devices are presented based on data obtained from physical experimentations. The basis of nonlinear analyses of steel and reinforced concrete systems in the static and dynamic regimes are introduced. The modelling and analysis methods presented in the course are the basis for the seismic design, performance-based design, and assessment and rehabilitation of existing structures. Examples of component modelling and system analysis are given to illustrate the concepts covered. The lectures are accompanied by a final project that involves the application of the topics covered in the course.

Learning Outcomes:

By the end of this course students will be able to

- Identify and describe nonlinear material models commonly used in advanced structural analysis
- Identify the cyclic behaviour and governing failure modes of steel and reinforced concrete seismic force-resisting systems
- Develop numerical models taking into account material, geometrical and loading nonlinearities
- Apply principles of linear and nonlinear modelling techniques using finite element programs
- Analyse structural systems under gravity and lateral loads for limit states design, performance-based design and seismic evaluation of structures

Lecture Topics:

- Introduction to advanced structural analysis and nonlinear simulation
- Material nonlinearity
- Geometric nonlinearity (P-Delta effects)
- Nonlinear behaviour of structural members including steel braces, beams and columns, and reinforced concrete beams and walls under static loads and cyclic loads
- Simulation models and methods with physical experimentation of structural components including, steel braces, beams and columns, and reinforced concrete beams and walls
- Modelling of soil and structure interaction
- Structural analysis methods and principles of linear and nonlinear analyses
- Nonlinear static (Pushover) analysis method
- Linear and nonlinear response history (dynamic) analysis methods
- Introduction to seismic assessment of structures and performance-Based Design (PBD)
- Application of Artificial Intelligence in structural analysis

Recommended Textbooks/Books/Standards:

1. Bruneau, M., Uang, C.M., Sabelli, R. (2011) "*Ductile Design* of. *Steel Structures*", McGraw-Hill Education; 2nd edition.
2. Filiatrault, A., Tremblay, R., Christopoulos, C., Folz, B., Pettinga, D. (2013) "*Elements of Earthquake Engineering and Structural Dynamics*", Presses internationales Polytechnique, 3rd edition.
3. Paulay T, Priestley, M.J.N. (1992) "*Seismic Design of Reinforced Concrete and Masonry Buildings*", John Wiley & Sons, Inc., 1st edition.
4. NRCC (2020) "*National Building Code of Canada*", National Research Council of Canada. Ottawa, ON.
5. ASCE. (2010) "*Minimum design loads for buildings and other structures*", ASCE/SEI 7-10, Reston, VA.
6. ASCE. (2013) "*Seismic evaluation and rehabilitation of existing buildings*", ASCE/SEI 41-13, Reston, VA.
7. Applied Technology Council (2017). "*Recommended Modeling Parameters and Acceptance Criteria for Nonlinear Analysis in Support of Seismic Evaluation, Retrofit, and Design*", NIST GCR 17-917-45
8. Applied Technology Council (2017). "*Guidelines for Nonlinear Structural Analysis for Design of Buildings, Part I – General; Part IIa – Steel Moment Frames; Part IIb – Reinforced Concrete Moment Frames*", NIST GCR 17-917-46v1
9. NEHRP Consultants Joint Venture (2013). "*Nonlinear Analysis Research and Development Program for Performance-Based Seismic Engineering*", NIST GCR 14-917-27.
10. FEMA 440 (2005) "*Improvement of nonlinear static seismic analysis procedures*", Applied Technology Council (ATC-55 Project), Washington, D.C.

Lecture Schedule:

Week	Date	Content
1	**Jan. 6**	Introduction to advanced structural analysis
2	**Jan. 13**	Material nonlinearity; Nonlinear behaviour of structural members
3	**Jan. 20**	Nonlinear behaviour of structural members (Cont'd)
4	**Jan. 27**	Geometric nonlinearity (P-Delta effects)
5	**Feb. 3**	Structural Systems **Homework 1 assigned**
6	**Feb. 10**	Nonlinear simulation models for structural components
7	***Feb. 17***	*Reading week*
8	**Feb. 24**	Nonlinear simulation models for structural components (Cont'd) **Homework 1 due; Homework 2 assigned**
9	**Mar. 3**	Modelling of soil and structure interaction
10	**Mar. 10**	Structural analysis methods and principles of linear and nonlinear analyses
11	**Mar. 17**	Nonlinear static analysis methods **Homework 2 due; Homework 3 assigned**
12	**Mar. 24**	Linear response history analysis method; Nonlinear response history analysis method
13	**Mar. 31**	Introduction to seismic assessment of structures and performance-based design **Homework 3 due**
14	**April 7**	Application of Artificial Intelligence in advanced structural analysis

Instructional Method:

The methods used in this course will be lecturing, group discussions, homework assignments, final project and final exam. Additionally, each lecture includes one/two learning exercise where students are expected to work in groups and share their answers to the problems. Practical examples will be solved to demonstrate the application of the structural analysis programs commonly used for the nonlinear simulation and analysis of structures.

Final project

Final project is considered to be the main component of this course where the student will apply the structural modelling and analysis techniques consistent with the selected material and lateral-load resisting system. The project consists of the nonlinear simulation and analysis of a framed structure. The project will be done in a group of **two students**. Each group should select a two-dimensional frame part of a building structure having an identical lateral load-resisting system in its principle directions. The selection of structural material and building layout is open. The configuration and characteristics of the frame should be finalized in consultation with the instructor by **February 10, 2026**. The evaluation of the final project will be based on the detail of modelling techniques as well as the analysis results submitted by each group (see *Final Project Outline & Checklist* on Canvas for more details).

Evaluations:

Homework Assignments 30%

Assignments should be submitted individually **on Canvas or in-person by 2:00 pm** on the date specified on the course schedule. The deadline to submit assignments will be provided on the question sheet. If submitting via Canvas, create as a single pdf file containing e-copies of the solutions along with the question sheet. The writing and the photos/scans need to be clear in order to be marked. The total mark of each assignment is 100/100. Late assignments will be penalized by 1 point/minute and will not be marked after the solution is uploaded on Canvas.

Final project 30%

Students must submit a final project. The evaluation of the final project will be based on the detail of modelling techniques, supporting research studies used in the simulation and analysis steps, and the analysis results submitted by each group. The outline of the report to be submitted by each group is provided on Canvas. The report should be submitted either via Canvas **or at DICE 7-263 by 5:00 pm on April 13th 2026**.

Final exam April 14, 9 AM – 12 PM, NREF 2-122 40%

The final exam will cover all topics presented in the lecture notes, **except** the lecture "*Application of Artificial Intelligence in Structural Analysis.*" The exam will be **closed book**. The final exam will include **one bonus question** based on the articles that will be shared throughout the term. The bonus question will be worth **10 marks**, bringing the total possible marks for the final exam to 110. If you miss the final exam, you can apply for a deferred exam through the Department of CEE Graduate Office.

Additional Notes on exams and assignments

All work submitted, including assignments, must be your own. Misconduct will be treated seriously according to the policy of Faculty of Engineering. See "Code of Student Behaviour" on Canvas and here: COSB-Updated-April 29-2024

Final grade

Students' grades on each evaluation will be weighted according to its assigned percentage and combined into a final grade. This final grade will then be converted to a letter grade using the following distribution (Grading System Explained | Office of the Registrar):

Final Marks*			Letter Grade	Grade Point Value	Description
95	–	100	A+	4.0	Excellent
88	–	94.99	A	4.0	
81	–	87.99	A-	3.7	
78	–	80.99	B+	3.3	Good
75	–	77.99	B	3.0	
72	–	74.99	B-	2.7	Satisfactory
69	–	71.99	C+	2.3	
66	–	68.99	C	2.0	Failure
63	–	65.99	C-	1.7	
60	–	62.99	D+	1.3	
50	–	59.99	D	1.0	
0	–	49.99	F	0.0	

*The upper and lower bounds may vary by –/+ 1 mark.

The final grade distribution is determined using a blended approach that is neither based strictly on an absolute numerical scale (e.g., > 90% of total marks for a 4.0) nor strictly on a grading curve (e.g., the top x% of students receive a 4.0). Instead, it considers historical averages for structures graduate-level courses and natural breaks in the score distribution.

Attendance:

Regular attendance in class is expected.

Calculator Policy:

All programmable and non-programmable calculators approved by Faculty of Engineering are permitted in the course.

Time zone

All times referenced in the lecture are local Edmonton time (GMT-6).

Miscellany:

Please turn off your cell phone during lectures.

Course Policies:

What you can expect from me
I am 100% committed to your learning, and you can expect from me feedback on your work and email response within two days on weekdays. I will not read emails on the weekends, except the days preceding the final exam. Finally, you can expect from me, fair, unified, and consistent grading.

What I expect from you
I expect that you engage in all learning activities in this course. This means that it is critical that you read thoroughly the lecture notes assigned, engage in lecture sessions, submit the assignments, and participate in the class discussions. You must display honesty and engagement through the class as per the Department of Civil and Environmental Engineering and School of Mining and Petroleum Engineering Graduate Studies Handbook (see Graduate Studies Resources | Department of Civil & Environmental Engineering for more information).

Academic Integrity

The University of Alberta places a very high value on academic integrity. Code of Student Behaviour (COSB) outlines what students are prohibited from doing and gives the rationale for those rules. (see COSB-Updated-April 29-2024 for more information).

You should read UofA or Faculty of Engineering **Code of Student Behaviour** posted on Canvas before the final exam.