Nonlinear Analysis of Steel Seismic Force-Resisting Systems (Fall Term 2023/24)

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Workload: 2 credits

Schedule:

Lecture	15h	10 AM – 1 PM (3 hours)

Recommended Prerequisites: Advanced Structural Analysis, Earthquake Engineering, Design of Steel Members

Course Description:

The course is offered by the Department of Structures for Engineering and Architecture in the fall term to Ph.D. students in Structural Engineering. The course gives the basics of nonlinear response of frame structures, computer-aided simulation methods, and nonlinear structural analysis techniques for steel seismic force-resisting systems. 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. Each seismic force-resisting system is followed by a practical example illustrating nonlinear modelling and analysis of the system.

Learning Outcomes:

By the end of this course students will be able to

- Develop numerical models considering material, geometrical and loading nonlinearities
- Analyze steel frames using nonlinear procedures
- Apply the principles of performance-based design to assess steel seismic force-resisting systems

Lecture Topics:

- Introduction to nonlinear analysis techniques
- Nonlinear behaviour of steel braces, beams and columns under cyclic loads
- Nonlinear simulation models and methods with physical experimentation of steel braces, beams and columns
- Nonlinear static and dynamic analysis methods
- Nonlinear modelling of steel CBFs combining *OpenSees* and *Python*
- Introduction to seismic assessment of structures and Performance-Based Design (PBD)

Recommended 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. Metten, A., and Driver, R.G. (2017) "*Structural Steel for Canadian Buildings – A Designer's Guide*" *Structured Solutions Inc.*, 3rd edition, 2nd printing.
4. Ziemian, R.D., (2010) "*Guide to Stability Design Criteria for Metal Structures*", John Wiley & Sons, 6th edition. (Chapter 19)
5. NRCC (2020) "*National Building Code of Canada*", National Research Council of Canada. Ottawa, ON.
6. ASCE. (2010) "*Minimum design loads for buildings and other structures*", ASCE/SEI 7-10, Reston, VA.
7. ASCE. (2013) "*Seismic evaluation and rehabilitation of existing buildings*", ASCE/SEI 41-13, Reston, VA.
8. 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
9. 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
10. NEHRP Consultants Joint Venture (2013). "*Nonlinear Analysis Research and Development Program for Performance-Based Seismic Engineering*", NIST GCR 14-917-27.
11. FEMA 440 (2005) "*Improvement of nonlinear static seismic analysis procedures*", Applied Technology Council (ATC-55 Project), Washington, D.C.

Lecture Schedule:

Lecture (3 hours)	**Date**	**Content**
1	**Nov. 24**	Introduction to nonlinear analysis techniques; Nonlinear behaviour of steel braces, beams and columns under cyclic loads
2	**Nov. 27**	Nonlinear simulation models and methods with physical experimentation of steel braces, beams and columns
3	**Nov. 29**	Nonlinear static analysis method
4	**Dec. 6**	Nonlinear modelling of steel CBFs combining *OpenSees* and *Python* (By Bardia Mahmoudi)
5	**Dec. 7**	Introduction to seismic assessment of structures and performance-based design

Instructional Method:

The methods used in this course will be lecturing and group discussions. Additionally, each lecture includes learning exercise/quizzes where students are expected to work in groups and share their answers to the problems. Practical examples will be provided to demonstrate the structural design concepts and the application of the structural analysis programs commonly used for the nonlinear simulation and analysis of structures.