UME School, a.y. 2016-2017

Course: Engineering Seismology and Seismic Hazard
Lecturer: Laurentiu Danciu, PhD
Date: 03/10/2016 – 28/10/2016
Classroom: 2 @ Eucentre Foundation

Course schedule

Week	Date	Lecture hours From__ To___	Tutorial hours From__ To___	Subject	Tot h
1	3.10.2016	9:00 – 12.15	13:45-16:30	L) Course Introduction, The Big Picture, Critical Thinking, Earthquake Hazards, Earthquake Basics T) GEM software setup (VirtualBox), Introduction to Unix (Linux terminal)	6
	4.10.2016	9:00 – 12.15	13:45-16:30	L) Basics of Engineering Seismology: Plate Tectonics, Mechanics of Earthquakes, Measuring Earthquakes, Magnitude, Seismic Moment, Intensity Scales, T) Basics of Python (coding), Introduction to iPython Notebook and QGis	6
	5.10.2016	9:00 – 12.15	13:45-16:30	L) Seismic Hazard Assessment: Introduction, Ground Motion, Deterministic and Probabilistic Methods. Variability and Uncertainties. T) Exercises on Deterministic Approach, Homework 1a (due on 11/10)	6
	6.10.2016	9:00 – 12.15	13:45-16:30	L) Probabilistic Methods: Introduction to probabilities, PSHA framework T) Exercises on Probabilistic Approach, Homework 1b (due on 11/10)	6
2	10.10.2016	9:00 – 12.15	13:45-16:30	L) PSHA Input and Analyses: Earthquake Catalogue, Active Faults t) GEM Hazard–Modeller Toolkit iPython Notebooks (EQ Catalogue, Magnitude Conversion, Declustering)	6
	11.10.2016	9:00 – 12.15	13:45-16:30	L) Seismogenic Sources (1): Seismic Source Typologies, Delineation of Seismic Sources/ Recurrence Models, Guttenberg-Richter relationships, Maximum Magnitude T) Exercises on Magnitude Frequency Distribution for Area Sources (hand calculations and toolkit)	6
	12.10.2016	9:00 – 12.15	13:45-16:30	L) Seismogenic Sources (2): Active Faults, Recurrence Models, Characteristic Model, Magnitude scaling relationships T) Exercises on Magnitude Frequency Distribution for Active Faults (hand calculations and toolkit) Homework 2 (due on 17/10)	6
	13.10.2016	9:00 – 12.15	13:45-16:30	L) Development of Seismic Source Model using seismicity and geology: Issues and Challenges T) Introduction to OpenQuake, Team Project (presentation due on 26/10, Report due on 28/10)	6

3	17.10.2016	9:00 – 12.15	13:45-16:30	L) Ground Motion Models (1): From Strong Motion Records to Predictive Models T) Exercise on GMPE regression (iPython Notebook)	6
	18.10.2016	9:00 – 12.15	13:45-16:30	L) Ground Motion Models (2): Ground Motion Prediction Equations (GMPEs) T) GMPE Selection: Trellis Plots (iPython Notebook)	6
	19.10.2016	9:00 – 12.15	13:45-16:30	L) Quantifying Model Uncertainties, Uncertainties of Seismogenic Sources, Ground Motion Models, Logic Tree, Sensitivity Analysis T) GMPE Selection: Data –Driven testing (iPython Notebook) Homework 3 (due on 21/10	6
	20.10.2016	9:00 – 12.15	13:45-16:30	L) PSHA Outputs to Engineering Uses and Applications Design Spectra, Disaggregation T) Preparation of OpenQuake input files	6
4	24.10.2016	9:00 – 12.15	13:45-16:30	L) Selection and Scaling of Real Records for use with Structural Dynamic Analysis T) Introduction to EQ-Tools (record selection)	6
	25.10.2016	9:00 – 12.15	13:45-16:30	L) Accounting and Modeling Local Soil Conditions into PSHA Analysis (Valerio Poggi) T) Toward a Global Seismic Hazard Model (Marco Pagani)	6
	26.10.2016	10:00 – 12.00	13:00-17:00	L) Exam Preparation/Review session/Office Hours T) Team Project Oral Presentations	6
	27.10.2016				
	28.10.2016	9:00 – 12:00		Final Exam	3

Short Description

The course integrates information from multi-disciplinary fields of engineering and scientific disciplines to provide a comprehensive understanding of earthquake hazard to further develop rationale for the design of earthquake-resistant structures. Topics covered by these lectures include basics of engineering seismology, tectonics, ground-motion characterization, seismogenic sources and probabilistic seismic hazard assessment. Various cases of seismic hazard models are illustrated from simple deterministic to more complex regional seismic hazard models (e.g. the 2013 European Seismic Hazard Model). The course also includes an introduction to aspects of probabilities relevant to probabilistic seismic hazard assessment for students who lack this pre-requisite knowledge. The state-of-practice application of selecting real ground motion for structural dynamic analysis is also covered.

Pre-requisites: All students are expected to bring their own personal computers in the tutorial sessions and know how to use Office Suites (Word, Excel) in particular. Basic knowledge of probabilities and of any programming language Python, *Matlab, R* might be extremely useful. Knowledge of basic Linux commands is also required. Last but not least, all students should already have installed *Virtual Box* *https://www.virtualbox.org* on their personal machine before the beginning of the first tutorial session.

Grade algorithm: Participation = 5%, Homework and tutorial demos: 20%, Project (presentation and report): 40%, Exam: 35%.

Course Outline

1. Introduction
- 1.1. Intro and the big picture
- 1.2. Critical Thinking
- 1.3. Earthquake Hazards
  - 1.3.1. Primary Effects the Ground Shaking
  - 1.3.2. Secondary Effects: Liquefaction, Landslides, Rock-Fall, Tsunamis
- 1.4. Earth's system
- 1.5. Earthquake Source and Seismic waves

2. Basics of Engineering Seismology: About Earthquakes
- 2.1. The Mechanics of Earthquakes
  - 2.1.1. Elastic Rebound Theory
  - 2.1.2. Types of Faults
- 2.2. Plate Tectonics
- 2.3. Measuring Earthquakes
  - 2.3.1. Magnitude Scales
  - 2.3.2. Seismic Moment
  - 2.3.3. Intensity Scales

3. Seismic Hazard: Overview of Methods
- 3.1. Seismic Hazard Analysis
- 3.2. Deterministic Approach
- 3.3. Probabilistic Approach

4. Probabilistic Seismic Hazard (Intro)
- 4.1. Probabilities
  - 4.1.1. Concepts of Probability
  - 4.1.2. Gaussian or Normal Distribution
- 4.2. Anatomy of probabilistic seismic hazard assessment (PSHA)

5. PSHA: Input Ingredients
- 5.1. Earthquake Catalogue: Harmonization, Completeness and Declustering
- 5.2. Active Faults, Harmonization, Slip-Rates, Magnitude scaling relationships

6. Seismogenic Sources (1): Definition and Use
- 6.1. Delineation and definition of seismogenic sources
- 6.2. Seismogenic source typologies: point and area
- 6.3. Source Characterization:
- 6.4. Earthquake Magnitude Frequency Distribution: Guttenberg Richter Model,
- 6.5. Maximum Magnitude, Definition and Evaluation Methods

7. Seismogenic Sources (2): Active Faults
- 7.1. Seismogenic source typologies: active faults
- 7.2. Earthquake Magnitude Frequency Distribution: Guttenberg Richter Model and Characteristic Model
- 7.3. Maximum Magnitude, Definition and Evaluation Methods

8. Ground Motion Models (1): From Strong Motion Records to Predictive Models
- 8.1. Strong Motion Database:
  - 8.1.1. Corrected and Uncorrected Records
- 8.2. Characteristics of Earthquake Ground Shaking
  - 8.2.1. Amplitude, Duration, Frequency and Energy Content
- 8.3. Ground Motion Intensity Measures
  - 8.3.1. Peak Ground Parameters
  - 8.3.2. Duration
  - 8.3.3. Arias Intensity, Cumulative Absolute Velocity
  - 8.3.4. Response Spectrum

8.3.5. Elastic Input Energy

9. Ground Motion Models (2): Ground Motion Prediction Equations (GMPEs)
- 9.1. Ergodic Assumptions
- 9.2. Description of Functional Forms
- 9.3. Regression Methods
- 9.4. Uncertainties in estimates of ground-motion intensity measures

10. Ground Motion Models (3): From Predictive Models to PSHA
- 10.1. Ground Motion Models for PSHA
- 10.2. Selection of GMPEs for use in PSHA

11. Uncertainties of Seismic Hazard Models
- 11.1. Nature of uncertainties
- 11.2. Epistemic vs. Aleatory Uncertainties
- 11.3. Logic Tree Definition and Applications
- 11.4. Accounting and Modeling Local Soil Conditions into PSHA Analysis

12. Seismic Hazard and Seismic Design
- 12.1. Engineering Application of PSHA output
- 12.2. Disaggregation of seismic hazard
- 12.3. Selection and Scaling of Real Records for use with Structural Dynamic Analysis
- 12.4. Definition of Target Spectrum: Uniform Hazard Spectra, Conditional Mean Spectra, Design Spectra

13. Seismic Hazard Models: From Local to Global Models
- 13.1. Site Specific
- 13.2. National Hazard Models
- 13.3. Regional Hazard Models

Textbook

DARIO SLEJKO: Seismic Hazard Assessment, Rose School Class Notes 2011, Pavia, Italy

REITER, L., Seismic hazard analysis: issues and insight Columbia University Press, 1990

KRAMER, S.L., Geotechnical earthquake engineering. Prentice-Hall, 1996

McGUIRE, R.K. Seismic hazard and risk analysis. EERI Monograph MNO-10, Earthquake Engineering Research Institute, 2004

CHEN, W.F. and C. Scawthorn, Earthquake Engineering Handbook. CRC Press, 2003

Online Resources

USGS Online Earthquake Topics	http://earthquake.usgs.gov/learn/topics/topics.php?topicID=56
Global Earthquake Model	https://www.globalquakemodel.org/
Seismic Hazard Harmonization in Europe	http://www.share-eu.org/
European Facilities of Earthquake Hazard and Risk	www.efehr.org
List of GMPEs	http://www.gmpe.org.uk/
OpenQuake	https://www.globalquakemodel.org/openquake
Hazard Modeller Toolkit	https://github.com/GEMScienceTools/hmtk
Introduction to Probability, Statistics, and Random Processes	https://www.probabilitycourse.com/
Python	http://www.diveintopython.net/
Basic Linux Commands	https://www.tutorialspoint.com/unix/unix-useful-commands.htm