GEOTECHNICAL EARTHQUAKE ENGINEERING

Institutions: University of Pavia and IUSS Pavia
Curriculum: ROSE
Term: Academic Year 2020-2021 – 2nd Semester
Credits (CFU): 6
Instructor: Prof. Carlo G. Lai (E-mail: carlo.lai@unipv.it)
Teaching assistant: Eng. Ricardo Rodríguez Plata (E-mail: ricardo.rodriguezplata@iusspavia.it)

Class duration: March 10, 2021 – June 14, 2021 (54 hours of classes + 8 hours of tutoring)
Class schedule*: Wednesday and Thursday 4–6 PM. Classroom: E4 (Wed), E2 (Thu) @ Polo Cravino (UniPV)
Link Zoom: https://us02web.zoom.us/meeting/register/tZUvdeqoqTwjGtPuPTgvfhKQ4V6MvbmlRKSJ
Office hours: Contact the instructor or the teaching assistant via email to schedule a colloquy

OUTLINE

Scope of the course is to introduce students to the basic theories and methods of earthquake geotechnical engineering and soil dynamics. Topics include propagation of mechanical waves in geomaterials, ground response analyses, soil liquefaction, seismic instability of slopes, surface fault rupture, dynamic soil-structure interaction, seismic analysis of foundations and earth-retaining systems.
In the first part of the course, basic concepts of propagation of mechanical waves are discussed in elastic, viscoelastic and poroelastic continua. They include mathematical classification of wave motion, Fermat's principle, Zoeppritz equations and physical causality. Surface Love and Rayleigh waves and their dispersive properties are also introduced including a discussion of the Lamb problem and of the differences between 2D vs. 3D radiation.
Next, fundamental concepts of seismometry are presented jointly with basic techniques of digital signal processing of earthquake recordings. Basic notions of engineering seismology are also reviewed; these include probabilistic and deterministic seismic hazard, design earthquake, intensity measures of ground motion, acceleration and displacement response spectra, selection of seismic- and spectrum- compatible accelerograms. These concepts will be applied to study ground response analyses of soil deposits in 1D linear and linear-equivalent modeling after introducing the concept of transfer function in elastic and viscoelastic layered systems. Examples of phenomena of ground amplification in well-known earthquakes are presented and thoroughly discussed. More advanced topics like non-linear effective stress analyses, numerical modeling of 2D ground response, basin effects and topographic amplification are introduced. Finally, ground amplification as treated in well-established building codes (e.g. Italian NTC 2018 and Eurocode EC8 Part 1) is illustrated jointly with the seismic micro- zonation of an extended territory such as an urban centre.
The second part of the course focuses on subjects of soil dynamics. They include the study of drained and undrained response of soils under earthquake loading, concepts of critical state theory, shear strength and stiffness degradation of soils under cyclic loading. These topics are preliminary to the subject of geotechnical site characterization via in-situ and laboratory investigations and to the study of phenomena of ground failure like earthquake-induced soil liquefaction, lateral spreading ground and seismic instability of natural slopes.
The course ends with an introduction to dynamic soil-structure interaction (SSI). After stating the problem, the notions of kinematic and inertial interaction are illustrated in association with that of dynamic impedance of a shallow foundation. This is used to solve SSI problems via the substructure approach. Finally, the pseudo-static and displacement-based methods are used for the seismic analysis and design of earth-retaining structures and foundation systems.
The course consists of lectures and interactive tutorial sessions. Each subject is illustrated with examples and well-documented case histories from major earthquakes worldwide drawn from the experience of the instructor.

COURSE REQUIREMENTS

Basic knowledge of geotechnical engineering, mechanics of deformable body and engineering seismology.

COURSE NOTES

The course material is posted at the KIRO web site accessible at the link: https://elearning2.unipv.it/ingegneria/

*Lectures and tutorials in classroom will be simultaneously broadcasted via web using Zoom

REFERENCES

- Kramer, S. (1996). Geotechnical Earthquake Engineering. Prentice-Hall, pp. 653. Basic textbook
- Kokusho, T. (2017). Innovative Earthquake Soil Dynamics. CRC Press, pp. 478. Reference monograph
- Ishihara, K. (1996). Soil Behaviour in Earthquake Geotechnics. Oxford Press, pp. 350. Reference monograph
- Verruijt, A. (2010). An Introduction to Soil Dynamics. Springer, New York, 431 pp. Reference monograph
- Lecture notes, scientific articles and reports will be provided throughout the course

ASSESSMENT

Assignments will be handed over and graded during the course. The final examination will consist of a 3 hours, written test. The final-exam format is closed-book. An equation-sheet will be provided, if needed. Grading: 40% assignments, 60% final exam.

FINAL EXAMINATION

1st Summer Session Appeal: *June 18, 2021* from 2:00 to 5 PM. The exam mode will depend upon health situation.
2nd Summer Session Appeal: *July 8, 2021* from 2:00 to 5 PM. The exam mode will depend upon health situation.

SCHEDULE OF LECTURES	HOURS	# LECTURES
1. Review of basic concepts of Fourier analysis	6	1–3
2. Propagation of mechanical waves in deformable continua	6	4–6
3. Principles of seismometry and of signal processing	6	7–9
4. Review of engineering seismology and seismic hazard analysis†	4	10–11
5. Local site effects and ground response analyses‡	6	12–14
6. Site characterization and geotechnical subsoil modeling§	6	15–17
7. Seismic stability of slopes	4	18–19
8. Surface fault rupture and foundation interaction	2	20
9. Liquefaction susceptibility and risk of soil deposits**	6	21-23
10. Dynamic soil-structure interaction	4	24-25
11. Seismic analysis of earth-retaining structures	2	26
12. Seismic analysis of foundation systems	2	27
TOTAL	**54**	

TOPIC OF TUTORIALS	HOURS	# TUTORIALS
1. Signal processing applied to strong ground motion records	2	1
2. 1D linear equivalent ground response analyses	2	2
3. Seismic stability of slopes using simplified methods	2	3
4. Assessment of liquefaction susceptibility and risk at a site	2	4
TOTAL	**8**	

ASSIGNMENTS

1. Signal processing and wave propagation in elastic solids (*tutorial 1*)
2. Case study on linear equivalent ground response analyses (*tutorial 2*)
3. Assessment of seismic slope stability using simplified methods (*tutorial 3*)
4. Assessment of liquefaction susceptibility and triggering at a site (*tutorial 4*)

† It includes definition of design earthquake and selection of spectrum– compatible accelerograms
‡ It includes specifications of seismic building codes (e.g. Italian NTC 2018 and Eurocode EC8 Part 1)
§ It includes treatment of in-situ (geophysical) and laboratory investigations
** It includes fundamentals of stress-strain response of soils under earthquake loading