Lecturers: Prof. Misko Cubrinovski and Prof. Carlo G. Lai
Teaching Assistants: Eng. Claudio Cappellaro

EARTHQUAKE GEOTECHNICAL ENGINEERING

Date: 30/10/2017 - 24/11/2017

Classroom: classroom 1@Eucentre Foundation

1ST WEEK					
CUBRINOVSKI	**No Class**				
LAI	**Basic Concepts of Wave Propagation in Elastic Continua. 1D Linear and Linear-Equivalent Ground Response Analyses. Introduction to 1D Non-Linear and 2D Linear Ground Response Analyses. Topographic Amplification and Basin Effects.**				
Day	**Date**	**Lecture**	**Subject**	**Tutorial**	**Subject**
Mon	**30/10**	**9:00-13:00 (CL)**	Review of frequency analysis. Fourier transform and its properties. Application to linear systems. Fundamentals of elastodynamics. Propagation of mechanical disturbances in an unbounded elastic medium. Transversal and longitudinal waves. Solution of one-dimensional wave equation. Stationary oscillations and harmonic waves. Initial and boundary conditions for the half-space.	**14:00-16:00 (CC)**	Examples and exercises of 1D wave propagation in a homogeneous half-space. Wave scattering along a discontinuity. Mode conversion. Definition of mechanical impedance. Free surface and fixed boundary conditions.
Tue	**31/10**	**9:00-13:00 (CL)**	Wave propagation in elastic heterogeneous continua, Fermat's principle and Snell's law. Reflection and transmission coefficients for normal incidence. Two-dimensional wave propagation. Rayleigh and Love waves. An introduction to viscoelastic waves. Review of basic notions of engineering seismology. Definition of earthquake size, ground motion intensity measures and seismic hazard.	**14:00-16:00 (CC)**	Exercises on surface wave computation. Rayleigh wave geometric dispersion. Multi-mode wave propagation. Calculation of Rayleigh dispersion curves. Forward and inverse modeling. Use of SWAMI computer program.
Wed	**01/11**	**9:00-13:00**	***NO CLASS***	**14.00-16.00**	***NO TUTORING***
Thu	**02/11**	**9:00-13:00 (CL)**	Advanced topics in ground response analysis. Effects of soil non-linearity. Site effects in liquefiable soils. Coupled and uncoupled analyses. Topographic amplification. Introduction to 2D ground response analyses. Basin effects. Focalization, de-focalization and trapped waves. Examples of 2D effects in recent earthquakes. Ground response analysis in building codes. Eurocode 8 Part 1.	**14:00-16:00 (CC)**	Examples and case studies of 1D linear-equivalent ground response analysis. Introduction to STRATA computer program. Selection of spectrum- and seismo- compatible real accelerograms. Dynamic soil properties. Empirical models of shear modulus and damping reduction curves.
Fri	**03/11**	**9:00-13:00 (CL)**	Steady–state response of a homogeneous layer overlapping an elastic half-space, ground amplification. Transfer functions of a homogeneous layer over a half-space, influence of material damping. Threshold cyclic shear strains. Examples of local amplification effects in recent earthquakes: the Mexico City case study. Linear and linear-equivalent 1D ground response analyses.	**14.00-16.00**	Definition of transfer function. Computation of response of a horizontally layered soil system using analytical transfer function. Numerical implementation in the frequency domain. Convolution and deconvolution of seismic input.

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2ND WEEK					
CUBRINOVSKI			Stress-Strain Behaviour of Soils Under Monotonic and Cyclic Loading. Conventional Liquefaction Evaluation Methods.		
LAI			No Class		
Day	**Date**	**Lecture**	**Subject**	**Tutorial**	**Subject**
Mon	06/11	9.00-13.00	*NO CLASS*	14.00-16.00	*NO TUTORING*
Tue	07/11	9:00-13:00 (MC)	Soil liquefaction during earthquakes: background. Stress-strain behaviour of soils under monotonic loading. State concept interpretation of sand behaviour (critical state framework). State parameters. Effects of fines on packing, structure and sand behaviour. Static liquefaction. Stress-strain behaviour of soils under cyclic loading. Liquefaction process and manifestation in the field.	14:00-16:00 (CC)	Examples and exercises of monotonic stress-strain behaviour of sand under both drained and undrained conditions. State-concept characterization of stress-strain behaviour of soils in the *e-p*, shear stress-shear strain, *q-p'*, volumetric strain - shear strain and EPWP-shear strain plots.
Wed	08/11	9.00-13.00 (MC)	Phenomena associated with soil liquefaction. Case studies from recent earthquakes. Observations from laboratory tests on soil samples. Key factors influencing liquefaction resistance: soil density, fabric, confining stress, initial shear stress, boundary and drainage conditions, fines content and plasticity of fines, age, previous seismic (strain) history.	14:00-16:00 (CC)	Liquefaction (cyclic) resistance curve (LRC): determination from laboratory test data. Effects of density and confining stress on LRC. Examples. LRCs derived based on Boulanger & Idriss (2015) simplified procedure.
Thu	09/11	9.00-13.00 (MC)	Conventional simplified liquefaction evaluation procedure. Site investigations. Determination of design earthquake load. Liquefaction susceptibility. Liquefaction triggering. Various methods and practices. Liquefaction evaluation for level ground free field deposits: CPT-based triggering procedure.	14:00-16:00 (CC)	Liquefaction triggering analysis. Hand calculations. Use of CLiq computer program for performing triggering analysis of a given site based on CPT data. Input data, analysis details, results and their engineering interpretation.
Fri	10/11	9.00-13.00 (MC) Classroom 1-15 @IUSS	Shear-wave velocity based methods, SPT-based procedure and alternative approaches for liquefaction triggering. Procedures for evaluation of liquefaction-induced ground deformation: settlement (permanent vertical) and transient (horizontal) displacements in level ground free field deposits. Lateral spreading: mechanism and simplified assessment. Residual strength of liquefied soils: definition and evaluation. Liquefaction damage indices. Liquefaction zoning.	14:00-16:00 (CC) Classroom 1-15 @IUSS	Evaluation of liquefaction-induced ground deformation (settlement and lateral spreading) and liquefaction damage indices for a given site. Hand calculations. Use of CLiq computer program for estimating ground displacements and liquefaction damage indices.

EARTHQUAKE GEOTECHNICAL ENGINEERING

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3RD WEEK					
CUBRINOVSKI			**Effects of Liquefaction on Structures: Case Studies and Experimental Observations; Analysis and Design; Countermeasures.** **Seismic Assessment of Geotechnical Structures: Simplified apaproaches; Advanced Seismic Analysis.**		
LAI			**No Class**		
Day	**Date**	**Lecture**	**Subject**	**Tutorial**	**Subject**
Mon	**13/11**	**9.00-13.00 (MC)**	Piles in liquefiable soils. Well-documented case studies from recent earthquakes (pile foundations of buildings, bridges and storage tanks). Observations from benchmark experiments on full-size piles utilizing large-scale shake table tests. Kinematic loads on piles due to ground movement. Ultimate soil pressure on piles. Key factors controlling the pile response. Stiff-pile behaviour vs. flexible pile behaviour. Analysis of piles under lateral loading: concepts. Closed-form elastic solution.	**14.00-16.00 (CC)**	Linear analysis (kinematic and inertial loads) of a single pile. Use of computer program Pile-1L. Calculation of soil spring constant. Demonstration through analysis of stiff-pile behaviour vs. flexible pile behaviour.
Tue	**14/11**	**9.00-13.00 (MC)**	Analysis and design of piles in liquefying soils. Pseudo-Static Analysis – PSA. Determination of parameters for non-linear PSA of piles. Step-by-step application. Case studies from recent earthquakes: effects of liquefaction on engineering structures (buildings, bridges, buried pipe networks, storage tanks, stop-banks). Liquefaction impacts on buildings on shallow foundations. Evaluation of bearing capacity and settlement. Deformation and failure modes. Key design issues.	**14.00-16.00 (CC)**	Pseudo-static analysis of piles. Nonlinear analysis using beam-spring model. Use of computer programs: MPHI and BS-Pile. Single pile model. Illustration of an integral bridge-foundation-soil model (whole bridge model).
Wed	**15/11**	**9.00-13.00 (MC)**	Liquefaction impacts on horizontal infrastructure (road, potable water and wastewater networks). Characteristic damage and weak links. Uplift of buried structures. Countermeasures against liquefaction. Mitigation strategies. Ground improvement: design and implementation issues.	**14.00-16.00 (CC)**	Liquefaction experiment (physical model): model preparation; observations; uplift calculations for buried manholes.
Thu	**16/11**	**9.00-13.00 (MC)**	Advanced constitutive modelling of soils. Key stress-strain relationships. The roles of elasticity and plasticity theories. State-concept based model for sand. Introduction to seismic effective stress analysis. Element test simulations. Numerical procedures. Application of seismic effective stress analysis to liquefaction assessment of sites, embankments, bridges, buildings, storage tanks and effectiveness of mitigation measures.	**14.00-16.00 (CC)**	Element test simulations using S-D Model (Stress-Density Model; computer program). Simulation of liquefaction resistance curve (cyclic strength curve). Seismic effective stress site response analysis (use of computer programs Diana-J and S-D Model) – illustration only.
Fri	**17/11**	**9.00-13.00**	***NO CLASS***	**14.00-16.00**	***NO TUTORING***

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4TH WEEK					
CUBRINOVSKI			**No Class**		
LAI			**Geotechnical Modeling and Site Characterization: Geophysical Onsite and Laboratory Tests.** **Seismic Stability of Earth-Retaining Walls and Seismic Instability of Natural Slopes.**		
Day	**Date**	**Lecture**	**Subject**	**Tutorial**	**Subject**
Mon	**20/11**	**9.00-13.00 (CL)**	Geotechnical modeling and site characterization for seismic design. Dynamic soil properties. Soil state and shear strength parameters. Laboratory tests: resonant column, cyclic torsional shear and triaxial tests. Geophysical seismic tests. Invasive and non-invasive tests. Cross-hole, down- hole, seismic cone, seismic dilatometer. Spectral analysis of surface waves and Nakamura techniques.	**14.00-16.00 (CC)**	Non-linear cyclic models of soil response. The notion of backbone curve. Hyperbolic and Ramberg-Osgood models. The Masing criterion. Comparison of linear- equivalent and non-linear ground response analyses. An introduction to effective stress-analyses using Cyclic 1D.
Tue	**21/11**	**9.00-13.00 (CL)**	Seismic stability of earth-retaining walls. Classification, modes of failures and seismic performance. Factors affecting the seismic response of retaining walls. Seismic stability. Force-based methods: yielding and non-yielding walls. The Mononobe-Okabe and Wood theory. Displacement-based methods. The Newmark sliding-block model for the seismic analysis of gravity walls.	**14.00-16.00 (CC)**	Seismic stability of gravity walls. Computation of seismic earth pressures using the Mononobe-Okabe method. The Newmark's equivalent block method of analysis. Yield acceleration. Assessment of permanent displacement.
Wed	**22/11**	**9.00-13.00 (CL)**	Stability of slopes under earthquake loading. Classification and relevance of landslides. Failure of embankments and levees. Seismic slope stability analyses. Inertial and weakening instabilities. Limit equilibrium and stress-deformation analyses. Pseudo static and displacement-based methods. Co-seismic and post-seismic stability. Monitoring and mitigation strategies.	**14.00-16.00 (CC)**	Review of static slope stability methods of analyses. Limit equilibrium techniques. Assessment of seismic slope stability analyses using the pseudo-static method. Peak and residual strength parameters. Computation of permanent displacement via the Newmark method. Examples.
Thu	**23/11**	**9.00-13.00**	***NO CLASS***	**14.00-16.00**	***NO TUTORING***
Fri	**24/11**	**9.00-12.00**	***FINAL EXAMINATION***		

Graduate Courses in Earthquake Engineering & Engineering Seismology
ROSE School, *Fall Term 2017*

Lecturers: Prof. Misko Cubrinovski and Prof. Carlo G. Lai
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Lectures and Tutorials October 30 – November 24, 2017

Monday	Tuesday	Wednesday	Thursday	Friday
October 30 **LAI** **9-13** **CAPPELLARO** **14-16**	**October 31** **LAI** **9-13** **CAPPELLARO** **14-16**	**November 01** **NO CLASS**	**November 02** **LAI** **9-13** **CAPPELLARO** **14-16**	**November 03** **LAI** **9-13** **CAPPELLARO** **14-16**
November 06 **NO CLASS**	**November 07** **CUBRINOVSKI** **9-13** **CAPPELLARO** **14-16**	**November 08** **CUBRINOVSKI** **9-13** **CAPPELLARO** **14-16**	**November 09** **CUBRINOVSKI** **9-13** **CAPPELLARO** **14-16**	**November 10** **CUBRINOVSKI** **9-13** **CAPPELLARO** **14-16**
November 13 **CUBRINOVSKI** **9-13** **CAPPELLARO** **14-16**	**November 14** **CUBRINOVSKI** **9-13** **CAPPELLARO** **14-16**	**November 15** **CUBRINOVSKI** **9-13** **CAPPELLARO** **14-16**	**November 16** **CUBRINOVSKI** **9-13** **CAPPELLARO** **14-16**	**November 17** **NO CLASS**
November 20 **LAI** **9-13** **CAPPELLARO** **14-16**	**November 21** **LAI** **9-13** **CAPPELLARO** **14-16**	**November 22** **LAI** **9-13** **CAPPELLARO** **14-16**	**November 23** **NO CLASS**	**November 24** **FINAL EXAMINATION**

CLASSES AND TUTORING HOURS					
CUBRINOVSKI			**LAI**		
WEEK	**CLASS HRS**	**TUTORING HRS**	**WEEK**	**CLASS HRS**	**TUTORING HRS**
30/10/2017–03/11/2017	0	0	30/10/2017–03/11/2017	16	8
06/11/2017–10/11/2017	16	8	06/11/2017–10/11/2017	0	0
13/11/2017–17/11/2017	16	8	13/11/2017–17/11/2017	0	0
20/11/2017–24/11/2017	0	0	20/11/2017–24/11/2017	12	6
TOTAL HOURS	**32**	**16**	*TOTAL HOURS*	**28**	**14**