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Perspectives on Earthquake Geotechnical Engineering

In Honour of Prof. Kenji Ishihara

Springer

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Foreword

It was a privilege to organize the International Conference on Earthquake Geotechnical Engineering from Case History to Practice in the honour of Prof. Kenji Ishihara in Istanbul, Turkey during 17–19 June 2013.

A very prominent group of specialists in the field of earthquake geotechnical engineering delivered lectures of significant importance reflecting the recent developments in their field of interest during this conference. It was decided to compile most of these presentations in one book so that it may be available to specialists and those that are involved with research and application in the field of geotechnical engineering. The book is composed of 18 chapters.

The first chapter by Kenji Ishihara and Toshiyuki Kamata is concerned with features of the 2011 earthquake in Japan, characterized by predominance of the ground failure due to liquefaction and scour of the ground caused by tsunami. Unprecedented long duration of the shaking combined with large aftershocks have generated the worst situations resulting in the extensive damage due to liquefaction over the Tokyo Bay and the downstream plain areas of the Tone River 300~400 km distant away from the epicentral area. This chapter focus on the characteristic features in the occurrence of liquefaction and consequent damage in the area of the downstream reaches of the Tone River.

The second chapter by Liam Finn and Francisco Ruz is concerned with the amplification effect of soft surface layers. The effect on the seismic response of shallow soft surface layers is evaluated for developing the seismic section of the National Building Code of Canada for 2015 (NBCC 2015). The response of such layers is studied using recorded data from the 2011 Tohoku Earthquake.

The third chapter by Kyriazis Pitilakis, Evi Riga, and Anastasios Anastasiadis is about the proposal of a new design spectra and its application to the seismic risk assessment. Based on a worldwide database of strong ground motion records in different well constrained site conditions, a new soil classification is proposed for EC8 with the associated amplification factors and the normalized response spectra. Amplification factors and normalized response spectra are also proposed for the current EC8 classification. A detailed seismic risk assessment was performed for the city of Thessaloniki using (a) the capacity spectrum method, (b) the Uniform Hazard Spectrum (UHS) for rock conditions compiled applying the SHARE approach, (c) the

current and the new site amplification factors to evaluate the site specific demand spectra, (d) the detailed inventory of the Thessaloniki building stock to select the appropriate capacity and fragility curves for each building typology, and (e) available functions to estimate the causalities and the economic losses from the physical building damages.

The fourth chapter by Ellen Rathje, Menzer Pehlivan, Robert Gilbert, and Adrian Rodriguez-Marek is on the topic of probabilistic approach related to site response analysis and for seismic hazard assessments. This chapter describes the convolution approach used to incorporate site response into PSHA. The main components used in the convolution approach are provided, and the required site characterization and site response analyses are discussed.

The fifth chapter by K. Önder Çetin and H. Tolga Bilge is on the stress scaling factors for seismic soil liquefaction engineering problems. On the basis of the compiled experimental data, a unified stress correction scheme, which enables to assess the combined effects of overburden (σ'_{v0}) and static (τ_{st}) shear stresses along with the degree of shear stress reversal, was introduced.

The sixth chapter by Takaji Kokusho is about the development of site amplification formula for virtual surface arrays to be consistent with vertical arrays using a number of KiK-net records during recent eight destructive earthquakes. A correlation between peak spectrum amplification and S-wave velocity ratio (base V_s/ surface V_s) improved much better if the surface V_s was evaluated from fundamental mode frequency combined with a thickness of equivalent surface layer in which peak amplification is exerted, rather than using the conventional V_s30.

The seventh chapter by Aslı Kurtuluş, Atilla Ansal, Gökçe Tönük, and Barbaros Çetiner is based on the observations recorded by the Istanbul vertical arrays during small earthquakes. Same events were also recorded by Istanbul Rapid Response Network (IRRN) which comprise 55 surface strong motion stations in the European side of Istanbul. An effort is made to model the recorded response at the downhole array sites as well as the at the IRRN stations using the acceleration records obtained by the deepest sensors on the engineering bedrock. Observations from the recorded response and results from 1D modelling of ground response have yielded in general good agreement between the observed and recorded soil response at the station sites.

The eighth chapter by Susumu Iai is about the centrifuge model tests and effective stress analyses performed on a breakwater subjected to tsunami, such as those that are seriously damaged during 2011 East Japan Earthquake. The centrifuge model tests at a scale of 1/200 are performed to simulate the failure of a breakwater subject to tsunami. With the effective stress analyses, this study demonstrates the importance of the mechanism of failure in the rubble mound due to seepage flow of pore water in addition to the force of tsunami action.

The ninth chapter by Sêco e Pinto, Pedro Simão points out the importance to analyze embankment dam behavior from the past experiences. Even though modern embankment dams may withstand the design earthquake without significant damages, it is important to prevent the occurrence of incidents and accidents of embankment dams under earthquakes and so a deep understanding of the triggering factors

is needed. The structural components of potential risk depend mostly on storage capacity and on the height of the dam, as the potential downstream consequences are proportional to the mentioned values. Socio-economic risks can be expressed by a number of persons who need to be evacuated in case of danger and by potential downstream damage. The risks associated with dam projects are discussed.

The tenth chapter by Ross W. Boulanger, Jack Montgomery, and Katerina Ziotopoulou is concerned with the nonlinear deformation analyses (NDAs) used for evaluating the potential effects of liquefaction on the seismic performance of embankment dams. Confidence in these applications of NDAs may be significantly improved by establishing calibration and analysis protocols that reduce undesirable sources of variability between analysis results obtained by different analysts or different models. A key protocol for improving the quality of NDAs is the calibration and validation of a constitutive model using single-element simulations with the types of loading paths potentially important to the structure's response. Examples of single-element simulations are presented for several constitutive models and loading paths to illustrate some of the important features for NDAs of embankment dams affected by liquefaction.

Chapter 11 by Steven L. Kramer, Bita Astaneh Asl, Pelin Özener, and Samuel S. Sideras is about ground surface motions during liquefaction. This chapter reviews the process of liquefaction, the hydraulic conditions required for the manifestation of surface effects, and limitations in the inference of liquefaction triggering from the presence or absence of such effects are discussed. The effects of liquefaction triggering on soil stiffness and procedures for identification of the timing of liquefaction triggering are reviewed. The abilities of four advanced site response programs to compute ground motions in liquefiable soils are evaluated from the standpoints of pre- and post-triggering response. The implications of post-triggering response for the evaluation of ground surface response spectra are discussed.

Chapter 12 by Ikuo Towhata, Masahide Otsubo, Taro Uchimura, Masato Shimura, Bangan Liu, Toshihiko Hayashida, Damoun Taeseri, and Bertrand Cauvin is about the liquefaction mitigation of embedded lifelines. The gigantic earthquake in 2011 caused significant damage in lifeline in the Tokyo Metropolitan Area. In particular, the damage was significant in recent artificial islands where liquefaction affected embedded sewage pipelines profoundly. The present chapter addresses the ongoing model tests by which a variety of mitigation measures for sewage pipelines are examined. In the regions where future earthquake is expected, it is not possible to excavate pipes and reconstruct backfills now because of financial limitations. To cope with this situation, less expensive measures such as mechanical constraint, partial injection of grout, or limited installation of drainage measures are studied.

Chapter 13 by Susumu Yasuda, Iwao Suetomi, and Keisuke Ishikawa is about the effects of long duration of shaking during the 2011 Great East Japan Earthquake. The main shock was followed by big aftershocks because the earthquake was a "megathrust earthquake" with extremely large magnitude; Mw = 9.0. The unique ground shaking caused serious liquefaction in a wide area of reclaimed land along Tokyo Bay though seismic intensities in the liquefied zones were not high. The occurrence of liquefaction, the settlement and the inclination of houses must have

been affected by the aftershock. Large horizontal displacements were induced and caused roads to thrust and large horizontal displacement of liquefied ground had caused the severance of pipe joints and the shear failure of manholes, allowing an influx of muddy water into the pipes and manholes.

Chapter 14 by Ramon Verdugo is about the liquefaction caused during the 2010 Chile Earthquake of Magnitude 8.8. Several of the available records show a ground motion that exceeds 2 min of duration, which may explain the significant amount of liquefied sites. Field observations have shown that the earthquake triggered liquefaction in more than 170 different sites, covering a north-south distance of about 950 km, which approximately corresponds to twice of the length of the rupture zone. Liquefaction phenomenon induced damages to the road infrastructure, railroads system, buildings and houses. Liquefaction-induced ground failure displaced and distorted pile foundations of piers impacting seriously the operation of several ports. Especially interesting is the case of Juan Pablo II Bridge, where significant differential settlements were observed.

Chapter 15 by Wei F. Lee, C. C. Chen, M. H. Chang, and Louis Y. N. Ge presents a case study on non-plastic silty sand liquefaction. A new sampling technique, Gel-Push sampler, that could retrieve undisturbed non-plastic silty sand and results of series dynamic triaxial tests those investigated influences of fines contents, void ratio, as well as sampling disturbance are reported. Research progress presented here is hoped to be helpful in understanding mechanism as well as consequences of non-plastic silty sand liquefaction.

Chapter 16 by Michele Maugeri and Francesco Castelli is about the case history of a seismic retrofitting of a piled foundation. The approach adopted for the structural upgrading of a six storey reinforced concrete frame building in Italy, damaged by the 13 December 1990 Sicilian earthquake, is described and discussed. For evaluating the possibility to repair the building, an investigation on soil, structure and foundation was carried out. As building was founded on piles, for the seismic retrofitting of the structure, the response of the piles subjected to earthquake loading has been studied. Loading tests showed that the seismic event of December 13th 1990 have not damaged the effectiveness of the soil-pile system. The numerical analysis showed that the existing foundation was unable to carry on design seismic actions, the structural upgrading and seismic retrofitting of the piled foundation required the enlargement of the foundation and new bored piles.

Chapter 17 by George D. Bouckovalas and Yannis K. Chaloulos summarizes the main findings of a systematic research effort regarding the response of pile foundations in laterally spreading soils. The incentive of the research were findings from properly scaled (with regard to the pore fluid) centrifuge experiments suggesting that severe soil dilation may occur at the upper part of the pile, as a result of large soil-pile relative movement, causing soil pressures to significantly increase. A 3D nonlinear numerical methodology was developed and tested against the aforementioned experiments. Comparative analyses, with the old and the new boundaries, revealed that the former (which also reflect the kinematic response of the laminar box containers employed in model tests) can significantly underestimate soil pressures imposed to the foundation. In the sequel, the numerical methodology was applied

parametrically (for various soil, pile and excitation characteristics) and a new set of multivariable relationships was statistically established for the practical estimation of ultimate soil pressures applied to the pile.

Chapter 18 by Yoshimichi Tsukamoto is about the use of Swedish weight sounding tests for earthquake reconnaissance investigations is integrated into one framework for analysing a wide range of stability problems of natural and reclaimed soil deposits during earthquakes, based on the past studies conducted by the author. It is highlighted that Swedish weight sounding tests are useful for subsurface soil profiling identifying thin weak soil layers, and can be used for determining the undrained shear strength, liquefaction strength and post-liquefaction settlement of natural and reclaimed soil deposits during earthquakes.

The editors would like to express their gratitude to all authors for their interest and efforts in preparing their manuscripts. Special thanks to Professor Kenji Ishihara for being so creative in generating major research in the area of earthquake geotechnical engineering and for his support in the organization of this conference.

Atilla Ansal and Mohamed Sakr

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