Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering

doi:10.3233/978-1-61499-656-9-3213

Technical session 4b: Earthquake related problems
Séances techniques 4b: Problèmes liés aux tremblements de terre

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R.W. Boulanger - *University of California at Davis, USA*
R. Verdugo - *University of Chile, Chile*
T. Kokusho - *Chuo University, Japan*
A. Ansal - *Bogazici University, Turkey*
G. Gazetas - *National Technical University of Athens, Greece*
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1 INTRODUCTION

The technical session for the earthquake related problems was held at the special conference room on the 12th floor, with the following role-playing persons.

Chairman	:	Professor K.H. Stokoe (U.S.A.)
General reporter	:	Professor R.W. Boulanger (U.S.A.)
Panelists	:	Professor R. Verdugo (Chile)
		Professor T. Kokusho (Japan)
		Professor A. Ansal (Turkey)
		Professor G. Gazetas (Greece)
Secretary	:	Dr. Y. Tsukamoto (Japan)

2 GENERAL REPORT

The technical papers submitted to this session were introduced by Professor R.W. Boulanger as a general report. There were 28 technical papers submitted to this session, which were classified into 3 sub-themes.

Sub-themes 1 : "Soil liquefaction"
Sub-themes 2 : "Site response, zonation and fault ruptures"
Sub-themes 3 : "Slope stability and retaining walls"

One of the major sub-themes was "Soil liquefaction", in which 20 technical papers were involved. The major topics in "Soil liquefaction" were as follows :

(1-a) Liquefaction characteristics of various soils
(1-b) Effects of irregular seismic motions on soil liquefaction
(1-c) Performance of foundations against soil liquefaction
(1-d) Field testing and laboratory testing
(1-e) Practical countermeasures against soil liquefaction

With regard to the other sub-themes, 6 technical papers were involved in the sub-theme of "Site response, zonation and fault ruptures", and 2 technical papers were dedicated to the sub-theme of "Slope stability and retaining walls".

3 PANELIST PRESENTATIONS

There were 4 panelist presentations in this session. The topics associated with the earthquakes related problems are diverse, so are the topics of panelist presentations, including "Soil liquefaction", "Site response" and "Zonation".

3.1 *Fines content and liquefaction resistance*

The liquefaction characteristics of tailing sand were presented by Professor R. Verdugo with regard to cyclic mobility and flow failure. In order to examine the influence of fines content on liquefaction resistance, tailing sand was mixed with various amounts of non-plastic fines, and series of laboratory undrained cyclic triaxial tests were conducted. The concept of relative density was exclusively developed to determine the state of density for clean sand. Therefore the use of the relative density concept had been in question for fines-containing sand. His study showed that as the fines content increases, the maximum void ratio e_{max} tends to increase. On the other hand, the minimum void ratio e_{min} tends to reduce, as the fines content increases. In addition, Proctor tests reproduced almost identical minimum void ratios obtained by vibration tests. Therefore, it was emphasized that the concept of relative density can be useful in defining the state of density even for sands with non-plastic silt. The undrained cyclic strength (liquefaction resistance against cyclic loading) as well as the undrained shear strength (static resistance against flow) is shown to generally become lower as the fines content increases.

3.2 *Post-liquefaction behaviour*

The topics presented by Professor T. Kokusho covered some recent developments in the interpretation of post-liquefaction behaviour, including the mechanism associated with post-liquefaction deformation and seismic isolation.

In explaining the mechanism of post-liquefaction deformation, there are 2 mechanisms proposed in the literature. One is obviously the "undrained" mechanism standing upon several assumptions as follows : (a) the inertia force during seismic shaking accumulates the residual displacement, (b) the flow occurs in the condition of the residual undrained shear strength lower than the static shear stress, (c) the residual deformation accumulated due to the action of minute aftershocks. In the other "partially drained" mechanism, the "void redistribution mechanism" and "water film phenomena" are attributed to the accumulation of the residual deformation, which are typically seen in layered soil deposits. It was emphasized here that the "partially drained" mechanism could explain the prolonged occurrence of flow deformation induced well after the main shocks. In his presentation, the influence of water films developed immediately beneath the thin impermeable layer within soil deposits was described in detail, based on the shaking table tests and centrifuge model tests.

In the topic of seismic isolation, the earthquake reconnaissance studies were described. The building structures standing upon the non-liquefied soil deposits were subjected to collapse and structural failures, while those standing upon the liquefied soil deposits were subjected only to minor cracks, in the events of 1964 Niigata earthquake, 1995 Kobe earthquake, 1999 Kocaeli earthquake in Turkey, and so forth. Those phenomena were examined based on the principle of seismic energy transmission.

3.3 *Site response and microzonation*

In the presentation given by Professor A. Ansal, the topics related to "site response and microzonation" were covered. His study was focused on the area near Istanbul in Turkey, in which the area was divided into the grids of 250 m by 250 m. His attention was given to the choice of input ground motion and the site characterization pertinent to site response analyses, and the resulting microzonation with respect to ground shaking. Based on this study, his presentation was extended to the application of microzonation to urban planning and possible earthquake scenario applications.

3.4 *2-D valley effects in site response*

The topics associated with two-dimensional valley effects on site response were covered by Professor G. Gazetas. Based on the findings that two-dimensional or three-dimensional soil amplification effects are evident, since one-dimensional soil amplification tends to under-predict the seismic motion at a ground surface, case studies in Greece and Japan were presented. The two main causes of aggravation with respect to one dimensional effects are the multiple reflections of seismic waves at the edges of valley-shaped soft soil deposits, and the generation of surface waves at the edges of such soil deposits. It was emphasized that the spatial distributions of seismic amplifications are sensitive to the frequency of seismic excitation. In high-frequency input motions, the significant aggravation is eminent near the edges of valley-shaped soil deposits due mainly to "wave focusing" effects. In low-frequency input motions, the significant aggravation is eminent at the centre of such soil deposits due to Rayleigh waves interfering with SV waves. His study was extended to non-linear site response analyses taking into account the strain-dependent shear modulus G and damping ratio h, and concluded that the valley effects on the seismic amplifications are significant, however, they drastically reduce with increasing soil non-linearity.

4 DISCUSSIONS

The audiences well responded to the presentations given by the general reporter and panelists. There have been lengthy discussions on whether liquefaction-induced flow deformation would be induced primarily by the localization of strain development within soil deposits or it would be induced in such a manner that cyclically softened soil deposits move as a block. In response to this question, Professor Kokusho and Professor Boulanger suggested that there can be various types of deformation clinging to soil liquefaction during earthquakes. In case of San Fernando Dam in USA, the progressive failures were well known to be observed, while the "water-film" phenomena can be seen in inhomogeneous layered soil deposits. With regard to the seismic isolation associated with soil liquefaction, an additional case study was brought in by Professor Yoshimi from the floor.