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US–Taiwan workshop on soil liquefaction: overview and research needs

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1. Introduction

Approximately four years after the devastating Chi-Chi earthquake, an international workshop on soil liquefaction was held on November 3–4, 2003 at National Chiao Tung University in Hsinchu, Taiwan. Organized by Prof. C.H. Juang of Clemson University, Prof. A.B. Huang of National Chiao Tung University, and Prof. Steven Kramer of the University of Washington, Seattle, and sponsored by the National Science Foundation (United States) and the National Research Council (Taiwan), the workshop attracted more than 120 participants from Taiwan, Japan, and the United States. Workshop attendees heard over 40 presentations on a variety of liquefaction-related topics in three plenary and six breakout sessions, and participated in two parallel discussion sessions on liquefaction research needs. This short note provides a brief overview of the workshop and a summary of the research needs discussions.

2. Workshop overview

The purpose of the workshop was to provide a forum for an international group of researchers to present and discuss recent findings on various aspects of soil liquefaction, and to identify and prioritize remaining research needs in that area. The workshop program was organized to facilitate discussions of the various presentations.

The first day of the workshop began with a series of status reports on soil liquefaction presented in a plenary session by experts such as Profs. I.M. Idriss of the University of California at Davis, T.L. Youd of Brigham Young University, and Y.B. Tsai of National Central University. This session was followed by parallel breakout sessions on Case Histories and Probabilistic Methods. After lunch, a plenary session on Recent Developments was followed by parallel breakout sessions on Numerical and Physical Modeling and on Effects of Fines.

A plenary session on The Japanese Perspective, featuring presentations by Profs. K. Ishihara, Y. Iwasaki, and K. Tokimatsu, began the second day of the workshop. The session was followed by parallel sessions on Use of Shear Wave Velocity and Recent Developments. The afternoon of the second day was devoted to two parallel discussion sessions and a concluding plenary session in which summaries of these discussions were presented.

The presentations made at the workshop covered an impressive array of topics relating to observations, prediction, and mitigation of liquefaction hazards. A good portion of the presentations dealt with liquefaction observed in the Chi-Chi earthquake since nearly all participants had either experienced that earthquake or been involved with reconnaissance and/or research activities immediately following it. Other presentations, however, described complementary observations of liquefaction behavior from recent earthquakes in Turkey and Japan. Several presentations dealt with characterization of ground motions for evaluation of the loading applied to potentially liquefiable soils, and another group of presentations described the evaluation of liquefaction resistance using a variety of in situ test measurements; the workshop included a significant number of presentations on shear wave velocity-based characterization of liquefaction resistance. The workshop also included strong groups of presentations on probabilistic approaches to liquefaction hazard evaluation and on the effects of fines on liquefaction behavior. The wide range of topics covered and the breadth of expertise represented by the participants made the presentations and subsequent discussion particularly valuable.

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3. Research needs discussion sessions

Following the presentations, two parallel discussion sessions were convened to identify significant research needs in light of the recent research findings presented at the workshop. One session, moderated by Prof. K.H. Stokoe of the University of Texas, focused on field testing and collaborative opportunities. The other session, moderated by Prof. S.L. Kramer of the University of Washington, focused on physical and numerical modeling. The discussions in both sessions were spirited and wide-ranging, and followed up in the Closing Remarks session that was chaired by Prof. T.L. Youd. Because both groups touched on a number of common topics, the general discussion and conclusions of both are combined in the subsequent paragraphs.

Workshop participants felt that identification, characterization, and instrumentation of sites at which future liquefaction is likely would be worthwhile. Such a program would involve identification of different types of sites, and should include sites with liquefiable soils containing appreciable fines. The characterization would include SPT, CPT, and Vs measurements, along with other tests (geophysical, electromagnetic, etc.) that could help characterize fines. The testing would be performed with spatial density sufficient to characterize spatial variability down to the level of thin layers that could influence liquefaction potential and effects. The site characterization data would be posted for interested researchers to make pre-event predictions of results, and for subsequent comparison with observed behavior following strong ground shaking.

A great deal of interest was expressed in further research on fine-grained soils and the effects of fines on the liquefaction resistance of coarse-grained soils. The need to develop new tools/techniques for evaluating hazards associated with fine-grained soils, i.e. to refine or replace the so-called Chinese criteria, was generally agreed upon. The plasticity of fines in soils such as silty sands is considered to have a significant, but as yet insufficiently quantified, influence on liquefaction resistance; their effects on the effects of liquefaction (e.g. post-liquefaction volume change and deformation behavior) were not considered to be well established. The workshop participants felt that physical model testing should play a significant role in establishing the effects of fines on volume change and permanent deformations. Recognition of the effects of fines on liquefaction potential and effects of liquefaction brings with it the need to characterize fines in subsurface investigations. Researchers felt that 'out-of-the-box' thinking is needed to identify new techniques, or apply techniques from other disciplines, to characterization of the content and character (plasticity, texture, etc.) of fines, and that further research on such topics is needed.

The residual strength of liquefied soil was identified in the first status report of the workshop as a pressing research need in the area of soil liquefaction, and the discussions confirmed this as an important topic for further research. The role of fines, in particular inclusions of fines that cause the accumulation of porewater and potential localized increases in void ratio, in the development of flow slides has become increasingly recognized. Other phenomena that influence the residual strengths backcalculated from case histories, such as mixing and hydroplaning, are also significant but less well recognized at this time. Researchers felt that physical modeling could play two important roles in improving the profession's ability to predict residual strength of liquefied soil. The first would be in supplementing the relatively meager database of well-characterized flow slide case histories. The second would be to clarify the relative effects of these various phenomena so that some of the substantial uncertainties in full-scale flow slide case histories could be reduced.

Workshop attendees discussed the three primary methods for characterization of liquefaction resistance, i.e. correlation to SPT resistance, CPT resistance, and shear wave velocity, and the potential roles of each in liquefaction hazard evaluation. It was felt that additional research aimed at identifying the complementary benefits of each approach would be worthwhile. It is clear that the use of more than one method for liquefaction resistance evaluation can lead to improved reliability, but the specific conditions under which it is advisable to do so are not well established. It was felt that physical model testing, such as centrifuge testing with simulated SPT and CPT tests along with shear wave velocity measurements, could help identify the complementary benefits of the different methods.

The potential for improved evaluation of liquefaction hazards through improved characterization of ground motions was also discussed. Workshop participants felt that alternatives to the PGA–MSF (peak acceleration and magnitude scaling factor) approach to ground motion characterization should be explored. The potential of non-traditional methods, such as wavelet analysis, to express the non-stationary time- and frequency-domain characteristics of loading applied to liquefiable soils should be further investigated. Such approaches would allow uncertainties in loading to be more accurately known and, potentially, to be substantially reduced. The researchers also felt that additional research to establish the uncertainty in liquefaction resistance models, and on the quantification and incorporation of uncertainties in liquefaction potential and effects, was needed.

Workshop participants also discussed research needs with respect to soil improvement and ground modification. Practitioners expressed the need for improved procedures for evaluating the required degree and spatial extent of improvement required to obtain desired levels of performance. The need for research aimed at improved prediction of the performance of improved soil, using three-dimensional analytical procedures calibrated by field and model test observations, was expressed. Because soil improvement and ground modification are frequently utilized to improve

the performance of structures and constructed facilities, the need to account for soil–structure interaction in both natural and improved soils was also noted.

Finally, workshop participants noted the benefits of collaborative research efforts, both following events such as the Chi-Chi earthquake which fostered many of the international interactions that ultimately led to this workshop and through established collaborative research programs jointly funded by various national agencies. The improved experimental capabilities that are being provided by the NEES program in the United States, and the unique experimental capabilities of research organizations in Taiwan and Japan offer potential for collaborative investigations of a scope and scale that have not been attempted previously. All participants agreed that such collaborative research opportunities should be explored and pursued to the greatest degree possible.

Acknowledgements

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Appendix A. List of invited workshop participants

Participants from US
Ronald D. Andrus
Ross W. Boulanger
Daniel B. Chu
Ahmed Elgamal
Michael S. Fraser
I.M. Idriss
C. Hsein Juang
Robert Kayen
Steven L. Kramer
Hoe I. Ling
James R. Martin, II
Dayakar Penumadu
Shamsher Prakash
Shamim Rahman
Ellen M. Rathje
Kyle M. Rollins
Thomas Shantz
Jonathan P. Stewart
Kenneth H. Stokoe, II
Jerry A. Yamamuro
T. Leslie Youd
Ray Ruichong Zhang

Participants from Japan
Yoshi Iwasaki
Kenji Ishihara
Kohji Tokimatsu

Participants from Taiwan
Wen-Jong Chang
Ming-Hung Chen
Yao-Chung Chen
J.C. Chern
Y.Yao Chi
An-Bin Huang
Jin-Hung Hwang
Chi-Sheng Ku
Chyi-Tyi Lee
Der-Her Lee
Wei F. Lee
Chih-Ping Lin
Ping-Sien Lin
C.H. Loh
Sheng-Huoo Ni
Yii-Wen Pan
Yi-Ben Tsai
Jiin-Song Tsai
Tzou-Shin Ueng