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NEWS ON RECENT CONFERENCES

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MESSAGE FROM TC203 VICE CHAIRMAN

Prof. R.W.Boulanger

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Professor Towhata (Editorial Board) asked me, as the incoming chair of TC203 on Earthquake Geotechnical Engineering and Associated Problems, to provide some reflections on a focused aspect of geotechnical earthquake engineering. I picked the present topic, out of all the exciting developments in our field, because I believe the emergence of shared-use facilities represents an important benefit to our international community. I would also like to acknowledge Dr. Dan Wilson, Associate Director of our Center for Geotechnical Modeling (CGM), for his assistance in putting this note together.

Advances in large-scale geotechnical dynamic experimental facilities have played a major role in the advancement of geotechnical earthquake engineering over the past twenty five years. Experimental facilities have become more technologically advanced, experimental techniques have improved, inverse analysis methods for data processing have become routine, numerical modeling has improved, and the spirit of data and facility sharing has transformed the way the community does research. This note reflects on these developments in dynamic centrifuge modeling and their importance to our international community, using examples from the CGM at the University of California at Davis, which operates and maintains two dynamic centrifuges (1-m and 9-m radii) as part of the George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES).

The scientific value of centrifuge tests has progressively increased as advances in technology and experimental procedures have enabled researchers to explore fundamental mechanisms in ever increasing detail. Advances in instrumentation and hardware have seen the number of sensors in a model test increase from dozens in the 1990s to routinely more than a couple hundred in the large centrifuge models today.

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Larger centrifuge models have enabled the construction of soil-structure systems with complex stratigraphic details or multiple structural models (Figure 1). In-flight characterization tools have enabled the tracking of shear wave velocities and cone or T-bar penetration resistances in soil profiles across multiple shaking events over several days in the case of some model tests (Figure 2). New camera technologies have made it possible to record multiple views at a fraction of the cost in years past. New containers and model preparation systems have enabled testing of a broader range of soil types, from soft silts to biologically treated sands.

These scientific and technological advances have, however, increased the number of researchers, time, and cost required to perform each test. In many cases, the more complex tests have been performed by multi-university teams working together on a common project. The trend toward larger teams working on more complex models reflects the general experience that the extra cost and effort is rewarded by results of greater scientific value.

Inverse analyses of high-resolution sensor data are now frequently used for interpreting physical mechanisms that could not otherwise have been measured. Inverse analyses of sensor data have been used to, for example: (1) define shallow foundation responses, including the interaction of axial, shear, and moment loads on the settlement, translation, and rotation responses during dynamic shaking (e.g., Gajan et al. 2005), (2) define cyclic stress-strain responses of soils (e.g., Kamai and Boulanger 2010), (3) define p-y responses between piles and liquefying soils (Wilson et al. 2000), and (4) define volumetric strains due to pore water flow (e.g., Malvick et al. 2008).

Figure 1: Centrifuge models of structure-soil-structure interaction problems with liquefying soil. (a) Several structures on shallow footings. High resolution and high speed cameras are used to monitor the structures while 150 sensors measure the model response. A servo-hydraulic actuator is used to drive a cone penetration test in flight. (b) Submerged transit tube with liquefying backfill. Dense pore pressure arrays define transient seepage patterns and non-contacting electro-magnetic position sensors track tube displacements. (Wilson and Allmond 2014)

The evaluation and validation of numerical simulation procedures against the results of centrifuge model tests has become more thorough with the increasing detail provided by the centrifuge tests and the inverse analyses of sensor data. The questions now become whether the numerical simulations can reproduce the more detailed patterns of dynamic response (e.g., pore pressures, displacements, accelerations) throughout the system as opposed to at a few points, as well as some of the interaction mechanisms quantified through the inverse analyses (e.g., foundation rocking, p-y reactions, localized loosening). Centrifuge tests have become more like well-documented case histories which will bear reexamination by many future researchers. Furthermore, the evaluation of numerical simulation procedures against sets of archived centrifuge test data covering a range of models and multiple input

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ground motions provides an improved basis for identifying strengths, limitations, bias, and dispersion in simulation procedures.

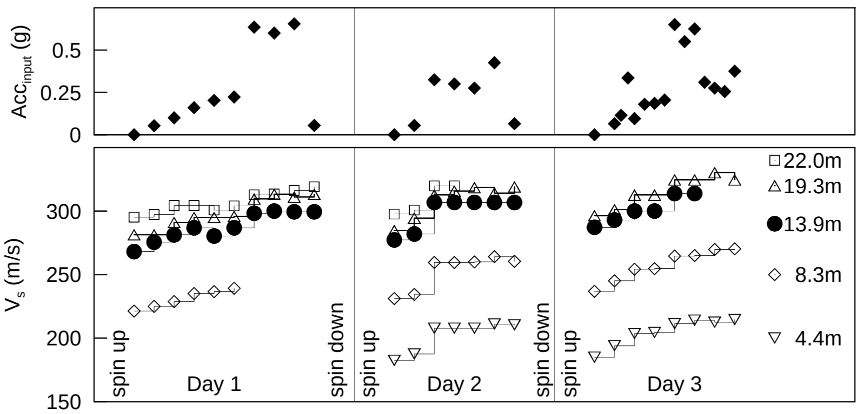

Figure 2: Chronology of shear wave velocity at five depths in a sand layer following successive shaking events with varying levels of peak base acceleration (Acc_{input}) (data from Trombetta et al. 2011). V_s increases with depth in the model due to the higher vertical effective stress. V_s increases with successive shaking events on Day 1, 2, and 3, with the increase attributed to a progressive increase in K_o and thus mean effective stress and increasing D_r. V_s reduces from the end of Day 1 to the start of Day 2 and from the end of Day 2 to the start of Day 3, with the decrease attributed to the relief of lateral stresses when the model is spun down. The residual increase in V_s from Day 1 to 2 to 3 is attributed to the progressive increase in D_r. (Wilson and Allmond 2014)

The multiple roles of a single centrifuge model test can be illustrated with any number of recent examples. Consider the centrifuge test shown in Figure 3 which involved lateral spreading of two slopes toward a central channel; one slope was treated with geosynthetic drains and one was not. This was one of several centrifuge tests (Howell et al. 2012, Conlee et al. 2012) performed as part of the NEESR-GC project on Seismic Risk Mitigation for Port Systems. This specific centrifuge test was performed by researchers from five universities working together, with the experimental results archived and publicly distributed at NEEShub (Kamai et al. 2013). Inverse analyses of the sensor data (Figure 4) were used to investigate stress-strain responses and the progressive loosening of the liquefied sand immediately beneath the overlying clay crust (Figure 5; Kamai and Boulanger 2010). Numerical simulations, such as shown in Figure 6, were performed by four of the collaborating universities using different software programs and procedures (Kano et al. 2007, Vytiniotis 2009, Kamai and Boulanger 2013, Howell 2013). The open availability of the archived data set means that these data can be used by researchers around the world to evaluate their own numerical methods and procedures.

Another example of the power of data sharing for the international community is a data set from five centrifuge models of soil-pile-structure interaction in liquefying sands and soft clays performed in 1995-96 (e.g., Wilson et al. 1997). The data from these five tests were among the first data published by the CGM for others to use. This data set has been analyzed by more than 30 research teams from academic and consulting organizations spanning 14 countries in the nearly 20 years since the data was produced.

The culture of sharing research facilities, as embodied in the shared-used nature of the NEES network, has made these technological advances available to the broader community and thereby multiplied their impacts on geotechnical earthquake engineering. For example, since 2000, our CGM has hosted researchers from 14 institutions across California and from 14 states outside California, as well as several international teams and numerous visiting scholars who collaborated on model testing. More than 30 projects have used our facilities under NEES, with 70% of the projects led by researchers outside of UC Davis. This is a dramatic increase in the use of the facility by outside users over pre-NEES operations.

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Large-scale shared-use experimental facilities for geotechnical earthquake engineering have contributed to major advances over the past twenty five years and offer a basis for further advances in coming years. In particular, the cultural change in the research community toward more openly sharing experimental facilities and making archived experimental data publically accessible is an important development for our international community and is especially beneficial for those who may not otherwise have access to these types of experimental facilities or data. The field of geotechnical earthquake engineering has many pressing challenges ahead of us, including much to learn from recent devastating earthquakes around the world. International collaborations and exchanges that are made possible through avenues ranging from shared-use experimental facilities to the numerous activities of TC203 are essential for our collective success in effectively reducing earthquake hazards around the world.

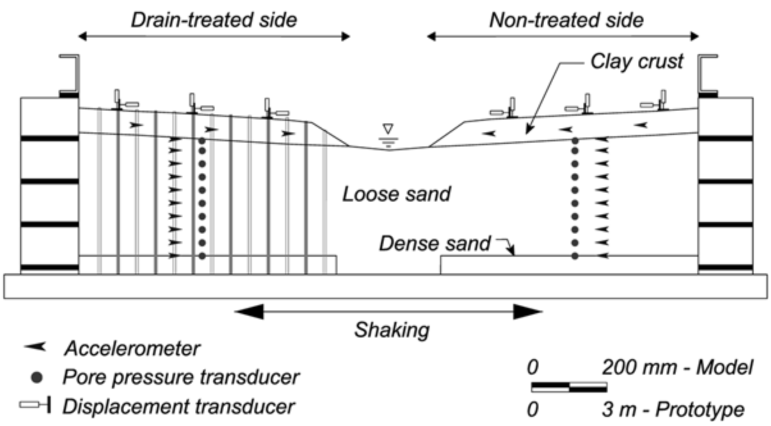

Figure 3: Cross section of model SSK01 involving lateral spreading of two slopes toward a central channel; the slope on the left is treated with geosynthetic drains, whereas the slope on the right is not. (Kamai and Boulanger 2013).

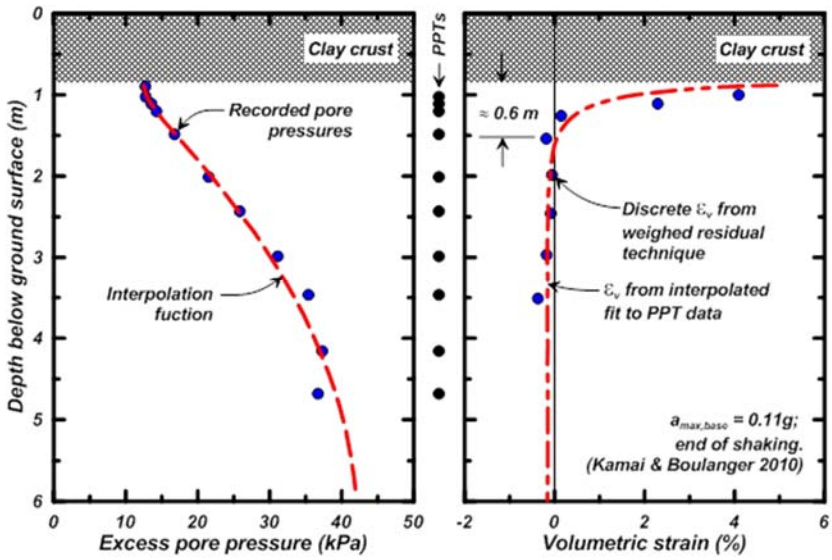

Figure 4: Dense arrays of pore pressure transducers on the right side of SSK01 (Figure 3) were used to calculate volumetric flow rates and changes in void ratio throughout the soil profile (Boulanger et al. 2012).

Message from TC203 Chairman (CONTINUED)

Figure 5. Photograph of strain concentration in the sand immediately below the clay crust on the non-treated side of the model shown in Figure 3 (Boulanger et al. 2012).

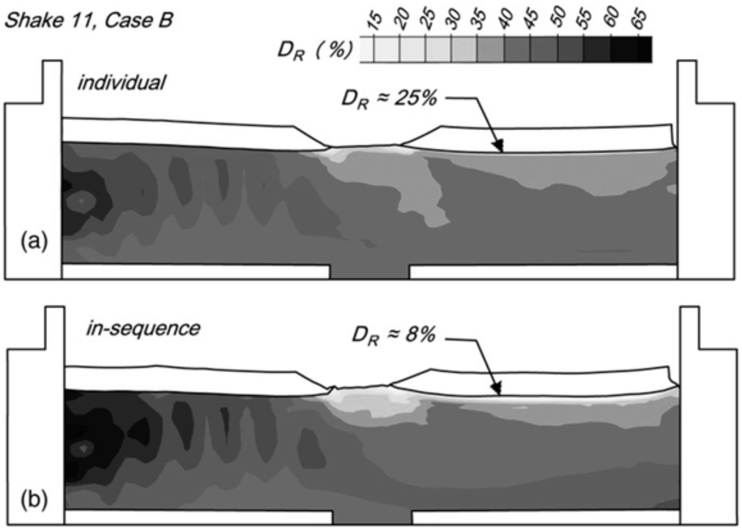

Figure 6: Numerical models of SSK01 were able to reproduce the loosening and concentrated strains in the sand immediately below the clay crust on the untreated side, as identified by the inverse analyses shown in Figure 4: (a) analysis of shaking event 11 alone, and (b) analysis of shaking event 11 in-sequence with previous events. (Kamai and Boulanger 2013)

Message from TC203 Chairman (CONTINUED)

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