The Promise of NEES

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Since the 1906 San Francisco earthquake, there has been growing awareness in the U.S. of the risk posed by earthquakes to the built environment. In recent years, this awareness has transformed into concern over economic losses in addition to life safety, resulting in a move to Performance Based Design concepts and away from more prescriptive methods. This shift in approach requires significantly more information as to *system* behavior under earthquake excitations than is required for the earlier force-based methods. The question is, how do we obtain system performance to use in design, especially in the current era of tight budgets and limited support for basic research?

One answer came in the late 1990s when Congress funded the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), a ten-year investment aimed at reducing the vulnerability of U.S. infrastructure to the damaging effects of earthquakes. The Network is built around the National Science Foundation's (NSF) $83 million funding of 15 geographically distributed NEES Equipment Sites, together with an integrative IT infrastructure (*Figure 1*). The NEES sites include three shake table facilities, two geotechnical centrifuge sites, one tsunami wave basin, six large-scale testing laboratories and three field sites; all sites are linked with IT systems and managed by the NEES Consortium, Inc. Through use of these NEES Sites, researchers seek to reduce the vulnerability of the built infrastructure to the damaging effects of earthquakes by finding answers to important and complex technical problems whose study is enabled by the Network. A secondary goal is to accelerate the rate at which research discoveries are made and then integrated into methods, technologies and products for engineering practice.

What separates NEES research from earlier efforts is the scale of the work and its integration. At present, there are about 100 projects underway in the Network, funded by NSF and other federal agencies, together with projects funded by Caltrans and others. The goal is the study of complex problems that could not be studied previously, due to size or testing lab capacities. These 15 sites represent the state-of-the-art in the U.S. and, in most cases, are not equaled anywhere in the world. The associate NEES research is of such a scale that collaborative work is

Figure 1: The NEES Equipment Sites.

required with project teams formed around expertise, including faculty and practitioners. Integration of the practitioner community has greatly helped focus the research and guide the overall effort with an eye towards implementation. The end result is not only better understanding of basic performance issues, but also the validation of new ideas and products, as well as new design provisions to improve performance.

Project examples include:

- Research into the behavior of precast concrete floor diaphragms, and the dynamic interactions between such diaphragms and the primary lateral-force-resisting elements, where the diaphragm flexibility is not negligible. This work is a direct result of performance issues observed following the Northridge earthquake and is partially supported by the Precast/Prestressed Concrete Institute, the Pankow Foundation and NSF (CMMI-0324522). The project has utilized detailed subassembly testing conducted at NEES@Lehigh to determine basic behavior, and together with detailed finite element studies, has developed new diaphragm design concepts. A half-scale, one-million-pound specimen was tested at NEES@UCSD on its shake table (*Figure 2*) to compare with smaller tests and analyses, and validate these simulations using various levels of

Figure 2: Half Scale Precast Structure Ready for Test on NEES@UCSD Shake Table.

ground motion to observe performance of the entire system. Design provisions from this work are under development.

- Planar wall research undertaken to determine performance characteristics and design recommendations (*Figure 3*). The test specimen is a ⅓-scale model of the bottom three stories of a ten-story building with uniformly distributed longitudinal reinforcement spliced at approximately mid-height of the first story. NEES@UIUC Load and Boundary Condition Boxes (blue and orange) were used to apply a constant axial load, as well as shear and moment, at the top of the specimen. Ancillary actuators applied story shears at the top of the first and second stories. Design provisions will be developed for review by the American Concrete Institute (ACI) Building Code Committee and possible inclusion in ACI 318. NSF funded this research under grant CMMI- 0421577.
- Research to understand sand liquefaction during lateral spreading near pile foundations (*Figure 4*). The project links large-scale tests with centrifuge and analysis to determine behavior. The goal is to determine how to design pile foundations against lateral spreading in simplified terms, and to provide a basic understanding for appropriate analytical platforms. The research uses the 6-meter-tall laminar box NEES@UB facility to induce two-dimensional shaking, together with the NEES@RPI centrifuge facility and the large E-Defense shaking table in Miki City, Japan. The project features the use

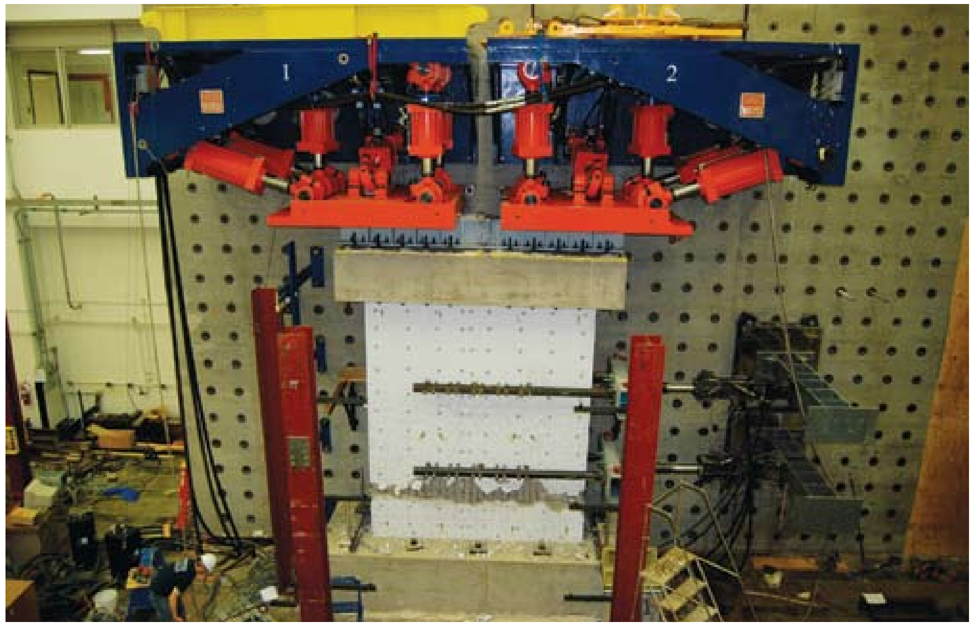

Figure 3: Planar Wall Test Specimen Following Testing to a Maximum Drift of 1.5% at NEES@UIUC.

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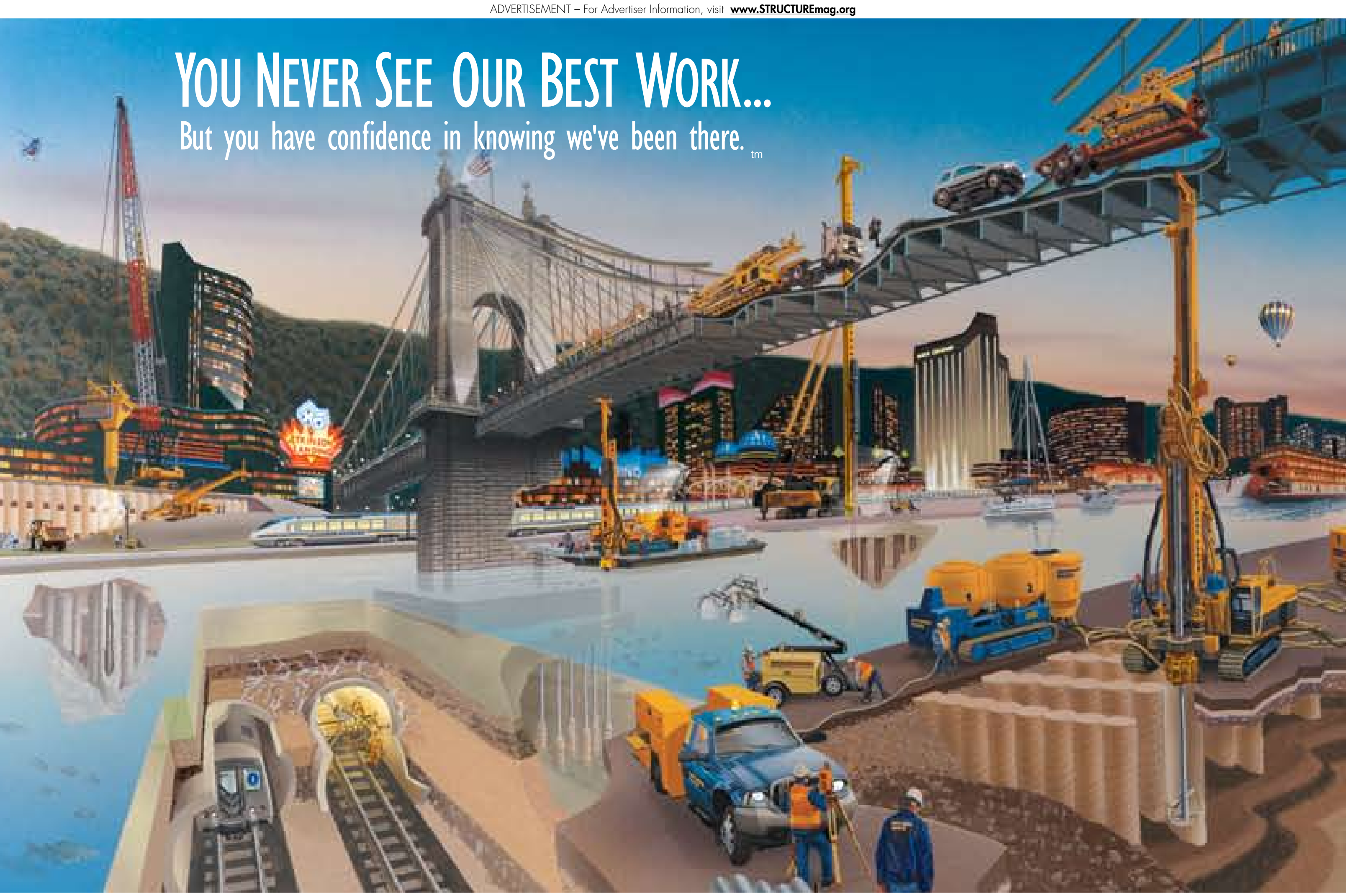

of novel advanced sensors to measure soil accelerations, deformations and pressures during shaking, and micromechanical discrete element numerical experiments and finite element analyses at RPI, UC San Diego and Tulane University. All are integrated by an appropriate identification and analysis framework including system identification and visualization capabilities. NSF funded this research under grant CMMI- 0529995.

The NEES collaborative environment itself, including both the shared experimental infrastructure and the integrative cyber infrastructure, ensures open and long-term access to the data resulting from experimental and numerical simulation. The NEES collaborative approach empowers researchers to form problem-focused project teams that serve as "virtual centers of expertise" constrained neither by geographical location nor by static organizational structures or limited local experimental facilities. Another aspect of NEES is the development of high-impact educational programs to enhance (1) the capabilities of the engineering workforce, (2) community diversity, (3) science and math education, and (4) public understanding of earthquake risks.

Operating since 2004, the first research projects conducted under NEES are just now finishing. In the next year, these results will be published and also seen in design provisions under consideration by ACI, the American Institute of Steel Construction (AISC) and the Precast/Prestressed Concrete Institute (PCI). The NEES program offers tremendous opportunities for developing new understanding of seismic demands and how to mitigate their effects through engineering solutions.▪

NEESR-SG: Experimental and Computational Study of Pile Foundations Subjected to Liquefaction-Induced Lateral Spreading

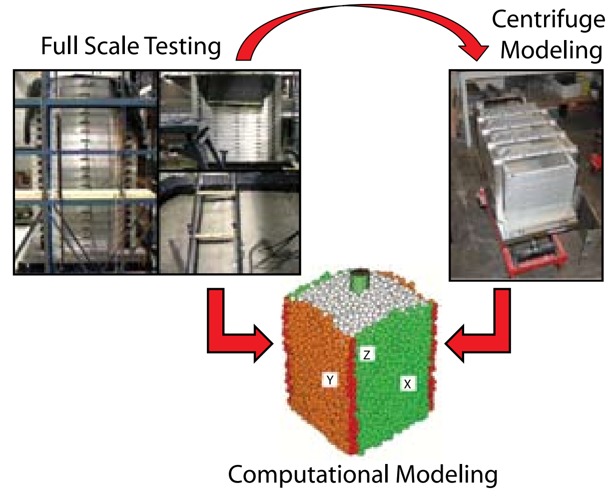

Figure 4: Pile Foundation Liquefaction Study at NEES@RPI.

Steven McCabe, Ph.D., P.E. is the CEO of The NEES Consortium, Inc., responsible for the management and operation of its $22 million program. Dr. McCabe is a professor emeritus of Structural Engineering at the University of Kansas and is an active member of many national and international professional societies.

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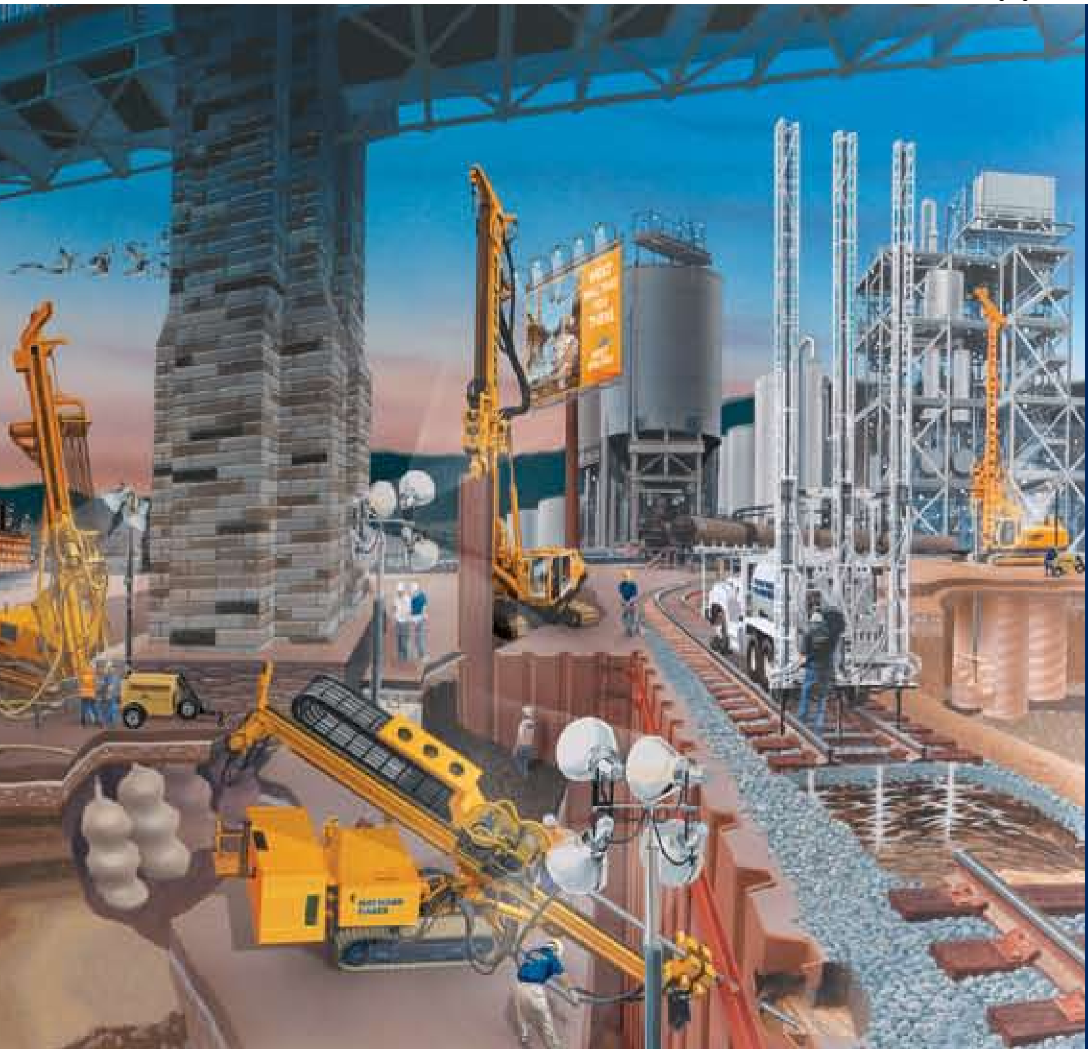

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