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How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety
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The Pacific Earthquake Engineering Research Center: A Decade of Achievement

This is the first in an intermittent series of articles about three earthquake engineering research centers funded over the past 10 years by the National Science Foundation. All three centers are "graduating" from the Foundation's engineering research centers program and are transitioning into the next chapters of their organizational lives. These stories briefly review the centers' accomplishments and plans for the future. This article focuses on the Pacific Earthquake Engineering Research Center; over the coming year, additional stories will spotlight the Mid-America Earthquake Center and MCEER.

In a perfect world, every building would be fully protected against earthquake hazards. In the real world, trade-offs must be made between safety, durability, and cost. These determinations have often been made unconsciously, by default, or on the basis of very limited information. This has begun to change, however, thanks to the efforts of the Pacific Earthquake Engineering Research Center (PEER).

Headquartered at the University of California, Berkeley, PEER is a center for multidisciplinary earthquake engineering research and education. Fifteen universities located in California, Hawaii, Oregon, and Washington participate in PEER, nine as core institutions and six as educational affiliates. Researchers and students from other campuses also participate in PEER-sponsored research and educational activities. The Center was established in 1997 through funding by the National Science Foundation (NSF, a NEHRP agency) and the State of California.

A Focus on Performance-Based Earthquake Engineering

PEER has worked to make decisions about seismic performance trade-offs more informed and science-based by advancing the development and use of performance-based earthquake engineering (PBEE). An emerging paradigm for earthquake engineering, PBEE recognizes that seismic performance requirements can vary from one structure to another based on site-specific hazards, facility-specific risks, and the risk acceptance of owners and society as a whole.

PBEE looks beyond immediate risks to life and limb to examine the full range of risks that earthquakes pose for buildings and other constructed facilities, including economic and societal risks deriving from the complex interdependencies that characterize today's built environment. PBEE practitioners help facility owners, managers, investors, and regulators to accurately identify and quantify the risks that they face, and then provide design options that enable these stakeholders to make informed decisions about seismic performance.

PEER has sought to advance PBEE through intertwined research, education, and technology transfer programs. Underlying each program is PEER's conceptual framework for PBEE, which builds upon earlier "first-generation" PBEE constructs, adding measures of probable damage severity and consequences (human casualties, facility downtime, and repair costs) to enhanced measures of seismic hazards and of structural responses to seismic forces.

PEER's Approaches

PEER has used an advisory board of government and industry partners to identify the knowledge, technology, and tools that are needed to shift earthquake engineering toward performance-based methods. The Center has then determined what must be done to address these needs and assigned this work to qualified researchers from both academia and industry.

PEER's education program has employed a variety of mechanisms—design competitions, internships, student organizations, summer field missions, and others—to engage undergraduate and graduate students in PBEE-oriented education and research and in the earthquake engineering profession. At the same time, PEER has targeted practicing engineers in government and industry, enabling them to help shape and collaborate in the Center's user-driven research, and sharing research results with them through seminars, publications, and other outreach efforts.

PEER Results

PEER-sponsored research has developed tools and models that have impacted not only PBEE, but also earthquake engineering practice and research methods in general. These include advanced simulation technologies such as the Open System for Earthquake Engineering Simulation (*OpenSees*), a widely used computational platform. *OpenSees* has helped PEER researchers and others to develop and test new computer models that show with greater accuracy

how buildings, bridges, and other structures respond to the forces unleashed by earthquakes. *OpenSees* has also been adopted by the NSF-funded George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) as one of its major simulation tools. PEER products also include improved models of the ground motions produced by earthquakes, such as those developed through PEER's Next Generation Attenuation (NGA) research. The U.S. Geological Survey (USGS, a NEHRP agency) used the NGA models in developing its latest (2007) national seismic hazard maps, which will impact seismic design throughout the western United States.

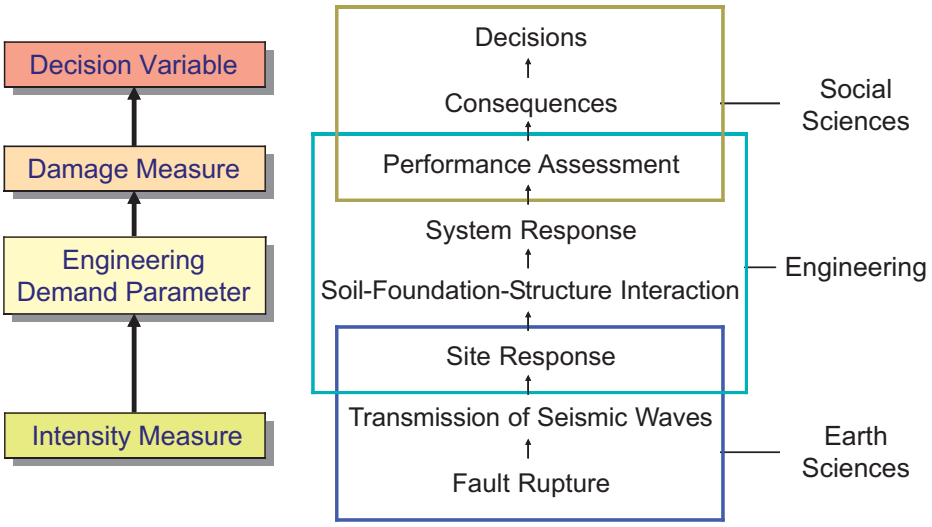

Illustration relating steps in PBEE (center) to PEER's PBEE framework variables (left) and traditional disciplines (right). Courtesy of PEER.

The research that PEER has undertaken, both to develop tools and models for PBEE and to apply those tools and models, has produced new fundamental knowledge used in earthquake engineering. For example, new knowledge about the seismic performance of new and existing reinforced concrete buildings has been used to enhance building codes and standards, and new knowledge about the performance of bridges and highway networks has facilitated investigations of new cost-effective bridge designs and strategies for emergency traffic routing.

Through its PBEE framework, its user-driven research, and its education and technology-transfer initiatives, PEER has engendered a culture of collaboration that is helping to shape the future of earthquake engineering. The Center has brought together academic investigators from earth science, engineering, and social science disciplines; has brought about systematic, synergistic collaboration between academic institutions and the practitioner community; and has helped to cultivate a future earthquake engineering workforce oriented toward PBEE and interdisciplinary, collaborative solutions.

Here Today—and Tomorrow

The NSF's engineering research centers program, which provided about a third of PEER's funding between 1997 and 2007, enabled the Center to establish a foundation for the future, one comprising not just a multi-institutional infrastructure but also a sustainable partnership between academia, business, and government. Over the years, PEER has expanded its funding sources. Additional sources of support for core operations or targeted research have included the State of California through its general fund, universities, and agencies; the Pacific Gas and Electric Company and other industry partners; the State of Washington; the Bay Area Rapid Transit District; and other Federal programs.

These and other relationships are expected to continue and grow in coming years. The California Seismic Safety Commission recently called for substantial increases in State and private-sector funding for PEER, and the Center has secured support for several new research initiatives. These include a project on mitigating collapse risks in older nonductile concrete buildings, which is being funded through the NSF's NEES research program, and a project to develop performance-based design guidelines for tall buildings, which has funding from the Pankow Foundation, the Southern California Earthquake Center (a research collaboration cofunded by the NSF and the USGS), the Federal Emergency Management Agency (FEMA, a NEHRP agency), and the USGS, among others. Through its continuing contributions to PBEE and to the safety and resilience of the west coast's built environment, PEER is advancing earthquake engineering in ways that benefit the entire Nation and the world.

More information about PEER is available online at http://peer.berkeley.edu/index.html.