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Seismic Waves
How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

Keeping the Containers Moving Through U.S. Ports

In the United States, container ports have become an important segment of the commercial infrastructure, a critical element of the economy, and a key gateway for exports and imports. However, the growing value of these facilities has generally not been accompanied by commensurate advances in their seismic risk management practices. This observation led to a major research effort initiated in 2005 by the Georgia Institute of Technology and partnering institutions. This work, supported by the National Science Foundation (NSF, a NEHRP agency), significantly advanced seismic risk-assessment and risk-mitigation knowledge applicable to container ports, an effort since furthered by the National Institute of Standards and Technology (NIST) through its work as NEHRP's lead agency.

A berthed ship and container cranes at the Port of Oakland in California. Courtesy of Glenn Rix.

Critical Yet Vulnerable

The use of containers for moving goods into and out of U.S. commercial ports has increased dramatically in recent decades. Between 1995 and 2009, the volume of such cargo nearly doubled, while its value rose from roughly $400 billion to $650 billion.[1] In addition to growing, container traffic has also become more concentrated in those ports able to accommodate the shipping industry's ever larger and more specialized vessels.

Six of the 10 busiest U.S. container ports are located in areas of high seismic hazard (Los Angeles, Long Beach, and Oakland, CA; Seattle and Tacoma, WA; Charleston, SC). In recent years, earthquakes have caused significant damage to ports in Japan, Chile, and Haiti, demonstrating the continuing vulnerability of these specialized facilities to earthquake-induced closures and disruptions. The Congressional Budget Office has estimated that an unexpected, protracted shutdown of the Los Angeles and Long Beach container ports would cost the U.S. economy from $125 million to $200 million *per day*.[2]

A Framework for Risk Analysis

Recognizing the apparent imbalance between ports' economic value and seismic vulnerability, NSF supported a George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) Grand Challenge project on "Seismic Risk Mitigation for Port Systems."[3] The agency awarded this 5-year, $3.78 million research project in 2005 to a consortium of universities and firms led by the Georgia Institute of Technology. Project researchers found that a majority of the ports located in areas of high seismic hazard had either no—or only informal—seismic risk mitigation plans. In addition, seismic design practices at such ports were often based on performance requirements that were vague, arbitrary, and selective.

The project team developed a new approach for assessing and managing seismic risk in container ports, an approach more useful to the stakeholders involved in owning, operating, designing, insuring, regulating, or using these facilities. This new framework measured seismic performance in terms of the probable costs of fully restoring the cargo-handling system

[1] U.S. Department of Transportation, *America's Container Ports: Linking Markets at Home and Abroad*, Jan 2011; W. W. Wilson and D. Benson, *Container Flows in World Trade, U.S. Waterborne Commerce and Rail Shipments in North American Markets*, Jan 2009.

[2] Congressional Budget Office, *The Economic Costs of Disruptions in Container Shipments*, Mar 29, 2006.

[3] NSF grant award number CMMI–0530478; a project abstract is available at http://www.nsf.gov/awardsearch/.

under the range of earthquakes that could affect a particular port. These costs included not only direct expenses incurred to repair or replace container cranes and wharves, but also indirect losses resulting from the interruption or reduction of container operations while repairs are under way.

To develop the framework, the team conducted interdisciplinary research on how to define the seismic hazards faced by individual ports, how typical container-handling wharves and cranes would respond to these hazards under existing and alternative seismic design and retrofit practices, the damage associated with such responses, and the direct and indirect costs likely to result from the damage. In so doing they used the full range of resources that were uniquely available through the NSF-supported NEES facilities, including state-of-the-art computer simulation tools, shake tables, centrifuges, and field-testing equipment.

Guidance Needed to Support the New Approach

As the new framework was taking shape under the NEES Grand Challenge project, NIST engaged the NEHRP Consultants Joint Venture, a partnership between the Applied Technology Council (ATC) and the Consortium of Universities for Research in Earthquake Engineering (CUREE), to identify what additional knowledge and guidance would be needed to enable ports to integrate the new approach into their seismic risk management practices. The consultants reviewed existing seismic-design requirements, related guidance, and the literature applicable to container port facilities. After finding several gaps in the existing guidance, they created a plan for developing this missing information and for making it available to port stakeholders in the form of three proposed documents collectively entitled *Seismic Design Guidelines for Port Container Wharves and Cargo Systems*.

The first of these proposed documents would help individual ports establish meaningful seismic performance standards for their container cargo systems. Performance criteria would be based on risk assessments carried out under the framework developed in the NEES project, using existing and enhanced levels of seismic risk mitigation. They would comprise not only standards applicable to the individual components of cargo systems (wharves, embankments (on which wharves are constructed), container cranes, and cargo storage yards), but also criteria for the cargo system as a whole that reflect the direct and indirect costs of alternative earthquake damage scenarios.

The consultants found that although guidelines are already available for the seismic design of new wharves and embankments, more guidance is needed for seismically retrofitting wharves and for designing ground improvements for existing embankments and storage yards. The second proposed document would fill this gap, while a related subject would be addressed in the third document: how best to incorporate kinematic seismic loading (i.e., the pressures on wharf piles generated by earthquake-induced deformation of the embankment) into assessments of the expected seismic performance of wharves.

The report prepared by the NEHRP Consultants Joint Venture, which NIST published in September 2012,[4] includes a breakdown of the specific tasks that would be required to develop these guidance documents. Tables detail the estimated duration and recommended sequencing of the tasks and the projected costs of developing each document. The report also describes the expert qualifications that will be needed to perform and review the results of the tasks, and identifies key groups that should be involved as collaborative partners. One such organization, the American Society of Civil Engineers (ASCE), has been active in the development of seismic design standards for selected port components, and the report suggests that the new guidance documents should be coordinated or integrated with ASCE's work.

[4] NEHRP Consultants Joint Venture, *Program Plan for the Development of Seismic Design Guidelines for Port Container, Wharf, and Cargo Systems*. NIST GCR 12–917–19. National Institute of Standards and Technology, Gaithersburg, MD: Sept 2012.