R/OE-38: 10.1.2002–9.30.2003

Seismic Performance of Port Facilities: Full-Scale Testing at the Port of Long Beach

Scott A. Ashford
University of California, San Diego

Background

The San Andreas fault, along with its complex network of sister faults, makes California one of the most seismically active regions in the country. Because of the high risk of seismic events, building codes for homes, hospitals and schools in California are among the strictest in the nation. The State Lands Commission is now implementing new design criteria that will extend this level of protection to marine oil terminals—huge piers from which supertankers pipe oil into holding tanks on land. The goal is to reduce the chances that moderate quakes will cause disastrous oil spills. There are about 60 marine oil terminals in ports such as Long Beach, Oakland and Los Angeles that may need to be retrofitted to meet new standards.

A 5,000 pound rotating shaker vibrates sections of a Long Beach pier at different frequencies to identify the structure's natural harmonics. More vigorous shaking simulates ground motions that might be felt during an earthquake.

A hydraulic piston bolted to two sections of the pier slowly expands, subjecting it to lateral loads that might be experienced during an earthquake. Photos: UC San Diego, Department of Structural Engineering

Project

This project was designed to gather information on how to best retrofit terminals and to validate new seismic design criteria. This was done by subjecting a 50-year-old former Navy pier in the Port of Long Beach to a battery of seismic tests. Because the pier was scheduled to be demolished, scientists were allowed to conduct seismic tests at an intensity that, under normal circumstances, would be infeasible.

The National Sea Grant College Program funded the project with a broader goal of helping to revitalize the nation's port infrastructure.

Experiment

In the first stage of testing, the pier was vibrated to determine its fundamental modes of vibration from which structural characteristics such as stiffness are inferred. In the second stage, it was tested vigorously with a 5000-pound rotating shaker to simulate how the pier might respond to ground motions caused by a quake.

The last and most dramatic experiments involved lateral load tests in which a series of hydraulic pistons pushed against one side of the pier. Under extreme loads, the

top of the pier was displaced four feet relative to the base of the pier's piles, some 40 feet beneath the waterline. The resulting structure resembled an odd rendition of the leaning tower of Pisa. Significantly, however, it never collapsed.

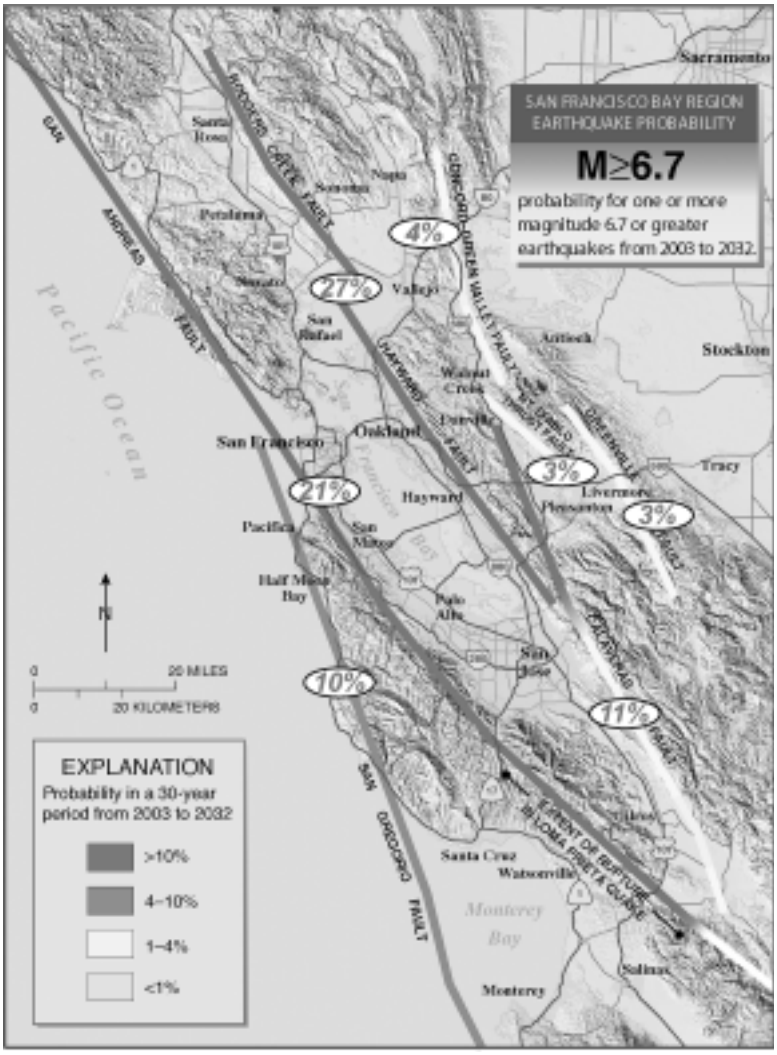
"All of us were surprised by how ductile it was," said structural engineering professor Scott Ashford of UC San Diego, the lead investigator on the project. "More ductile means more earthquake resistant. It just kept on going. We kept pushing it, and it did not fail. All of us were surprised. We expected the pier to perform poorly."

If Ashford's tests are a reliable indication, old working piers in California may be less prone to collapse during moderate earthquakes than previously thought.

Applications

What is learned from the tests will be shared with port authorities, oil companies and other interested parties in a series of educational workshops to be held at all major ports in the state. Ashford will be leading these workshops.

Data from the experiments will also be used to truth-check computer simulations of how structures respond to seismic events. "These tests will give us some confidence that when we use our computer models, they are predicting what will happen in reality," Ashford said.



Using newly collected data and evolving theories of earthquake occurrence, U.S. Geological Survey and other scientists predict that there is 62 percent chance of at least one quake of magnitude 6.7 or greater in the San Francisco Bay region before 2032. Graphic courtesy U.S. Geological Survey

Collaborators

Han-Padron Associates
Manson Construction-Connolly Pacific JV
Penhall Company
Port of Long Beach
Port of Los Angeles
State Lands Commission

For more information:
Dr. Scott A. Ashford
Department of Structural Engineering
University of California, San Diego
Tel.: (858) 822-0431
Email: sashford@ucsd.edu

July 2003

This work is sponsored in part by a grant from the National Sea Grant College Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, under grant number NA06RG0142, Project number A/P-1. The views expressed herein are those of the author and do not necessarily reflect the views of NOAA or any of its subagencies. The U.S. Government is authorized to reproduce and distribute for governmental purposes.

California Sea Grant College Program
Russell A. Moll, Director • Dolores M. Wesson, Deputy Director • Paul Olin, Associate Director for Extension • Marsha Gear, Communications Director
University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0232
Phone: (858) 534-4440 Fax: (858) 453-2948 Web site: http://www-csgc.ucsd.edu