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SeismicWaves

How NEHRP is Advancing Earthquake Safety

Strengthening Pipeline Survivability to Avoid Post-Quake Devastation

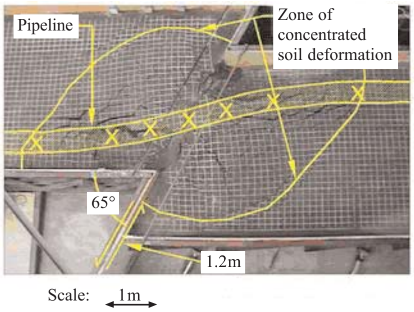
When earthquakes impact urban areas, the resilience of underground utilities can have a tremendous effect on what happens after the shaking stops. Broken water pipes led to the spreading fires that consumed more than three-quarters of San Francisco in the days following the great earthquake of 1906. Much of the city's water supply flowed through rigid iron pipes that were ruptured by the intense shaking. When fires sparked by broken gas connections, crossed electrical wires, and overturned stoves began to grow out of control, the fire department had virtually no water with which to fight them.

A similar tragedy unfolded in Japan in 1995, when a powerful earthquake shook Kobe, a city of 1.5 million residents. The quake knocked out about 70 percent of the city's water system and collapsed many older wood-frame houses. Within minutes more than 300 fires ignited, and with responders hampered by the lack of water and traffic disruptions, at least 12 conflagrations developed and burned for 24 to 48 hours.

A team of researchers from Cornell University and Rensselaer Polytechnic Institute (RPI) are responding to such events by conducting a systematic and comprehensive assessment of ground rupture effects on critical underground lifelines. Their objective is to improve the design and construction of buried pipelines and conduits used for water, natural gas, liquid fuel, electricity, and telecommunications.

The research, led by Cornell Professor Thomas O'Rourke, is supported by a 4-year grant (CMMI-0421142) from the National Science Foundation (NSF), one of the Federal agencies participating in NEHRP. The project was made possible by the unique experimental facilities available through the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) under NSF award CMMI-0402490. These facilities, which comprise 15 shared-use, experimental laboratories linked by an information technology infrastructure, include Cornell's Large Displacement Lifeline Testing Facility and RPI's Geotechnical Centrifuge Center, both of which are being used for this study.

At the Cornell site, O'Rourke and his colleagues have been conducting full-scale tests that subject 35-foot-long pipelines to simulated earthquakes. The pipes are buried in a test basin filled with about 100 tons of soil. The basin is split into two sections, one of which is moved in various directions during the tests to simulate earthquake fault ruptures. The forces exerted on the pipes and surrounding soil and the ways in which the pipes and soil respond to these forces are measured using sophisticated sensors deployed on and around the pipes and laser-equipped robotic devices placed inside the pipes.



Overhead view of a large-scale fault-rupture test on a 400-mm-diameter HDPE pipeline at the Cornell University NEES laboratory; X's mark locations of sensors.
Photo Courtesy: N. Olson, Cornell University

These tests are being applied to conventional steel pipelines as well as to newer, high-density polyethylene (HDPE) pipelines that are being used by industry in a growing number of sizes and settings. Test results have already confirmed that use of HDPE in earthquake-prone areas would help prevent quake-induced pipeline ruptures and their potentially catastrophic consequences. HDPE, a type of plastic, has demonstrated that it can stretch and deform without breaking when strained by extreme forces.

The large-scale tests are but one part of this project. Additional experiments are being carried out at RPI, where the geotechnical centrifuge and a scaled-down model of the Cornell test basin allow researchers to simulate pipeline dimensions and ground-rupture characteristics that are not practical for full-scale testing. Hundreds of numerical simulations are also being conducted to help design the experiments and to investigate additional combinations of pipeline and ground-faulting conditions.

Improved pipelines are needed to keep future earthquakes from becoming the two-stage disasters seen in San Francisco and Kobe, where damage from shaking is followed by damage from fires that are ignited, fueled, or allowed to grow by ruptured gas or water lines. This research is producing findings that can lead to better, more quake-resistant pipelines as the findings are put into practice. The researchers are disseminating these findings through engineering publications and conferences and through collaboration with a dozen pipeline-industry partners. Additional information about this project is provided at http://nees.cornell.edu/NEESR.htm.