Bridges will rock -- safely -- with new quake design

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Bridges that "dance" during earthquakes could be the safest and least expensive to build, retrofit and repair, according to earthquake engineers at the University at Buffalo and MCEER.

The researchers recently developed and successfully tested the first seismic design methodology for bridge towers that respond to ground motions by literally jumping a few inches off the ground.

The new methodology allows steel truss towers that support bridge decks to be built or retrofitted at far less expense than conventional approaches, where each leg of a bridge tower is strongly anchored to its footing.

The design recently underwent successful testing on a model truss tower that is 20 feet high and weighs nine tons.

Testing was conducted on a six-degrees-of-freedom shake table in UB's Structural Engineering and Earthquake Simulation Laboratory (SEESL). One of the world's most versatile earthquake engineering laboratories, it is a facility within the UB School of Engineering and Applied Sciences.

"Our approach is unconventional, counterintuitive," admits Michel Bruneau, Ph.D., director of MCEER and UB professor of civil, structural and environmental engineering, who developed the new approach with Michael Pollino, a doctoral candidate in the UB Department of Civil, Structural and Environmental Engineering.

"With an earthquake, conventional wisdom dictates that the most important thing is to anchor the bridge tower," explained Bruneau. "The mass wants to overturn, so you have to tie it down."

To do that, he explained, the tower must be anchored with a very expensive foundation system, which in turn, subjects it to the full force of the earthquake.

"In this scenario, something usually has to yield," he says. "Here, we're standing that concept on its head. By letting the tower rock, we're significantly reducing the overturning force."

The UB engineers developed a design procedure in which the legs of the truss tower are disconnected from their base and briefly uplifted by a small amount if significant ground motions occur.

One of the options they evaluated includes using specialized devices to control the structure's uplift. The devices, called hysteretic or viscous dampers, some of which were provided by Taylor Devices, Inc., were inserted at the base of the towers to allow the tower to rock while absorbing part of the earthquake's energy and helping to control the amount of uplift to the structure.

During the series of tests at UB on SEESL's state-of-the-art shake table, the experimental truss tower fitted with these devices was subjected to ground motions simulating the 1994 Northridge, California earthquake; testing also was conducted without any devices attached, as the design procedure was developed to generally address performance both with and without dampers.

Typically, during testing, the tower's legs uplifted nearly two inches in the air for less than a second. For some of the free-rocking cases, the tower legs lifted nearly four inches.

"All of the tests were successful," said Bruneau. "The damper systems typically reduced the magnitude of uplift and the velocity upon impact, which may be important, in some conditions."

The methodology will not allow uplifts to exceed limits considered safe by the design procedure and dictated by the tower design, local conditions and the need for the tower to return safely to its original position, according to Bruneau. The UB methodology is the first to be established for this application, but Bruneau notes that engineers previously have employed the concept, such as in the approach spans of the Lions Gate Bridge in Vancouver, British Columbia.

"Professional engineers are starting to recognize that it is economical to allow this type of rocking in their designs, as long as the structure remains stable and the speed with which the legs come down is carefully controlled to minimize the forces that develop during the rocking," said Bruneau.

In addition to the cost savings in construction, this design also saves money if seismic retrofit needs to be done, he added.

"It's much easier to fix a tower to enhance its seismic resistance if the crew only has to work at the base, instead of having to climb 60, 80 or 120 feet to strengthen individual members along the height of those towers," he said.

Movies:
www.buffalo.edu/news/videos/bridge_shake_close.mpg
www.buffalo.edu/news/videos/bridge_shake_far.mpg

Source: University at Buffalo