Slow-Motion Earthquake Testing Probes How Buildings Collapse in Quakes (w/ Video)

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No shake table needed: UB civil engineering professor Gilberto Mosqueda has successfully tested a method of simulating earthquakes in the lab that makes shake tables unnecessary in some cases.

(PhysOrg.com) -- It takes just seconds for tall buildings to collapse during powerful earthquakes. Knowing precisely what's happening in those seconds can help engineers design buildings that are less prone to sustaining that kind of damage.

But the nature of collapse is not well understood. It hasn't been well-studied experimentally because testing full-scale buildings on shake tables is a massive, expensive and risky undertaking.

That's why researchers at the University at Buffalo and Japan's Kyoto University teamed up recently to try an innovative "hybrid" approach to testing that may provide a safer, far less expensive way to learn about how and why full-scale buildings collapse.

"One of the key issues in earthquake engineering is how much damage structures can sustain before collapsing so people can safely evacuate," explains principal investigator Gilberto Mosqueda, Ph.D., UB assistant professor of civil, structural and environmental engineering. "We don't really know the answer because testing buildings to collapse is so difficult. With this hybrid approach, it appears that we have a safe, economic way to test realistic buildings at large scales to collapse."

The UB/Kyoto team's positive results could enable engineers to significantly improve their understanding of the mechanisms leading to collapse without the limitations of cost, reduced scale and simplified models necessary for shake table testing in the U.S.

In the unusual "slow motion earthquake" test conducted in late July, UB and Kyoto engineers successfully used the hybrid approach (see video at seesl.buffalo.edu/projects/hybridmoment/video.asp) to mimic a landmark, full-scale experiment conducted in 2007 on the E-Defense shake table at the Miki City, Japan, facility. In that test, a four-story steel building was subjected to a simulation of ground motions that occurred during the 1995 Kobe earthquake.

But instead of using a full-scale steel building, this time, the researchers developed a hybrid representation of that test by combining experimental techniques carried out in earthquake engineering labs in Buffalo and Kyoto with numerical simulations conducted over the

Internet.

The landmark data from the E-Defense test was used to verify the effectiveness of the hybrid approach. Only the parts of the buildings that were expected to initiate collapse were tested experimentally.

"If this had been a real building, it would have toppled over," says Mosqueda.

That presents a real problem in a laboratory.

"You can't allow a structure to collapse completely on a shake table," he said. "You need to have support mechanisms in place, like scaffolds, to catch the falling structure."

The building in the original full scale test weighed more than 200 tons. That kind of weight puts shake tables under enormous stress, Mosqueda explains. It not only forces them to operate at full capacity, there is the additional potential for the heavy structure to crash down on the equipment.

"But in this case, we simulated the load with high-performance hydraulic actuators so the specimen overall was actually pretty light," explains Mosqueda. "We completely did away with the hazard of having tons of weight overhead that could come crashing down. Here, we just shut off the hydraulics and the load disappeared."

It took the U.S. and Japanese researchers, who were communicating over the Internet, about two hours to subject the hybrid model to the powerful ground motions that represented approximately the first five seconds of the 1995 Kobe quake.

According to Mosqueda, the hybrid test paves the way for additional experiments that will allow researchers to more precisely learn about the nature of structural collapse.

"We want to know, for example, what is the probability that a building will collapse in the next expected earthquake," says Mosqueda. "First, we need to develop this capability to understand and simulate how they collapse. Then we can determine how to improve new construction or retrofit existing buildings so that they are less likely to collapse."

The experimental part of the test involved a half-scale, nine-foot-tall structure in UB's Structural Engineering and Earthquake Simulation Laboratory (SEESL), while a second experimental component was located at Kyoto University. Together, the two experimental substructures represented the first one-and-a-half stories, while numerical simulations represented the rest of the building.

Mosqueda explains that while reduced-scale models were used in this preliminary test to evaluate the method, the capacity exists at UB and other laboratories to apply this approach to full-scale buildings.

Mosqueda's colleagues on the test include Maria Cortes-Delgado, a doctoral student in the UB Department of Civil, Structural and Environmental Engineering, Tao Wang, Ph.D., of the Institute of Engineering Mechanics in Beijing, and Andres Jacobson, a doctoral student, and Masayoshi Nakashima, Ph.D., a professor at Kyoto University

These "distributed hybrid tests," were made possible by UB, its international collaborators at Kyoto University and the Institute of Engineering Mechanics in Beijing, and the National Science Foundation's George E. Brown Jr. Network for Earthquake Engineering Simulation (NEES) Facility, a nationwide earthquake-engineering "collaboratory" of which UB is a key node.

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