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Table discussion

Seismic experiments at Nevada-Reno show promise

The huge shake tables rumbled and the 70-ft-long, 52-ton concrete bridge survived a series of intense simulated earthquakes in the first multiple-shake-table experiment at the University of Nevada, Reno's new Earthquake Engineering Lab, the latest addition to the world-renowned earthquake/seismic engineering facility that has been in operation for more than 25 years.

The experiment was testing a new design featuring accelerated bridge construction and a rocking, pre-tensioned concrete bridge support system.

"It was a complete success. The bridge withstood the design standard very well and today went over and above 2.2 times the design standard," said John Stanton, civil and environmental engineering professor and researcher from the University of Washington. Stanton collaborated with foundation professor David Sanders of the University of Nevada, Reno, in the novel experiment.

"The bridge performed very well," Sanders said. "There was a lot of movement, about 12% deflection—which is tremendous—and it's still standing. You could hear the rebar inside the columns shearing, like a zipper opening, just as it would be expected to do."

The set of three columns swayed precariously, the bridge deck twisted and the sound filled the cavernous high-bay laboratory as the three 14 x 14-ft, 50-ton-capacity hydraulically driven shake tables moved the massive structure.

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"Sure we broke it, but we exposed it to extreme, off-the-scale conditions," Stanton said. "The important thing is it's still standing, with the columns coming to rest right where they started, meaning it could save lives and property. I'm quite happy."

Rocking it

The bridge was designed and its components were precast at the University of Washington, Seattle, then transported to Reno to be built atop the shake tables in the 24,500-sq-ft lab. It was shaken in a series of simulated earthquakes, culminating in large ground motions similar to those recorded in 1995's deadly and damaging 6.9-magnitude quake that rocked Kobe, Japan.

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"By building the components off-site, we can save time with construction on-site, minimizing interruptions in traffic and lowering construction costs," Sanders said. "In this case, the concrete columns and beams were pre-cast and tensioned at the University of Washington. Other components were built here at the University of Nevada, Reno. It took us only a month to build the bridge on-site, in what would otherwise be a lengthy process."

"This can't be done anywhere else in the nation, and perhaps the world," claimed Ian Buckle, director of the lab and professor of civil engineering, of the test. "Of course we've been doing these types of large-scale structure experiments for years, but it's exciting to have this first test using multiple tables in this building complete. It's good to see the equipment up and running successfully."

The university's earthquake simulation facility is managed as a national shared-use network for earthquake engineering simulation equipment site created and funded by the National Science Foundation to provide new earthquake engineering research testing capabilities for large structural systems. When combined with the university's Large-Scale Structures Laboratory, which is just steps away from the new lab, the facility comprises the biggest, most versatile large-scale structures, earthquake/seismic engineering facility in the U.S., according to the National Institute of Standards and Technology, and possibly the largest university-based facility of its kind in the world.

A grand opening was held recently for the $19 million lab expansion project. It was funded with $12.2 million by the U.S. Department of Commerce's National Institute of Standards and Technology, along with funds from the Department of Energy and university and donor investments, as well. The expansion allows a broader range of experiments, and there is additional space to add a fifth large-scale shake table.

"Our facility is unique worldwide and, combined with the excellence of our faculty and students, will allow us to make even greater contributions to the seismic safety of our state, the nation and the world," said Manos Maragakis, dean of the College of Engineering. "We will test new designs and materials that will improve our homes, hospitals, offices and highway systems. Remarkable research is carried on here. Getting to this point has taken a lot of hard work. It's both a culmination and a beginning, ushering in a new era."

Another element of this "new era" is the university's Tier 1 transportation research initiative, a federal University Transportation Center grant that will investigate seismic and other extreme load effects on prefabricated materials used in accelerated bridge

Right: Four ABC projects are currently in progress at the Reno facility. Through the aforementioned UTC grant, these projects will be expanded and integrated.

Far right: One of the focal points of this research project is to design bridge columns that can be disassembled and reassembled. Saiidi and his team are optimistic about the outcome.

construction (ABC)—a novel technique that allows quicker and more efficient new bridge construction or rebuilding of bridges after damaging earthquakes.

According to Saiid Saiidi, principal investigator for the university's UTC grant, "The world-class earthquake engineering laboratory here at the university allows us to investigate bridge seismic performance at a level that no other lab in the country can match."

With a budget of $750,000 over two years, Saiidi will work with fellow civil engineering professor Ahmad Itani, co-principal investigator at the university's center, and a group of postdoctoral students and research assistants. The ABC transportation center is led by Florida International University, which, along with Iowa State University, will study other aspects of the bridge technology.

Extreme engineering

The University of Nevada, Reno, is the only research center in the U.S. to specifically address the issue of extreme loading in ABC. Despite the tremendous advantages of the technology, such as increased safety, lowered costs and time-saving for the traveling public, it is not being applied in California, Nevada and other moderate and high seismic states due to a lack of research. Saiidi and his colleagues are changing that, one bridge at a time.

In June 2010, a 110-ft-long, four-span bridge model supported on piers incorporating glass and carbon fiber composite fabrics and tubes, precast columns, segmental columns and novel connections withstood strong shaking with only minor damage during shake-table testing at the university's large-scale structures lab. The model was built using ABC methods and was tested under simulated ground motions that were three times larger than the 1994 southern California earthquake at Northridge. Knowledge gained from that and previous research is being used in the current research projects.

Saiidi and a large number of doctoral research assistants have been investigating conventional and innovative ABC methods that have taken place over the past 10 years through multiple research grants from the National Science Foundation, the California Department of Transportation and the Nevada Department of Transportation, in an effort to remove the inherent hurdles that prevent widespread use of the technology.

Four ABC projects are currently in progress at the Reno facility. Through the aforementioned UTC grant, these projects will be expanded and integrated with the ultimate goal of widespread implementation of the technology in areas with high potential for seismic events, hurricanes and storms, among other hazards.

While the bridge experiment involving researchers from the University of Washington used no exotic materials and was intended to be both economical and not frightening to contractors, the next ABC bridge to be shaken by the Nevada engineers will use novel materials not originally intended for bridge construction.

Instead of conventional concrete, strand, rebar, grout and structural reinforcing steel, Saiidi and his team will use superelastic shape memory alloys combined with engineered cementitious composites (ECC) with special fibers. Saiidi's past research has demonstrated proof of concept when he used nickel-titanium bars instead of steel. In his latest exploration, Saiidi is investigating newly developed superelastic copper-aluminum-manganese alloy bars combined with ECC. These alloys are substantially cheaper than nickel-titanium alloys.

The new ABC bridge experiment, funded by the National Science Foundation Partnership for Innovation program, is now being built upon the shake tables. It includes three different column types using different materials and construction. The bridge is a two-span bridge model about 70 ft long. It will employ three shake tables, one for each support structure.

"We have several industry partners to help with the novel details," Saiidi said. Materials—including rubber components, shape memory alloys and ECC—are being sourced from disparate providers in New York, Japan, and locally in Nevada.

Several different combinations of the material in the lower sections of the six columns will be used with carbon composite wraps, steel alloy bars and different concrete mixtures to instill a variety of design.

Unlike conventional steel and concrete, which are prone to damage under high winds or earthquakes, these materials are damage-tolerant and can remain functional even after extreme events. Because segments of bridge columns are envisioned to be set in pieces, they have to be precast, meaning they can be built in a plant and transported to the bridge construction site for assembly in a relatively short period of time. This would shorten the construction time substantially and provide a new and potentially superior type of bridge for ABC.

"We'll be putting this bridge through very demanding motions, typical of a near-fault earthquake," Saiidi indicated. "Typically,

structures—bridges—will be pushed to one side or the other and stay in that position. With our columns and construction the bridge will return to its original position. We've tested the single columns already, with good results, so we have a pretty good idea that it will work in the large-scale testing."

The desired result is a bridge or overpass structure that not only is still standing after a large magnitude earthquake, but one that will remain straight and usable, with no lost chunks of concrete or buckled bars.

"Following a natural disaster, fire trucks, ambulances and other emergency-response vehicles are left in the cold, even if the structure doesn't collapse but is tilted or damaged too much," Saiidi said. "This technology allows a structure to remain in use, at least for emergency response, but also could be economical, not requiring costly and time-consuming repairs or complete replacement."

And while avoiding complete replacement is certainly a goal, Saiidi also suggests a solution for partial replacement of damaged components and is pursuing it with a new research project funded by the National Science Foundation that aims to build sustainable, resilient bridges. One of the focal points of this research project is to design bridge columns that can be disassembled and reassembled.

Saiidi and his team are optimistic about this pioneering project and its potential outcome.

"This is a totally new concept requiring extensive research and study to make it work," Saiidi said. "Various connections and details are being considered, including those in industrial facilities, and yes, even those used in furniture assembly." **R&B**

Wolterbeek is a communications officer at the University of Nevada, Reno.

For more information about this topic, check out the Bridge Rescue Channel at www.bridgerescue.com.