ABSORBING THE SHOCK

by Judith Wall
OU Public Affairs

A couple of curious professors have developed the technology that could earthquake-proof buildings and make highway bridges last longer.

photos by Dave Smeal

Like most scientific inquiry, a dramatic University of Oklahoma project that can protect buildings from earthquakes and bridges from wear and tear started with someone wondering *what if*?

The someone in this case is civil engineer Ronald Sack, who was intrigued by the way mechanical engineer Bill Patten had smoothed out the ride in a red '91 Corvette supplied by General Motors as a research vehicle.

Patten's research into hydraulics and semiactive systems had garnered more than $600,000 in GM grants, which has funded his efforts to make their vehicles—including Corvettes—more comfortable. The popular GM sports car may be spirited, but it has never been known for a smooth ride.

When GM asked Patten what he could do about the car's bumpy ride, he invented a new approach to shock absorption that he has been testing on the OU Corvette. Sensors on the car's front axle can "read" a bump in the road and tell shock absorbers on the back axle how much compensation is needed to adjust to it.

"I saw Bill driving down the street one day in that modified Corvette and got to thinking about those shock absorbers," says Sack, who is director of the OU School of Civil Engineering and Environmental Science.

What if, Sack found himself wondering, buildings and bridges were equipped with similar "smart" shock-absorbing systems? Could they save structures from the destructive force of a powerful earthquake? Could they help highway bridges adjust to the horrific pounding they receive from heavy traffic?

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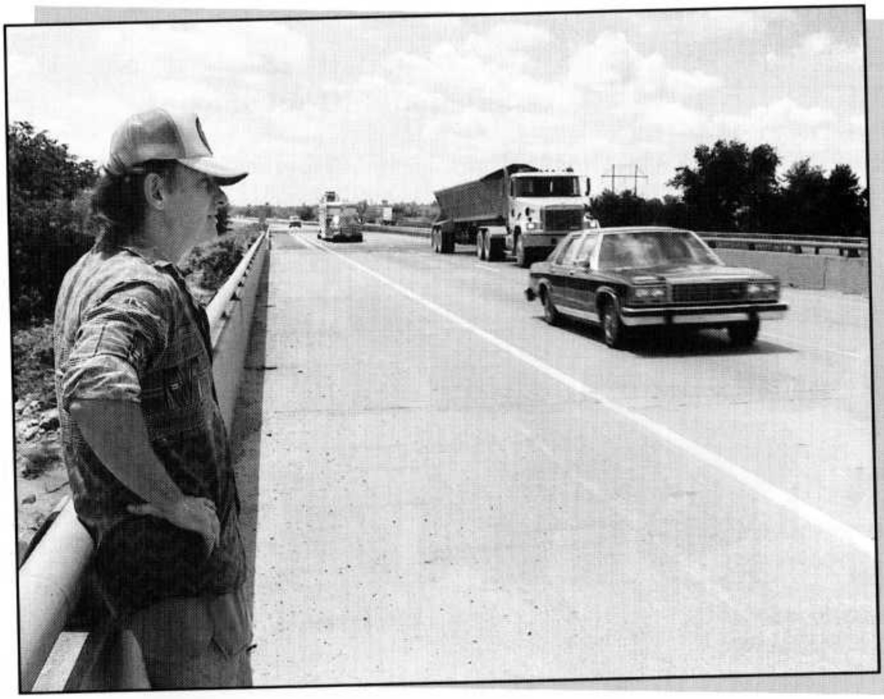


If I-35 through Oklahoma becomes the NAFTA corridor as expected, OU engineering professors Bill Patten, above at the Purcell test bridge, and Ronald Sack predict that their shock absorber technology can enable state bridges to handle the heavier trucks without jeopardizing their life span.

The two OU researchers are excited and confident they are onto something big.

Sack took his theory to Patten, who agreed it needed to be investigated, thus launching an interdisciplinary research collaboration that has captured the attention of government officials, including the Oklahoma Department of Transportation, and researchers around the world.

Sack and Patten, with funding from the National Science Foundation, created shock absorbers for buildings and bridges that can dissipate energy whether caused by earthquakes or 16-wheelers. They were assisted by numerous bright OU students and faculty colleagues in math and geology.

Of course, the devices they developed are larger and more complicated than the ones Patten installed on the Corvette. But the same principle that makes them work in vehicles applies to structures.

Sack and Patten's invention, called the "semiactive damper," has withstood rigorous testing on a 40-foot demonstration bridge on the University's south campus and in a multi-story, scaled-down laboratory structure that has come through unscathed during simulated earthquakes of varying intensities.

The key to the success of the new technology is the introduction of an automatically controlled valve in the otherwise generic hydraulic damper. The valve regulates the amount of force used to resist motion while dissipating the vibration energy of the structure.

The two OU researchers are excited and confident they are onto something big. "It's the most promising research I have seen in my years as a structural engineer," Sack says. While not alone in this area of research, the Oklahomans feel that their work has certain advantages over their competitors.

"Competing technologies being studied require electrical power," Sack points out. "And just look at what happened in the L.A. quake—electrical power was lost."

"And other technologies would be quite expensive and require considerable maintenance to keep them operational," Patten adds.

Some current research is looking at passive devices composed of springs and weights that would change the natural frequency of floors.

Typically, a large piece of concrete would be mounted on springs so that, as the floor moves, the mass reacts to the floor via the springs, the professors explain. But vibrations can be reduced at only one frequency, and an earthquake has a mix of frequencies.

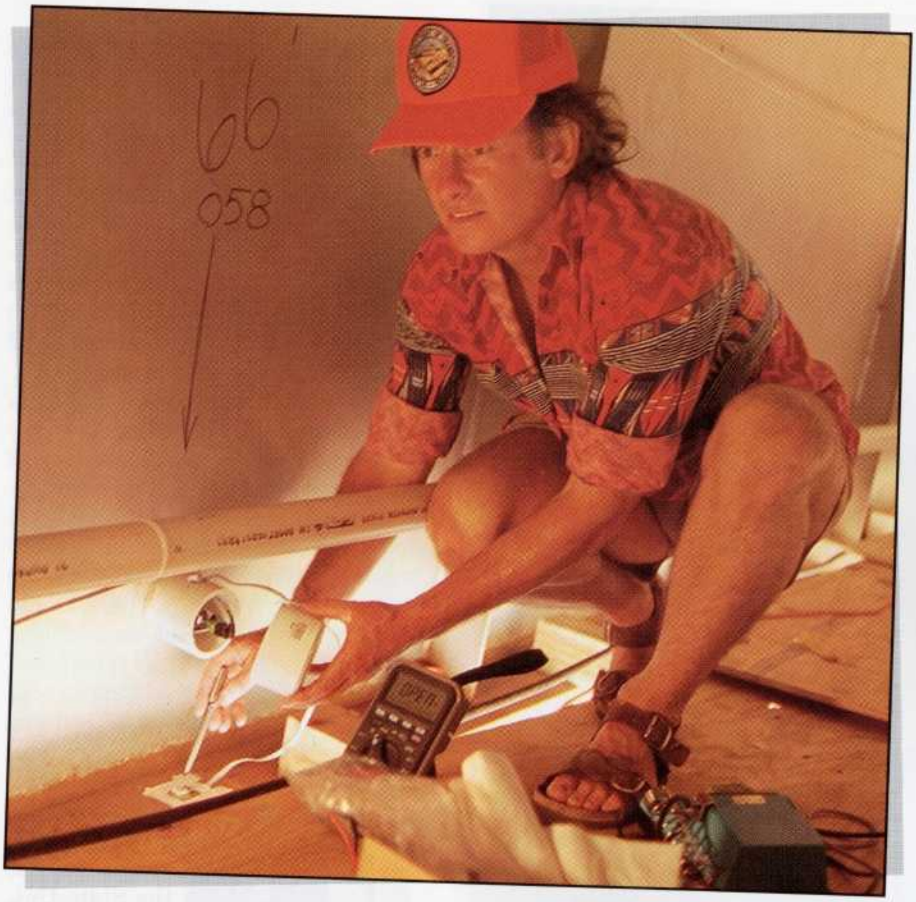
The OU approach is somewhere between active and passive.

"Our device pushes on the structure in a way that will dissipate energy from the building or bridge," Patten says.

On high-rise buildings, sensors in the buildings detect the dynamics of the earthquake system and make continual adjustments to hydraulic jacks that regulate the amount of tension needed to adjust X-braces installed in the walls. Only about .005 second is needed for the valve to adjust to the sensor's message—plenty of time to prepare for the quake.

The amount of energy required to change the valve in the hydraulic jacks can be contained in one penlight battery, and the system will cost only a fraction of other proposed systems.

An analytical assessment shows that the taller the building, the better the device works. But even in a three-story building, the device reduces relative motion by more than 60 percent.



Bill Patten goes under the I-35 test bridge near Purcell to check the accelerometer for electrical continuity.

OU engineers attach a motion sensor called an accelerometer to a bridge beam at the Purcell test site.

On the 40-foot test bridge, Sack and Patten have demonstrated a 70 percent displacement reduction—a feat that attracted a $300,000 grant from the Oklahoma Department of Transportation and the opportunity to use their invention in a real-life situation for the first time.

The two engineers and a team of students will manufacture and install semiactive vibration absorbers on the northbound-lane bridge beams of an I-35 bridge over Walnut Creek, near the Purcell exit. Since it might be years before devices installed on a building could be put to the test by an actual earthquake, the heavily used Walnut Creek bridge is an ideal demonstration structure.

The first time Sack and Patten took their students under the bridge and a semitrailer truck rolled over the 400-foot structure, the shaking and rolling were so extreme the students thought the bridge was about to collapse on them. While any highway bridge endures extreme punishment on a continuous basis, the Purcell bridge actually gets more than its fair share from trucks hauling crushed rock from a nearby quarry.

Sack and Patten are in the process of installing vibration absorbers on the bridge beams to reduce movement, as well as sensing instruments and a control system to "warn" the devices to adjust the stiffness and damping of the actuators in preparation for the approaching load.

"It will be an amazing demonstration!" Sack says.

Patten estimates the system will extend significantly the expected life of the Purcell bridge. He and Sack suggest installing the devices on state I-35 bridges in a staggered fashion so that all the aging structures do not need to be replaced at the same time—a situation that would place impossible demands on an already stretched state budget.

Bridges in Oklahoma and all over the country are subjected to much greater use than anticipated by their designers, the engineers point out. As a result, the bridges' lives are being shortened, and the country is facing an infrastructure crisis.

"The interstate highway system is especially problematic since so many of the bridges were built during the same decade and will need to be replaced about the same time," Sack adds.

"Once we have fine-tuned our system, it can be added to a bridge for a fraction of the cost of building a new bridge," Patten says.

The new technology also can affect the way new bridges are designed. The semiactive vibration absorbers require less material, making construction less costly. The addition of the system to an existing bridge also

International student engineers working under the bridge to pull wire through a conduit are, from left, L. Liu, C. Mo, Q. He and S. Sha.

Engineers Ronald Sack, left, and Bill Patten stand before the seismic shaker table discussing the schedule for the earthquake test facility.

will make it possible to increase the maximum legal weights for trucks that use the bridge, which should have a positive effect on inter- and intrastate commerce.

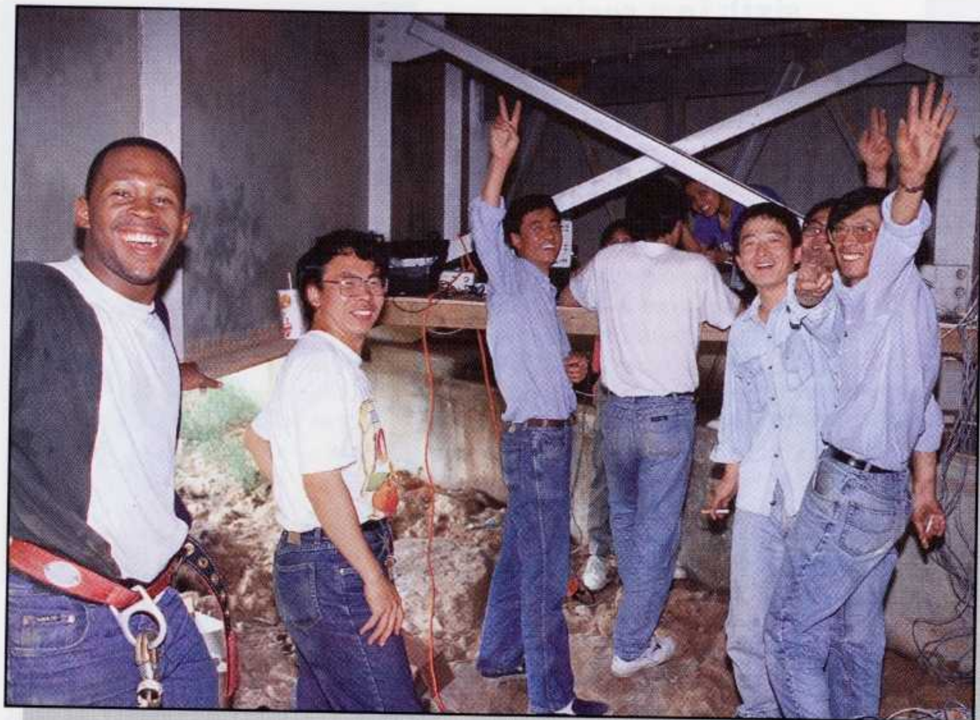
The bridge demonstration project will help the two OU researchers prove the effectiveness of their technology not only to the Oklahoma Transportation Department but also to those who construct buildings and bridges in earthquake-prone locales.

The next step for Sack and Patten is to convince the world that their way is the right way to earthquake-proof structures—and that will not be easy. Including the OU project, the National Science Foundation has funded 15 research projects that deal with the control of structures. The Oklahomans are relative Johnny-come-latelys to the field. They face the scrutiny of government officials and building-industry representatives and will be bucking vested interests in the scientific community.

The NSF earthquake center at the State University of New York in Buffalo, for example, has a different approach to outfitting structures to withstand earthquakes, Sack explains. SUNY scientists advocate hydraulic actuators with pumps that work against the force of the earthquake to push the building back in place—rather than adjust to the movement, as the OU researchers propose. However, unlike the OU technology, the SUNY system is quite expensive and requires electrical power.

Sack and Patten have been invited to present their research at national and international conferences. One country that has taken a great interest in the OU approach is Japan.

"The Japanese build stiff, stout buildings that withstand moderate earthquakes but can suffer damage in severe ones like the Kobe quake," Sack says.



Members of Patten and Sack's bridge team start under the test bridge to check the electronics that have been installed to "shock-proof" the structure.

The bridge demonstration project will help the two OU researchers prove the effectiveness of their technology.

OU engineering professor Bill Patten, left, and C. Mo, a graduate student from Korea, outfit themselves with blaze orange jackets and safety belts recommended by the Department of Transportation for their work at the bridge near Purcell.

"In this country, we construct buildings to absorb the energy by letting the materials bend," he continues. "This approach can save lives but frequently damages structural interiors. With this new technology, we're trying to let the buildings stay undamaged by dissipating all the energy with the semiactive vibration absorbers, which is a very different way of doing things."

If the bridge project is as successful as Sack and Patten expect it to be, they plan to commercialize the new technology and enhance the economy of Oklahoma with a new value-added engineering industry.

In the meantime, they continue to speculate.

"*What if*," Patten asks, "we could circle San Francisco with a ring of sensors five or seven kilometers out that would sense the oncoming earthquake and adjust all the structures in the city in anticipation of the punch that was coming?"