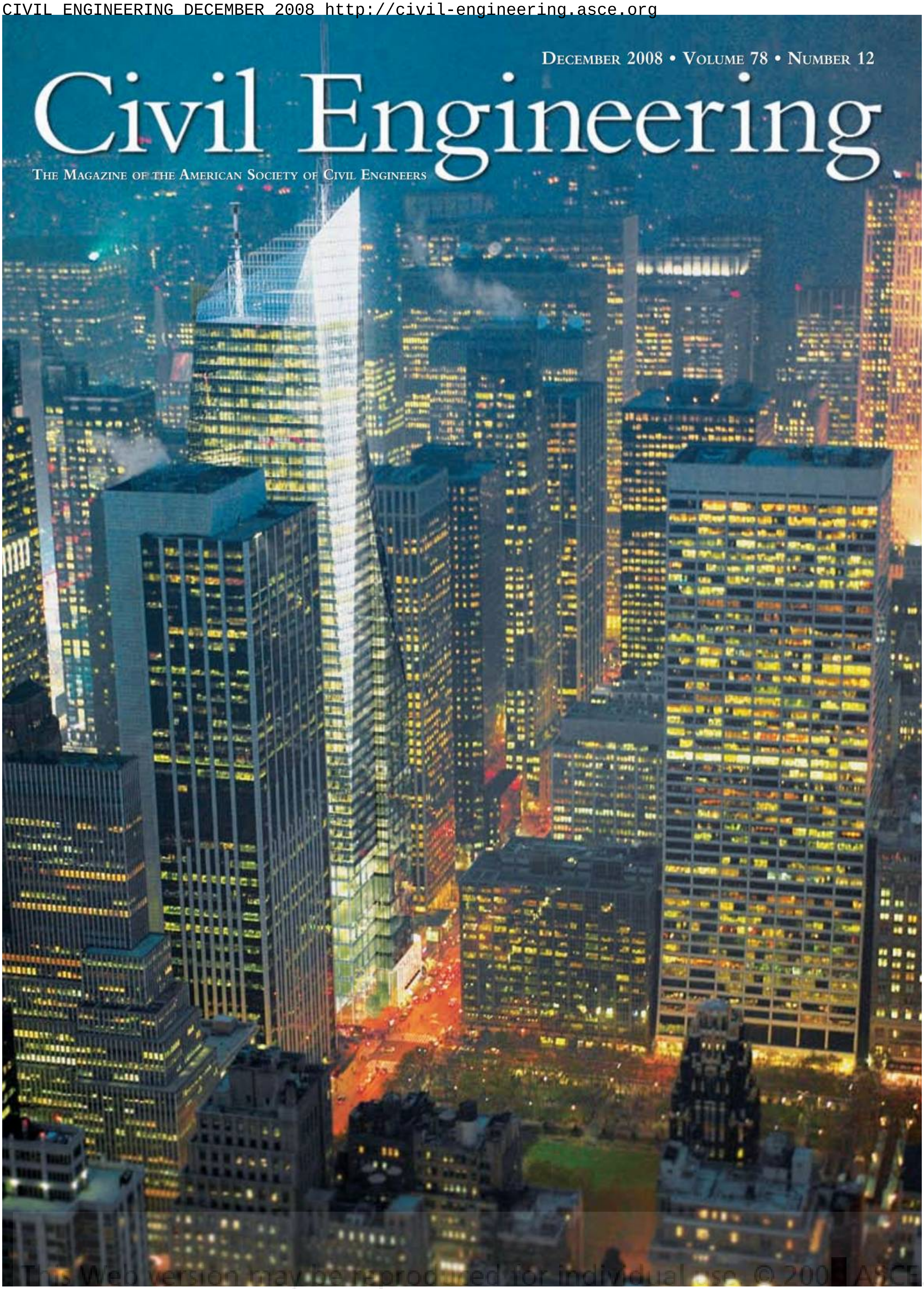
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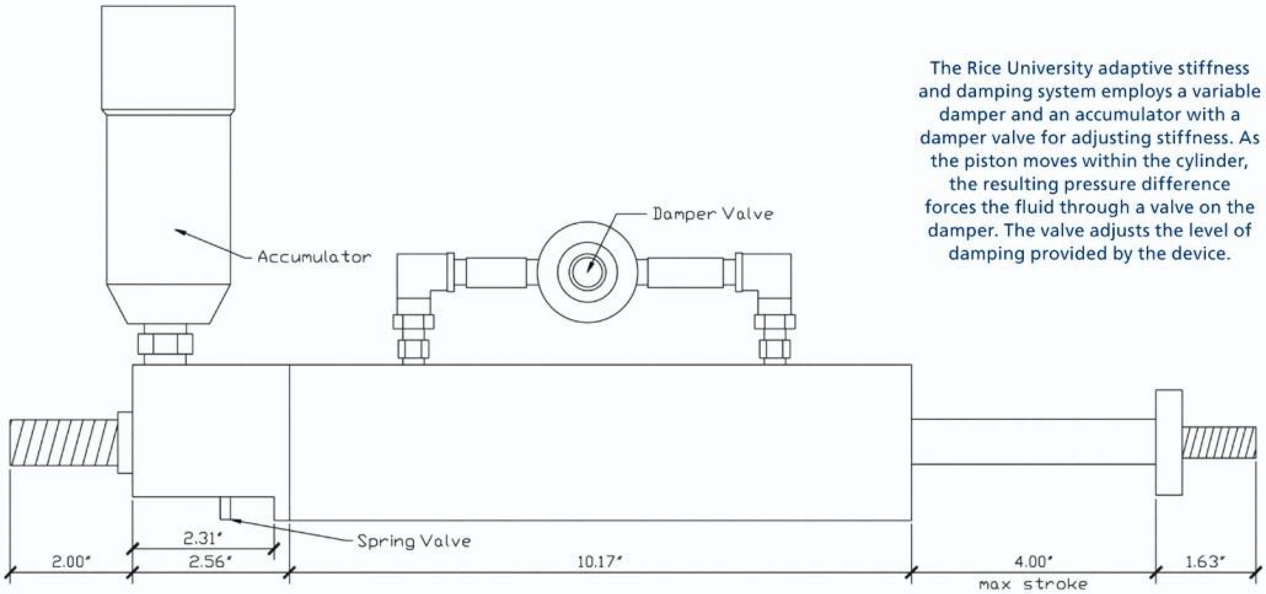


The Rice University adaptive stiffness and damping system employs a variable damper and an accumulator with a damper valve for adjusting stiffness. As the piston moves within the cylinder, the resulting pressure difference forces the fluid through a valve on the damper. The valve adjusts the level of damping provided by the device.

*Satish Nagarajaiah, Rice University, and Douglas Taylor, President, Taylor Devices*

## Researchers Seek To Develop Adaptive Seismic Protection Systems

Seeking to address a "significant gap" in existing devices that are designed to protect structures from seismic damage, a team of researchers from several institutions led by Rice University recently embarked on an effort to develop and test an adaptive stiffness and damping (ASD) system that would be capable of adjusting its performance in response to earthquake characteristics. In August the team received a $1.6-million research grant from the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES), which is overseen by the National Science Foundation (NSF). (See "A Concerted Effort," *Civil Engineering,* November 2004, pages 62–71.)

Existing systems for protecting structures from seismic damage are generally passive, meaning that they cannot adjust their performance. For example, typical supplemental damping systems that dissipate seismic energy in order to limit structural damage respond in the same way to every earthquake.

The vision informing the research effort—dubbed the NEESR Adapt–Struct project—is to develop a class of seismic protection devices that would be able to automatically adjust the level of damping or stiffness offered depending on the characteristics of a given earthquake, says Satish Nagarajaiah, Ph.D., M.ASCE, the principal investigator of the NSF-funded research and a professor in both the civil and environmental engineering department and the mechanical engineering and materials science department at Rice University.

The ASD system that the researchers aim to develop could afford greater seismic protection than passive systems in that it would offer the optimal levels of damping and stiffness for protecting a structure during a particular earthquake. "To date, adaptive stiffness systems have received relatively little attention as compared to supplemental damping systems and represent a significant gap in earthquake engineering," Nagarajaiah says.

Although a variable adaptive passive damper has been developed and successfully installed in Japan, the system there cannot adjust its performance with respect to stiffness, Nagarajaiah says. An ASD device would also differ from actively controlled systems, which are capable of monitoring and adjusting their performance based on external feedback and computer control, as well as from so-called semiactive damping systems, which use digital feedback from a computer to adjust fluid viscosity or other methods to alter the level of damping provided. Although such systems are useful, Nagarajaiah says, some structural engineers have questioned the necessity and reliability of feedback and computer control during strong earthquakes.

"The goal of the NEESR Adapt–Struct project is to mimic the behavior of actively and semiactively controlled devices by developing self-contained, adaptive passive stiffness and damping devices with internal hydraulic feedback but without the associated digital feedback and computer control," Nagarajaiah says. To achieve the desired internal hydraulic feedback, the ASD device will employ valves and orifices through which fluid will pass. Changes in hydraulic pressure within the device will modify its damping and stiffness performance.

The basic system to be tested by the researchers consists of a variable damper and an accumulator with a spring valve for adjusting the stiffness. As the piston moves within the cylinder, the resulting pressure difference forces the fluid through a bypass valve on the damper. In turn, the bypass valve adjusts the level of damping provided by the device. Meanwhile, fluid in the device provides stiffness when compressed, while opening the spring valve on the accumulator decreases the stiffness of the device. By introducing "internal hydraulic feedback loops in place of external valves," Nagarajaiah says, the researchers aim to create an adaptive system capable of adjusting its damping and stiffness characteristics automatically, thereby eliminating the need for external feedback or computer controls.

Physical testing of the ASD device will occur at the State University of New York at Buffalo's Structural Engineering and Earthquake Simulation Laboratory. The laboratory houses three earthquake simulators, or shake tables, as well as other equipment designed to simulate seismic conditions. A prototype version of the ASD device will undergo testing alone and as part of a structure, says Andrei Reinhorn, P.E., F.ASCE, the Clifford C. Furnas Professor of Structural Engineering at Buffalo. The structure with the ASD device incorporated within it will be tested on a shake table. At the completion of the testing, the research team hopes to have a finished ASD device that performs predictably, Reinhorn says, along with a computer program that can help structural engineers determine how to incorporate such devices in the structures they design.

The first shake table tests at Buffalo are expected to occur in early 2009. Until then, the researchers will be engaged in efforts to simulate the behavior of structures outfitted with ASD devices. The four-year research project will extend through 2012, and testing is scheduled to be conducted during each of the four years, followed by an analysis of the results. But it is likely that the initial results from the testing will be made public in two years, Nagarajaiah said.

In addition to Rice University and the State University of New York at Buffalo, the research team includes investigators from Rensselaer Polytechnic Institute; the University of California at Los Angeles; California State University at Fresno; and Taylor Devices, Inc., a maker of seismic protection systems headquartered in North Tonawanda, New York.

—*Jay Landers*

## Research Briefs

### UCSD Tests Concrete And Masonry Structure For Earthquake Effects

While the residents of Southern California participated in the largest earthquake preparedness drill in U.S. history—the Great Southern California ShakeOut, held on November 13—professors and students at the University of California at San Diego (UCSD) spent the day testing a three-story masonry-infilled, reinforced-concrete frame to determine how structures built with such frames will withstand earthquakes as large as the one that struck Loma Prieta, California, in 1989, and had a magnitude of 7.1. The many brick and concrete structures in the region dating from the 1920s are vulnerable to strong earthquakes, and the goal was to determine the most effective retrofit designs for such structures. A secondary objective was to refine and calibrate the UCSD's analytical models so that researchers can better determine the response of such structures to earthquakes of varying magnitudes. The researchers are collaborating with practicing engineers from around the country who specialize in seismic retrofits to determine the best way to protect such structures, which often are of historical importance and cannot be replaced, from moderate to strong earthquakes. The tests were performed at the UCSD's Englekirk Structural Engineering Center, which has the only outdoor shake table in the world.

— University of California at San Diego

### Department of Energy Funds Research On Wave Energy

In September the U.S. Department of Energy (DOE) awarded grants to the University of Washington and Oregon State University to establish what will be called the Northwest National Marine Renewable Energy Center. The research carried out there will explore ways of harnessing tidal and coastal wave energy in the Pacific Northwest. The grant will help the University of Washington study tidal energy in such estuaries as Puget Sound and will assist Oregon State University in its efforts to exploit coastal wave energy. The DOE has asked the center to elucidate the uses and limitations of wave-powered energy generation devices, provide information to guide regulatory and policy decisions, and assist in the commercialization of devices that are effective in using wave energy. The department is also funding a similar research center at the University of Hawaii, and one of its goals will be to assist the private sector in moving ocean thermal energy conversion systems beyond the proof-of-concept stage to long-term pilot testing.

—U.S. Department of Energy

### Computer Company To Develop Multiple Advanced Sensors

Hewlett-Packard Company, of Palo Alto, California, has announced that it will establish a "central nervous system for the earth," or CENSE, a group of sensors that could number in the trillions to monitor the environmental health of the planet and help warn of impending natural disasters. The sensors will mimic the five human senses but at much higher levels of sensitivity and will be able to detect chemical compositions, moisture levels, and the presence of bacteria or viruses, among other warning signs. The company expects its first customers for the sensors to come from the fields of energy and chemistry, but it hopes to expand those markets as the price of the sensors falls.

—BBC