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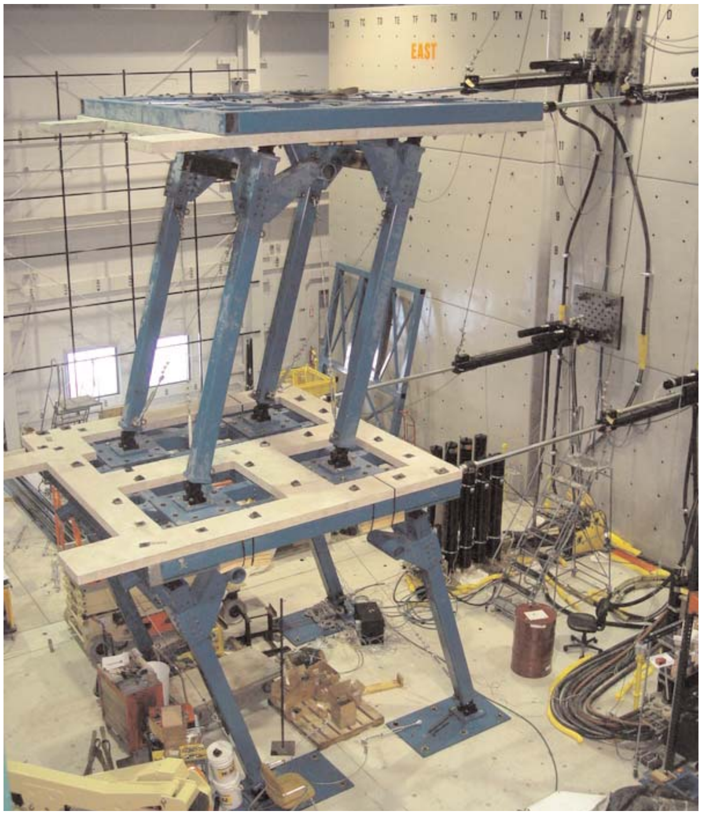
SeismicWaves

How the National Earthquake Hazards Reduction Program Is Advancing Earthquake Safety

Bringing Cutting-Edge Science to Nonstructural Mitigation

What images come to mind when you think of buildings damaged by earthquakes? Chances are, you see building exteriors with cracked or crumbled walls and collapsed floors or roofs. Perhaps because of the power required to produce it and the fears that it inspires, structural damage has long attracted the attention of photographers, the public, and earthquake engineers. Structural components—foundations, columns, beams, floors, load-bearing walls—are, after all, the elements that can hold buildings up or bring them crashing down.

Damage to other, nonstructural parts of buildings, including their contents, has garnered much less attention. The University at Buffalo (UB), part of the State University of New York, has taken a significant step toward changing that, however. With funding from the National Science Foundation (NSF, a NEHRP agency), the university has developed a first-of-its-kind seismic testing system, the Nonstructural Component Simulator (NCS), to make available state-of-the-art testing capabilities for nonstructural components and equipment.



The Nonstructural Component Simulator. Courtesy of SEESL

Structural versus Nonstructural Damage

This added attention to buildings' nonstructural side is justified. Although nonstructural damage may be less dramatic or threatening than structural failures, it nevertheless can be dangerous or even lethal to building occupants, and in terms of property damage and loss of use, can be even more costly than structural damage. A study partially funded by NSF through the Pacific Earthquake Engineering Research Center[1] found that nonstructural components and contents account for most of the costs of constructing and furnishing commercial buildings. According to the study, 82 percent of the money spent on office buildings is devoted to nonstructural components and contents, while just 18 percent is used for structural components. In hospitals, whose contents include expensive medical and laboratory equipment, nonstructural components and contents account for 92 percent of total investments in health care infrastructure.

The recent growth of performance-based earthquake engineering has further emphasized the contribution of nonstructural components to overall building performance. As the developers of the NCS have pointed out, "Even if the structural components of a building achieve an immediate occupancy performance level after a seismic event, failure of… [nonstructural] components… can lower the performance level of the entire building system."[2] This was illustrated in the Northridge earthquake of 1994 in California, when the Olive View Hospital of Sylmar, California, sustained no structural damage but still had to be evacuated due to breaks in sprinkler and chilled-water pipes.[3]

What Will Be Tested, and How?

The NCS has been designed to evaluate the seismic performance of nonstructural building components, which commonly

[1] Taghavi, S., Miranda, E. (2003). Response Assessment of Nonstructural Building Elements, *PEER Report 2003/05*, University of California Berkeley. http://peer.berkeley.edu/publications/peer_reports/reports_2003/reports_2003.html

[2] Mosqueda, G., Retamales, R., Keller, D., Filiatrault, A., Reinhorn, A. (2006). Experimental Evaluation of Nonstructural Components under Full-scale Floor Motions, *4th International Conference on Earthquake Engineering, Paper No. 301*, October 2006, Taipei, Taiwan. http://seesl.buffalo.edu/publications/

[3] United States Geological Survey (1996). USGS Response to an Urban Earthquake: Northridge '94, *Open-File Report 96-263*. http://pubs.usgs.gov/of/1996/ofr-96-0263/

include the following: (1) utility systems, such as heating, ventilating, and air conditioning systems, fire detection and suppression systems, plumbing, and other built-in mechanical and electrical components; (2) architectural elements, such as non-load-bearing walls, ceilings, windows, doors, and light fixtures; and (3) building contents brought in by or for occupants, such as furniture, cubicles, office equipment, storage cabinets, medical support systems, and other specialized equipment.

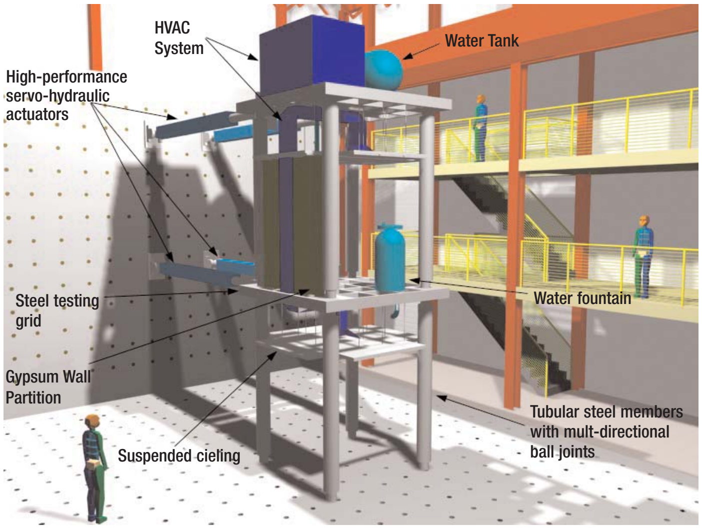


Illustration of the NCS with items to be tested. Reproduced from Mosqueda et al. (see footnote 2)

These and other nonstructural components can be attached to or placed in the NCS for full-scale seismic testing. The simulator consists of two raised platforms, each 3.8 meters square, built one atop the other to simulate two contiguous upper levels of a multi-story building. The platforms are attached to the laboratory's reaction wall through four powerful hydraulic actuators capable of pushing and pulling the platforms in ways that replicate how the upper floors of buildings move in real time during earthquakes. Vertical motions can be added by mounting the NCS on one of the laboratory's shake tables.

Typical rooms from hospital, office, or residential buildings—complete with partition walls, suspended ceilings, ductwork, piping, freestanding and anchored equipment, and other furnishings—can be set up on the NCS platforms and subjected to the floor motions generated by earthquake ground shaking. Movements in upper floors are typically much greater than those at ground level, which can be tested using conventional shake tables. The objectives are to understand and control the response of nonstructural components to the sudden accelerations and displacements (back-and-forth movements) produced by seismic waves magnified in buildings.

A Threshold of Understanding

The NCS is located in UB's Structural Engineering and Earthquake Simulation Laboratory (SEESL), which is the flagship laboratory of MCEER, a nationwide consortium of researchers supported in part by NSF. SEESL hosts one of 15 experimental facilities in NSF's George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). The NCS was developed principally through NEES funding from NSF (grant award CMMI-0429331).

UB researchers finished developing and testing the NCS in April 2007. This fall, the new simulator will be used for the first time to study the seismic fragility of medical equipment and the seismic performance of nonstructural partition walls. A fully equipped hospital emergency room will be assembled on the simulator, including walls typically found in hospitals and offices, and equipment critical to the continued operation of trauma services after an earthquake. Donated medical equipment has been secured through MCEER's partnership with the Pan American Health Organization (PAHO, the World Health Organization's regional office for the Americas), and the results of these experiments will be used to improve seismic guidelines in the United States and in the developing countries served by PAHO.

In inaugurating the NCS, this research will open the door to a new level of understanding about the seismic performance of nonstructural building components. UB will hold the Symposium on Seismic Regulations and Challenges for Protecting Building Equipment, Components & Operations on October 12, 2007, as part of the dedication activities for the NCS (see http://mceer.buffalo.edu/ for information). The NCS is also scheduled to be used to investigate the seismic performance of nonstructural ceiling-piping-partition systems in buildings. This research will be conducted by a multi-organizational and multidisciplinary team of researchers led by the University of Nevada, Reno, under a new 5-year project funded by NSF (grant award CMMI-0721399).

More information about the NCS, and videos of the simulator in motion, are available on the SEESL Web site at http://seesl.buffalo.edu/facilities/major_equipment/ncs.asp.