As earthquakes take their toll, engineers look at enhancing building designs

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Finley Charney is part of a team of engineers at Virginia Tech that is developing new structural systems that are geared to perform optimally during earthquakes. Credit: Virginia Tech Photo

A next generation of design criteria for buildings located in geographic regions where earthquakes are known to occur, either rarely or frequently, is under development at Virginia Tech through a research contract awarded by the National Institute of Standards and Technology (NIST).

Finley Charney, a structural engineering associate professor in the civil and environmental engineering department, and Mahendra Singh, the Preston Wade Professor of Engineering in the engineering science and mechanics department, are developing new structural systems that are geared to perform optimally during earthquakes. Singh's background is also in civil and structural engineering, and one area of his expertise is in earthquake engineering.

It's no secret that earthquakes come in all sizes with varying degrees of damage depending on the geographic locations where they occur. And even a small one on the Richter scale that strikes in an impoverished nation can be more damaging than a larger one that occurs in a city where all buildings have been designed to a stricter building code.

And to listen to Charney speak on the subject, attaining acceptable structural performance is a problem even when the current building codes are used as intended for the structural design.

"In my opinion, the current building codes are insufficient because buildings designed according to these codes have evolved only to avoid collapse under very large earthquakes. These same buildings, subjected to smaller, more frequent earthquakes, may have excessive damage, as happened during the 1994 Northridge, California earthquake. I tell my students that good performance for these buildings is not in their DNA," Charney said.

In the future, structural engineers will base their designs on the concepts of Performance Based Earthquake Engineering (PBEE), where the objective is to control damage and provide life-safety for any size of earthquake that might occur. Charney and Singh said they are developing a variety of new structural systems that "will inherently satisfy PBEE standards, yet have negligible damage when subjected to frequent earthquakes, acceptable damage from moderate earthquakes, and a low probability of collapse during the rare, severe earthquake." To achieve their goal, they are creating four new PBEE compliant systems called: hybrid yielding, standard augmented, advanced augmented, and collapse prevention systems.

Charney explained the hybrid yielding system is an improved configuration of an existing system. The key aspect of this enhanced system is that certain components in a structure are designed to yield sooner than what would occur in a traditional system, and other components are designed to yield later. By controlling the sequence of yielding, the dissipation of the seismic energy that comes with the early yielding should allow the structure to meet low-level and mid-level performance requirements, and the residual stiffness provided through delayed yielding will enhance life safety under larger earthquakes.

The standard augmented system will provide an enhanced performance because it utilizes devices called visco-elastic solid or viscous fluid dampers to help control vibrations. "The additional damping provided by these devices is intended to enhance a system's performance primarily at the mid-level limit states," Charney said.

The third system, the advanced augmented, uses the damping devices in conjunction with special metallic yielding devices. "Typically the combination of the devices is two-phased, with the yielding component only engaging after a certain deformation occurs in the damping component," Charney said.

He described the last system, the collapse prevention system, as "being analogous to an air bag in a car." This system is completely passive until it is needed. It is designed for use in situations where the damage associated with frequent or occasional earthquakes is negligible, but a total structural collapse cannot be tolerated.

The researchers said all four new designs have common features; they improve structural integrity by limiting residual deformations, controlling dynamic stability, and minimizing the uncertainty in predicting response.

To complete all of this work, Charney will develop a computer program that will automatically set up and execute all of the structural analysis required for assessing compliance with the next generation of PBEE. Potentially, he will be analyzing hundreds of thousands of mathematical models of buildings, using one of Virginia Tech's supercomputers. Charney and Singh have three Ph.D. and several master's students working on these projects. The project team is called VT-ACES, where ACES stands for Advanced Concepts in Earthquake-engineered Systems.

Charney is the author of Seismic Loads, a Guide to the Seismic Load Provisions of ASCE 7 published in 2010 by the American Society of Civil Engineers (ASCE). He is a regular seminar speaker for ASCE on the subject of earthquake engineering. In addition he has developed two educational earthquake engineering computer programs NONLIN and EQ-Tools. These programs, used worldwide, have been recently updated though a grant received from the Building Seismic Safety Council.

Provided by Virginia Tech