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TOPIC:

Ultimate Verification of Seismic Safety of Steel Building Structures in Japan, the United States, and Other Countries Around the World.

BACKGROUND:

- Steel is a very popular structural material in Japan and the U.S., comprising about 40% in the constructed floor area in Japan. Large, old steel buildings are very common throughout the urban areas of Japan and the U.S. These structures are highly vulnerable to damage in a moderate-to-large earthquake, since they were designed for inadequate seismic loads. It is important for the building engineering profession to offer cost-effective and workable technologies to retrofit the steel buildings that are considered highly vulnerable.
- The 1994 Northridge and 1995 Kobe earthquakes highlighted vulnerabilities in steel buildings - particularly in their welded beam-to-column connections. The past ten years of strenuous effort on upgrading the seismic performance of steel buildings have let to significant progress. Various innovative devices and systems have also been proposed by engineers in the US and Japan. They are believed to enhance the seismic capacity of steel buildings significantly. However, their performance has not yet to be verified at realistic scales and under realistic earthquake loads.
- The recent advancements in seismology reveal the possibility of seismic events that are significantly larger in the level of shaking than that considered in the contemporary seismic design practices. In such extreme events, the buildings properly designed according to the current seismic design practices are likely to sustain some level of damage. The degree of damage to be expected is a critical concern for society.

OBJECTIVE:

The best and ultimate means of addressing the concerns and issues raised above is to shake a real building fully equipped with sensors and to observe the response behavior in full detail. Here, a series of tests using full-scale steel building specimens is proposed. Specific objectives of the test are summarized as follows;

- To accumulate data on initiation, progress, and collapse of the conventional steel moment frames under various levels of ground shaking.
- To provide data useful for characterizing various limit states in the performance-based design format such as acceptable damage for continuing use, tolerable damage to maintain “quality of life”, and most importantly “collapse margin.”
- To provide benchmark information that serve for the calibration of the capacity of existing numerical analysis techniques to predict the nonlinear behavior of buildings up to collapse.
- To provide data on the interaction of various nonstructural components with the structural frame and the progression of damage to the components.
- To provide data on the effectiveness of retrofit techniques to upgrade the seismic capacity of existing steel moment frames.
- To provide data for detailed calibration on the degree of improvement of seismic capacity achieved by steel buildings featured with innovative devices and systems, by which stiffness, strength, and ductility are increased significantly compared to the conventional steel moment frames.
- To provide data for the verification of contemporary “health monitoring” technologies to detect damage and estimate the severity of damage.

PLAN:

A three-step approach is adopted in the test program. First, a full-scale four-story steel moment frame is designed and constructed following the present design and construction practices in Japan and the U.S. and tested on the E-defense shaking table. The frame follows a real steel building frame, including RC floor slabs and various nonstructural components such as exterior cladding, interior partitions, and typical building contents. The frame is also to be equipped with various sensors that are used for detection of damage during the shaking. The frame is subjected to various levels of ground shaking – low, moderate, large, and finally extreme. In the last stage of shaking, the tested frame is expected to "collapse." Second, the same frame is constructed again, but this time equipped with innovative devices and components. These might include fluid dampers, oil dampers, buckling-restrained braces, and low-yield steel dampers, modifications to the connection, shape-memory alloy dampers, among others. The frame is set on the E-defense shaking table, and the test is repeated for various levels of ground shaking, from small to large. Third and final, a steel frame having the same size as those of the previous two frames is designed as an innovative system, and shaken again for various levels of ground shaking, from small to large. A few alternatives including zipper-frame systems, buckling-restrained-brace system, knee-brace systems, rocking systems, and others, are adopted as the innovative system that ensures increased stiffness, strength, and ductility and improved performance under moderate-to-strong earthquakes.

IMPACT ON SCIENCE:

The following academic incentives are notable in the test;

- Enhancement of performance-based design particularly with respect to the characterization of critical limit states, including both structural but nonstructural components.
- Stimulation of further advancement of numerical analysis techniques for tracing the structural behavior involving strong nonlinearities, both material and geometrical, changes in topologies, and others.
- Incentives for developing much better alternatives for detail and global design and construction of steel moment frames.
- Identification of research targets for further advancement of health monitoring technologies

IMPACT ON SOCIETY:

The following outputs directly benefit society for its preparedness for future earthquake disasters.

- Quantifying collapse margin, i.e. limit state for ensuring life safety, of existing building stocks, which enhance the policy making for renewal of urban areas.
- Offering practical solutions for upgrading existing building structures for their seismic capacity and for designing and constructing much more seismic-resistant steel buildings.