A Retrofit Strategy for Framed Structures using Damage-Tolerant Cement-Based Composites

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In light of the lessons learned from past earthquakes and the advances in earthquake engineering, critical facilities such as hospitals are in need of conforming to current earthquake resistant design specifications. This is particularly true in California, where the California Senate has set a timeline within which all hospitals, existing and new, must not only remain standing following a "major" earthquake, but also be operational. The timeline, established in California Senate Bill 1953, requires that by 2008 all general acute care inpatient hospitals must remain standing following a major earthquake. Furthermore, a hospital's secondary systems (mechanical, plumbing, heating, electrical, etc.) must be adequate to enable patients to be transferred from the facility after the earthquake, if necessary. By 2030, hospitals must meet the more stringent criteria of remaining operational following a major earthquake. For many such facilities, retrofitting the structure poses a considerable problem in that the facility should be allowed to function while the retrofit strategy is being implemented. This need for continuing functionality motivates the necessity for a flexible and portable retrofit strategy that can be put in place with minimal disturbance to the facility.

The focus of this research is a proposed retrofit strategy for steel framed structures that can not only accommodate floor plans and secondary system layouts of the existing facility, but also possibly provide minimal disturbance to the function of the building during installation. The retrofit strategy is an infill panel system consisting of a series of precast panels that act as deep beams under lateral load within the frame. The panels are composed of a high performance, fiber-reinforced cementitious composite (HPFRCC) material that does not spall and exhibits fine multiple cracking leading to energy dissipation under cyclic loading.

Of particular interest in this work is the ability to simulate the behavior of a structure with the retrofit system in place. Reliable simulations not only provide information as to how well key structural elements will respond to seismic loads, but also allow us to predict interstory drifts and floor accelerations. The latter information can then be used to determine if important secondary systems will be damaged during an earthquake. In the current work, simple finite element models using beam elements have been investigated for simulating the hysteretic behavior of individual panels and compared to experimental results. An investigation of various modeling strategies for a single steel frame bay with the retrofit system in place has also been performed. Modeling a full bay with a plane stress continuum approach and with a 2D beam element approach showed minor differences in predicted response. It was found that there is a mesh dependency for the simple beam models for this application and that with incorporation of slip at the panel base connection, the simple models could predict the initial stiffness of the panels with reasonable accuracy. However without modeling bond-slip and reinforcement fracture, the peak strength and pinching of the hysteresis cannot be simulated with reasonable accuracy.

On-going research includes strain rate experiments on the HPFRCC material to determine if a rate-dependent finite element model is warranted. Finally, the behavior of a complete structure with the retrofit system in place will be investigated using a finite element analysis. The interstory drift and floor accelerations from this large scale structural analysis will be evaluated to indicate the effectiveness of the proposed retrofit system as well as predict the extent of damage to secondary systems in a building.