ABSTRACT

This study focuses on non-ductile reinforced concrete (RC) frames built outside current practices. These structures are quite vulnerable to collapse during earthquakes. One option to retrofit buildings with poorly detailed RC columns is to construct full-height masonry infill walls to provide additional means to resist loads caused by gravity and increase lateral stiffness resulting in a reduction in drift demand. On the other hand, infill can cause reductions in drift capacity that offset the benefits of reductions in demand. Given these two opposing effects, this investigation addresses the following question: are poorly detailed RC frames with masonry infill walls any safer than similar RC frames without infill walls?

To investigate the effects of infill on drift demand and drift capacity, two one-bay one-story reinforced concrete frames were built with minimal column shear reinforcement. The frames were tested on a unidirectional earthquake simulator. Ties in columns were spaced at a distance equal to the effective depth of columns ($s = d$) to represent details common in older construction. Each specimen was subjected to simulated earthquakes in four series of tests including configurations of frames with infill walls and configurations without infill. External confinement consisting of post-tensioned clamping devices were installed on columns in some tests of bare frames and infilled frames. These devices present an additional option to retrofit buildings by increasing drift capacities of flexural elements. The advantages of both retrofit options - infill walls and clamping devices - are that each can be built, fabricated, and installed with minimal expertise using readily available and inexpensive materials and tools. In total, five different configurations of frames were tested in this investigation:

- Bare frame
- Frame with infill
- Frame with column external transverse reinforcement (clamps)
- Frame with infill and clamps
- Frame with infill and clamps tested at 90 degrees to direction of motion (out-of-plane)

In this investigation and one other (Lee, 2002), it was observed that infilled frames drifted no more than one-third the amount that similar frames without infill drifted when both were subjected to

nominally identical simulated ground motions. Drift capacities of bare frames and infilled frames were not reached in tests conducted in this investigation because of the limits of the earthquake simulator. Nevertheless, wide inclined cracks associated with the onset of shear failure were observed in tests of bare frames and infilled frames without external confinement. Inclined cracks formed in columns of the bare frame in less intense simulations compared with simulations causing inclined cracks in columns of the infilled frame.

In other investigations of non-ductile bare frames and infilled frames, drift capacities of infilled frames were no less than half the drift capacities of bare frames when the latter was not larger than 4% (that is when the latter referred to relatively vulnerable frames). Experimental evidence of drift demands and drift capacities of bare frames with columns with minimal transverse reinforcement suggests that an infilled frame with a 50% reduction in drift capacity is safer than the associated bare frame (assuming the infilled frame drifts one-third the amount of the bare frame) because the capacity of the system without infill is reached before the capacity of the infilled system is reached if the ratio of infilled frame strength to bare frame strength is smaller than 7.

An infill wall ratio defined as the ratio of cross-sectional area of masonry infill wall in one direction on ground floor to total floor area was useful in organizing the extent of structural damage observed in buildings surveyed after major earthquakes. Projections of the data obtained from the mentioned surveys suggest that if a school building has an infill wall ratio of at least 0.5% in both directions, the likelihood of severe damage decreases by a factor of 3. An infill wall ratio of 0.5% represents modest amounts of infill as ratios larger than 0.5% were observed to be common in surveyed buildings.

Because the nature of future earthquakes is anything but known and the protection of children in school buildings is nothing short of essential, it is recommended to construct additional full-height infill walls in any direction quantified to have an infill wall ratio less than 1%. Using a lower-bound approximation, an infilled frame with an infill wall ratio of 1% is safer than the associated bare frame without infill and the peak story drift of said infilled frame subjected to a base motion with a peak base velocity of 15 in./sec. (40 cm/sec.) was estimated to be no larger than 1% while the peak story drift of the associated bare frame without infill was estimated to drift to approximately 3%.