Seismic Performance of Non-Ductile RC Frames with Brick Infill

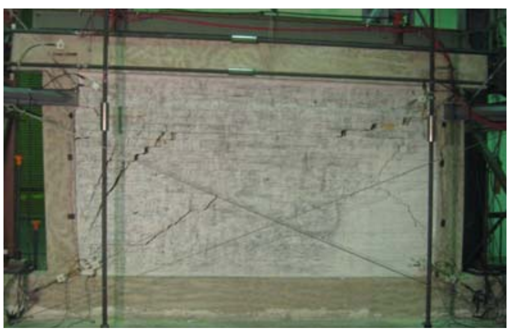
P. Benson Shing, Andreas Stavridis, and Ioannis M. Koutromanos
Department of Structural Engineering
University of California, San Diego

Kaspar Willam and Ben Blackard
Department of Civil, Environmental, and Architectural Engineering
University of Colorado, Boulder

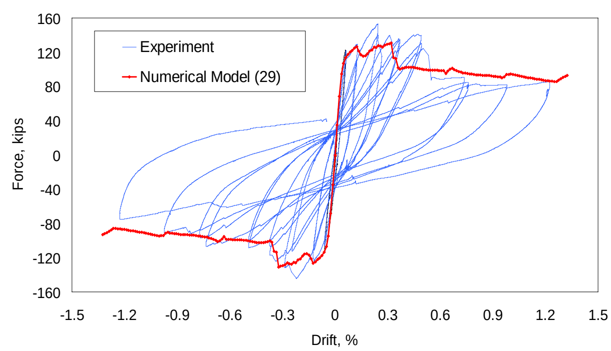
Many reinforced concrete (RC) and steel frame structures have unreinforced masonry infill walls to serve as interior and exterior partitions. Such construction can be found in older buildings in the western United States, such as pre-1930 RC buildings in California, and in many newer buildings in the midwestern and eastern parts of the country. In fact, RC frames with brick infill are common construction practice in many parts of the world, such as China and Mediterranean countries. However, even though unreinforced masonry infill walls are often treated as non-structural components, they will interact with the bounding frames when subjected to earthquake loads. The beneficial influence of infill walls in protecting a structure against earthquake loads has been recognized by many engineers. Nevertheless, they were associated with catastrophic failures and undesired soft-story mechanisms of RC structures in a number of severe earthquake events. These failures were mostly caused by the poor quality of the structural systems, inferior infill materials, or the absence of infill walls in some critical locations such as open first stories. The assessment of the seismic resistance of these structures presents a major challenge. The interaction of an RC frame with masonry infill can result in a number of possible failure mechanisms including the cracking and crushing of the infill walls and the shear failure of the columns. The lateral load resistance of an infilled frame depends very much on the failure mechanism that develops. Currently, the simplified assessment methods for infilled frames provided in *Seismic Rehabilitation of Existing Buildings* (ACSE 7-06) are far from complete. Even though the document allows the use of nonlinear finite element models, it provides no guidelines for such analysis.

This paper will present an overview of a research project supported by the Network for Earthquake Engineering Simulation Program of NSF focusing on the assessment and improvement of the seismic performance of masonry-infilled non-ductile RC frames, and some research findings based on the results of the large-scale table tests conducted on a three-story, two-bay frame structure and nonlinear finite element analysis. The project is a collaborative effort among the University of California at San Diego, Stanford University, and the University of Colorado at Boulder. The design of the shake table specimen is shown in Figure 1. It had a non-ductile RC frame that reflects a 1920's design for California. In the shake table tests, the structure survived a ground motion equivalent to the maximum considered earthquake for Seismic Design Category D without collapse and sustained light damage with the design basis earthquake. Nonlinear finite element analyses have been conducted with the test structure as well as with single-story, single-bay frames tested quasi-statically at the University of Colorado. Good correlations have been obtained between the numerical and experimental results as shown in Figure 2. The results of the quasi-static and shake-table tests will be compared. The finite element models and model calibration procedure will also be described.

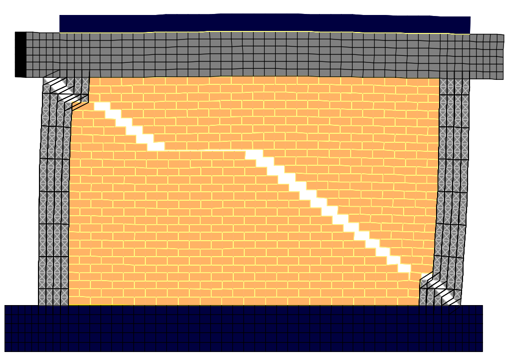
Figure 1 – 2/3-Scale Frame Tested on Shake Table



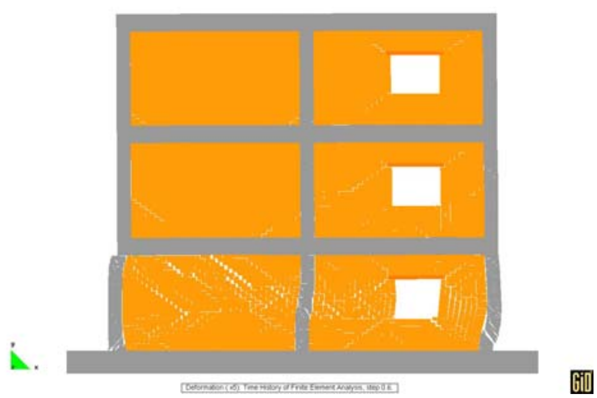
Single-Story Frame Test



Hysteresis Curves from Single-Story Frame Test



Finite Element Model of Single-Story Frame



Finite Element Model of Shake-Table Specimen

Figure 2 – Test and Analysis Results