# Seismic Response of an Existing Reinforced Concrete Building

by
Bugra Barin, Devanshu Kant, Olga Reyes and José A. Pincheira
Department of Civil and Environmental Engineering
University of Wisconsin - Madison

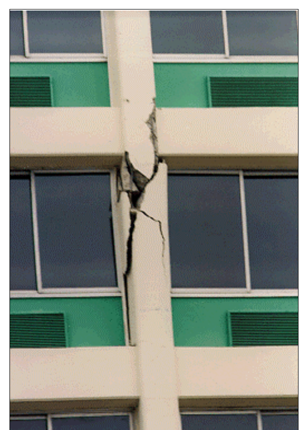
Older reinforced concrete buildings (those built prior to the 1970s) have performed poorly in recent earthquakes (1994 Northridge earthquake in California and 1995 Hyogo-Ken Nabu earthquake in Japan). Past research has shown that these types of buildings often lack adequate strength and ductility to withstand the forces and displacements imposed by strong earthquakes. For example, the columns in older buildings are often susceptible to brittle failures which can cause the partial or total collapse of the structure. Engineers are then faced with the decision to either improve the seismic resistance of the building in anticipation of future events or tear down the existing structure and construct a new building. To make such a decision, a detailed evaluation of the deficiencies of the building using realistic and validated behavioral models must be conducted.

The main purpose of this study was to evaluate current analysis procedures and to develop improved models for the seismic evaluation of older reinforced concrete frame buildings (frame buildings are designed to resist seismic forces using beams and columns, but without walls). This objective was accomplished through the development and validation of realistic behavioral models, parametric studies of modeling parameters, and by comparing the measured seismic response of an existing reinforced concrete building with that calculated from analyses.

Overall view of the building studied.

In the first phase of the project, behavioral models that simulate the seismic response of older reinforced concrete beams and columns were developed and validated using experimental data. Specifically, this was done by comparing the response of building columns tested in the laboratory with that computed from the model.

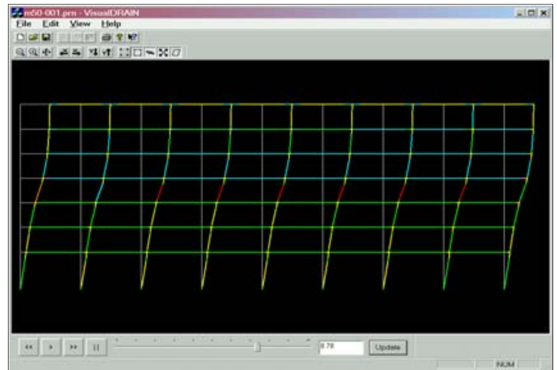
In a second component of this study, the seismic response of an existing building was calculated and compared with its measured response. The building studied was a seven-story reinforced concrete frame constructed in 1966 that had been struck by the 1994 Northridge earthquake. An overall view of the building studied and the shear failures (characterized by diagonal cracks) observed in several fourth story columns are shown in the enclosed figures. The movement of the building during the earthquake was measured by sixteen sensors located on several floors, which provided a unique opportunity to compare the calculated and measured response for an existing building. Using the behavioral models developed in the first phase, the behavior and performance of the building during the Northridge earthquake was calculated for a range of plausible response parameters. The results showed very good agreement between the measured and calculated responses, although there was not a perfect match at every instant of the response. A perfect match between the computed and measured responses is impossible since not all of the variables that affect the behavior of the structure can be modeled with certainty at this time. In practice, however, engineers are primarily concerned with estimating the maximum response of the building. From this point of view, the results showed that the model and analysis procedure used in this study provide a very good estimate of the maximum expected displacement of the building, as the maximum measured displacement at the roof was calculated within ten percent of the measured value.



Typical damage in the fourth story columns.

To assist in the interpretation of the analysis results, a graphics interface was developed to visualize the deformations and damage imposed on the building when subjected to an earthquake. The tool allows the display of the movement of the building, in real time or step-by-step for detailed analysis, as the building is shaken by an earthquake (see attached figure). In the figure, lateral displacements have been amplified 20 times their actual value for clarity. Also, beams and columns have been color coded to illustrate different levels of damage. It may be seen, for example, that seven columns in the fourth story are shown in red to illustrate that they have suffered substantial damage due to high shear forces, a result that is in close agreement with the observed damage for the building during the actual earthquake.

The models and computer tools developed in this project will allow engineers to obtain more realistic estimates of the likely response of older reinforced concrete buildings and to improve their decision-making process for the selection of optimal rehabilitation alternatives. Seismic rehabilitation, however, is not mandatory in the U.S. (except for schools and hospitals). Thus, when a decision is made to upgrade a structure, the type and extent of the upgrading depend on the needs and available budget from the client. The tools developed in the project are rather sophisticated and although some consulting firms have occasionally used these tools, they do not use them on an everyday basis. Few consulting firms can afford the additional training required to use these tools, except in special projects. In time, however, it may be expected that they will be used on a regular basis.



Visualization of the deformed shape of the building during the 1994 Northridge earthquake.