Final Project Summary — PEER Lifelines Program

Project Title—**ID Number**	*Development of Improved Methodology for Buildings w/ Rigid Walls & Flexible Diaphragms*—**504**		
Start/End Dates	5/1/00 – 1/31/03	Budget/ Funding Source	$129,991 / PG&E/CEC
Project Leader (boldface) and Other Team Members	**Anderson (USC)**		

1. Project goals and objectives

The goals of this research are to develop improved practical analysis procedures for evaluating the seismic performance of low rise buildings with rigid walls and flexible diaphragms and to use these procedures to evaluate current seismic design provisions. Representative of this type of building system are one story buildings with concrete tilt-up walls and low rise buildings with reinforced masonry walls.

2. Benefits of the results of this project to develop technologies and protocols to mitigate the vulnerability of electric systems and other lifelines to damage directly and indirectly caused by earthquakes. Also, benefits to develop assessment techniques to evaluate damage to electric systems caused by earthquakes and to assess fiscal impacts due to the loss of electric service to the community.

Analysis and modeling techniques have been developed for commercial computer programs that can be used by engineering offices to better design new buildings and to better evaluate the seismic performance of existing buildings and indicate areas of structural weakness. Areas where modifications to current building lateral force requirements could be made to improve building performance are identified.

3. Brief description of the accomplishments of the project

Comparison of the recorded response at all instrument locations shows good correlation with the time history response calculated using the computer models and the idealizations discussed. In general, the responses of all three buildings were either less than or near the minimum lateral force requirements of the Uniform Building Code ’97. therefore, the behavior was primarily linear elastic with on some limited cracking of the concrete. This was verified by site visits to the three buildings. However, using acceleration records of near fault earthquakes indicate force values that far exceed minimum code requirements and suggest significant inelastic behavior. It was also noted that the criteria currently used by building codes to classify diaphragms as rigid or flexible contains considerable uncertainty. Significant differences were observed between the use of static or dynamic loading.

Connection details used prior to the San Fernando earthquake (1971) are referred to as “old” connections whereas connection details used in the late 1970’s and beyond are referred to as “new” connections. The results of this study confirm that the “old” connections are not adequate for the stronger earthquake ground motions. The “new” connections offer a significant improvement, particularly when used in combination with a strengthened diaphragm that remains elastic. When “new” connections are used with existing diaphragms having dense nailing, ductility demands in the connection and diaphragm are not excessive. Sparse nailing of the diaphragm results in performance that is not adequate.

4. Describe any instances where you are aware that your results have been used in industry
None identified to date.

5. Methodology employed
In order to evaluate the accuracy of the analytical models, three instrumented buildings (one tilt-up and two masonry) were selected for detailed study. Detailed three dimensional finite element models were developed for use with the SAP2000 and ETABS computer programs. Following verification of the models for the recorded earthquake motions the effect of stronger, pulse-type ground motions was evaluated. For the tilt-up building, available nonlinear elements were used to evaluate the push-over behavior and the nonlinear seismic response. Within the limitations of the experimental data base, the effect of vertical accelerations on the long span roof of the tilt-up was estimated.

6. Other related work conducted within and/or outside PEER
Tokoro, K. A. T. (2002), "Seismic Performance of Two Instrumented Masonry Buildings," Thesis presented to the University of Southern California in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering

7. Recommendations for the future work: what do you think should be done next?
Only a limited amount of full scale testing has been conducted on building components including the critical floor and roof diaphragms and the connections of these elements to the rigid walls. Connections have not been tested under the multiaxial loading experienced in the actual building. A detailed consideration of the performance of tilt-up walls without pilasters was beyond the scope of this investigation. This construction procedure which is representative of current practice need to be investigated. Results of this study have shown that inelastic behavior of the various elements of the building are very important for building performance. These aspects need to be investigated more thoroughly when test data becomes available.

8. Author(s), Title, and Date for the final report for this project
Tokoro, K. A. T., Anderson, J. C., and Bertero, V.V. (2004), "Seismic Performance of Masonry Buildings and Design Implications," PEER Report 2004/01.

Anderson, J. C. and Bertero, V.V. (2004), "Seismic Performance of an Instrumented Tilt-up Wall Building," PEER Report 2004/04, In Review.