Final Project Summary — PEER Lifelines Program

Project Title—**ID Number**	*Evaluation and Application of Concrete Tilt-up Assessment Methodologies*—**509**		
Start/End Dates	4/1/03 – 6/30/04	Budget/ Funding Source	$68,130 / PG&E/CEC
Project Leader (boldface) and Other Team Members	**Malley (Degenkolb Engineers)**		

1. Project goals and objectives

Task 1

The goal of Task 1 is to provide input to existing codes (e.g. International Building Code) and guidelines (e.g. FEMA 356) that will improve the seismic design and assessment methodologies of concrete tilt-up and other low-rise, rigid-wall, flexible diaphragm buildings. The input will be based on research findings and results of previous (PEER) research projects on concrete tilt-up buildings. These research projects are: 1) *Seismic Response of Tilt-up Buildings* by John F. Hall; 2) *Modeling and Evaluation of Tilt-up and Steel Reinforced Concrete Buildings* by John W. Wallace; 3) *Stiffness of Timber Diaphragms and Strength of Timber Connections* by Gerard C. Pardoen; and 4) *Improved Methodology for Evaluating the Seismic Resistance of Low Rise Buildings with Flexible Diaphragms* by Jim Anderson.

Task 2

As practicing structural engineers, we will apply the building assessment methodology developed in PEER Task 507*, Advanced Seismic Assessment Guidelines* by C. Allin Cornell, Paolo Bazzurro, Charles Menun, Maziar Motahari, to a concrete tilt-up building in the Pacific Gas & Electric (PG&E) building inventory. The selected building is the PG&E Fremont Materials Distribution Center that Degenkolb Engineers has previously designed seismic upgrades for.

The objectives are to: 1) identify potential difficulties that Structural Engineers would encounter in using the procedure described in the *Advanced Seismic Assessment Guidelines*; 2) recommend possible revisions to the procedure to address any identified difficulties; and 3) identify and make recommendations on other issues related to assessing the seismic reliability of utility structures and systems.

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.

Predicting the post-earthquake functionality of utility structures is a crucial step in evaluating the likelihood that the PG&E power distribution network will not be able to provide power to customers. The final product of the guidelines is a set of fragility curves for structural limit states directly related to post-earthquake building occupancy status; namely green, yellow, or red tags.

The project is a key step in investigating the practical application and potential of performance-based seismic assessment methods. As such, the project will lead to the wider application of seismic and structural engineering procedures that use these state-of-the-art techniques.

3. Brief description of the accomplishments of the project

Task 1

Each of the four reports was reviewed and summarized. The data from the reports was evaluated to test the validity of design procedures and see what changes, if any, could be made to current design methodologies. Each report raised questions regarding assumptions and procedures in the research process, and the questions are presented for the authors. The reports also illuminated ideas for further research in the area of tilt-up building construction. From the four reports evaluated, some suggestions are presented for changes in design. However, no major changes to the current codes and guidelines were recommended due to this review.

Task 2

A 2D Static Pushover Analysis was performed on the roof diaphragm of the selected building for the intact structure. The analysis confirmed that a plywood roof diaphragm could be modeled using truss elements and that the results obtained would be comparable to those predicted using FEMA 356. Further application of the guidelines yielded Incremental Dynamic Analyses curves, the residual dynamic capacity and the occupancy status of the structure in each damage state, and a set of fragility curves. The authors confirmed the successful application of the guidelines. At the same time, difficulties associated with using the Guidelines and possible clarifications were identified.

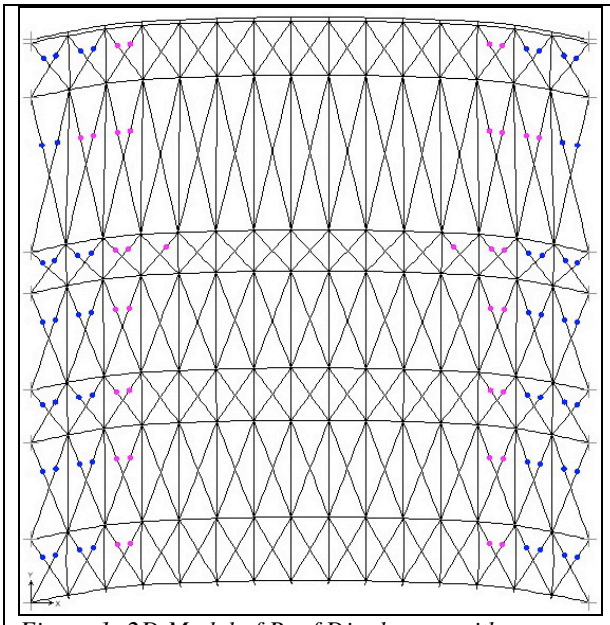

Figure 1: 2D Model of Roof Diaphragm with Diaphragm Represented by Axial Elements with Nonlinear Hinges

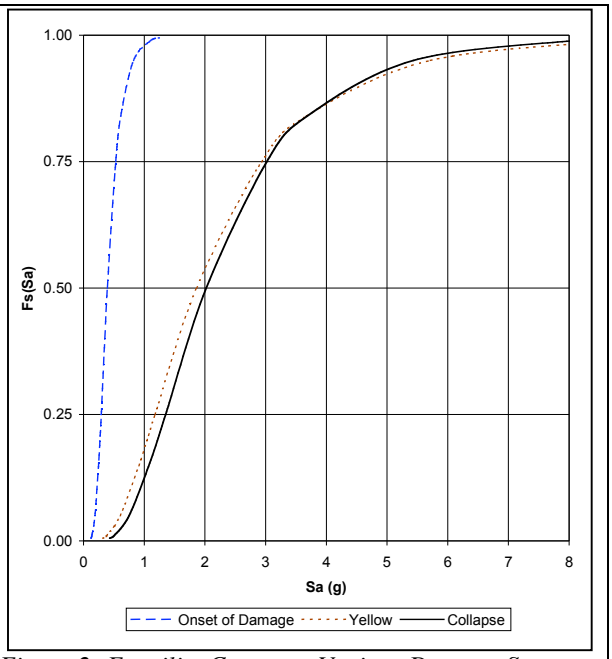

Figure 2: Fragility Curves at Various Damage States

4. Describe any instances where you are aware that your results have been used in industry

None to date.

5. Methodology employed

The Nonlinear Static Procedure (NSP) is performed on the structure using SAP 2000, commercially available software frequently used by practicing structural engineers.

Incremental Dynamic Analysis (IDA) is performed using the SPO2IDA spreadsheet tool developed by Vamvatsikos and Cornell.

6. Other related work conducted within and/or outside PEER

Within PEER, this project is integrally related to Task 507, the development of the Advanced Seismic Assessment Guidelines. Task 508 is similar to Task 2 of this project in its investigation of the use of the guidelines, in which a steel moment frame building was studied. This project applies the guidelines to a different type of construction, a concrete tilt-up building with a flexible diaphragm.

The reports reviewed in Task 1 were PEER projects concerned with experimental and analytical studies of concrete tilt-up buildings. This project seeks to summarize these studies and to make further recommendations for research as well as practice.

Outside PEER, two other related documents include: 1) *Guidelines for Seismic Evaluation and Rehabilitation of Tilt-up Buildings and other Rigid Wall/Flexible Diaphragm Structures* by the Structural Engineers Association of Northern California; and 2) *FEMA 356, Prestandard and Commentary for the Seismic Rehabilitation of Buildings*. These documents have not fully incorporated all of the findings from the previous PEER studies. Also, the application of the guidelines offers an advanced tool for the post-earthquake assessment of tilt-up buildings that has never been used in practice.

7. Recommendations for the future work: what do you think should be done next?

Research recommendations for tilt-up building construction include further research suggestions for the authors of the reports reviewed, and research not specific to any of the reports. Suggestions for research for the authors of the reports range from studying the anchorage forces along the short side of the building versus the long side, rerunning analysis done in the reports using the current building code, FEMA 356 values, or updated data, and more laboratory testing of tilt-up building components. Suggestions for other areas of research include instrumentation of more tilt-up buildings, studies of connection improvement in existing tilt-ups, better period estimation, additional and better documentation of damage in tilt-ups, investigating the strength of connections in cross grain ledger bending, and estimating the amplification of forces at pilasters.

Additional application of the Advanced Seismic Assessment Guidelines by practicing structural engineers is also recommended. This would provide additional input to the authors with regards to the ease or difficulties of using the guidelines.

8. <u>Author(s), Title, and Date</u> for the final report for this project

Tim Graf and Jim Malley, Evaluation and Application of Concrete Tilt-Up Assessment Methodologies, May 27, 2004
Jack Hsueh and Jim Malley, Application of Advanced Seismic Assessment Guidelines, August 15, 2004