SEISMIC PERFORMANCE OF AN EXISTING TALL STEEL BUILDING

PEER Internship Program – Summer 2013

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Project Overview

Pre-Northridge steel moment resisting frame (MRF) buildings were analyzed because advances in seismic analysis and design since their construction combined with uncertain connection response led to uncertainty in their seismic performance. The approach used in this assessment consisted of a PBEE methodology. The focus on this aspect of the project was the structural analysis phase.

Background

Existing Tall Buildings

There is a large number of tall buildings in San Francisco (Figure 1). Limited requirements address the complex dynamic behavior of existing buildings. U.S. design guidelines are intended for low to mid-rise structures.

Figure 1: Tall Buildings in San Francisco

Historic Building Codes

No seismic requirements for tall buildings prior to the 1970s. No drift limits for seismic loads prior to 1976.

Northridge Earthquake

Potential brittle moment connections (Figure 2).

Figure 2: Beam-column connection in a MRF during 1994 Northridge Earthquake
Photo taken from EERI

Objective

To select an existing building, analyze its response using non-linear time history analysis, and summarize the response quantities for input into PACT.

Methodology

PBEE Methodology

This project focuses on the structural analysis phase of the PBEE approach (Figure 3) implemented in this study.

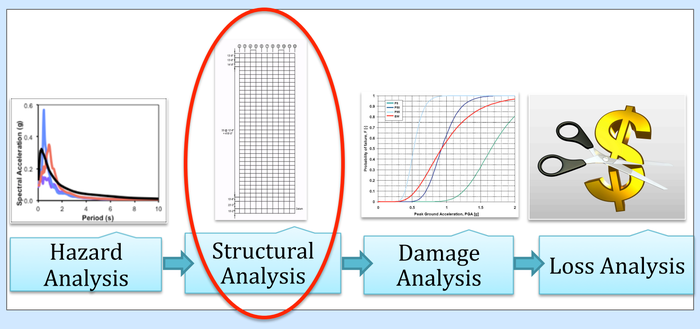


Figure 3: Four stages in PBEE methodology

Structural System

Obtained information from the structural plans (Figure 4) to generate a simplified model with member details representative of construction practices in this era.

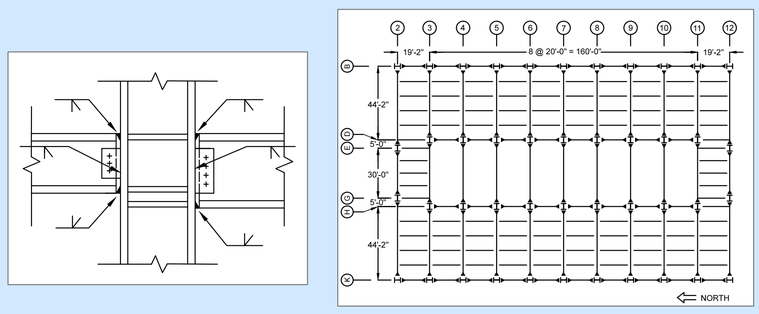


Figure 4: Typical moment connection detail and floor plan of the structure

Model Description

The 40-story three-dimensional model (Figure 5) was generated in OpenSees.

Assumptions

- Omitted basement and intermediate beams
- No soil-structure interaction considered
- Fully ductile moment connections
- Mass lumped at the column nodes
- Fully ductile model
- Rigid diaphragm

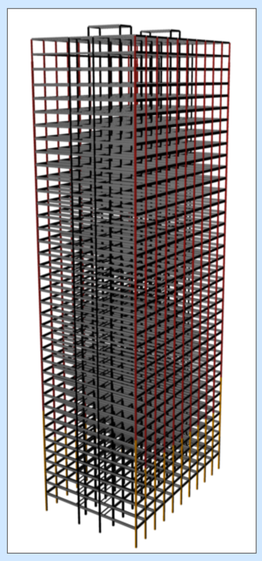


Figure 5: Model of structure

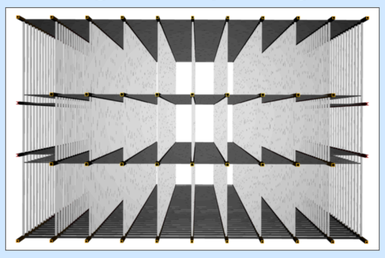


Figure 6: Typical model of floor system

Ground Motions

Loma Prieta recordings and 20 ground motions at 3 hazards were selected, service, design, and MCE levels, with 3 components: vertical, fault normal, and fault parallel.

Ground Motions Cont.

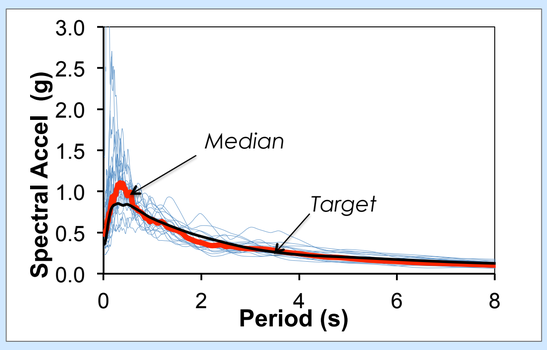


Figure 7: Design level 5% damped spectra

Results

Pushover Analysis

The peak base shear is 8800 kips (Figure 8). P-delta effects caused negative stiffness at a roof displacement of 63 in. (1.1%).

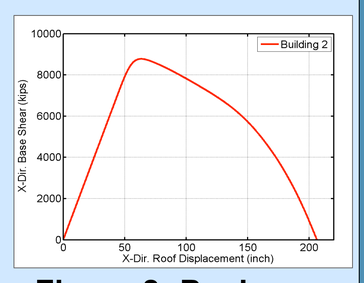
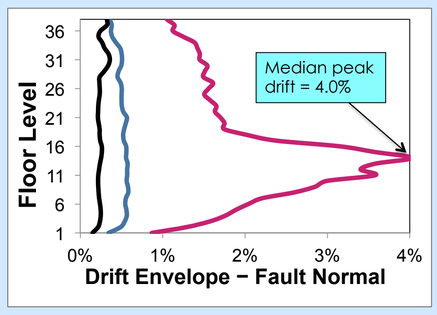
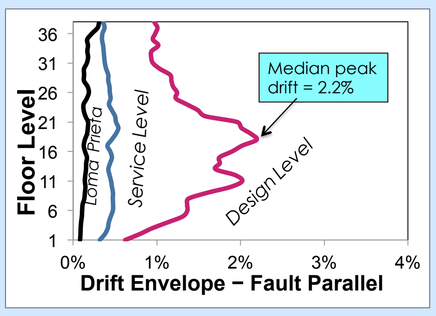


Figure 8: Pushover results – Fault Normal





There are large story drift demands at the design level. Soft story behavior is observed in the bottom half. Median peak drifts at the design level exceed the 2% requirement in current code provisions. The structure failed at the MCE since it didn't converge.

Conclusion

From the results, it is seen that the 40-story structure is unsustainable. At the design level, displacement demands are large and likely considering possible brittle connection behavior. Tall MRF structures with shaking levels consistent with the MCE are expected to face severe damage. Further research is required to establish evaluation guidelines for existing tall buildings. Future work includes incorporation of non-ductile elements and analysis of possible upgrades to the structural system.

Acknowledgements

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