CHAPTER 7

Conclusions and Future Work

The overall goal of the research presented in this dissertation is to extract as much information from seismic records as possible. The aim is to extend the understanding of wood-frame structures without relying solely on full-scale experimental tests. With new knowledge and data, necessary updates to wood-frame building codes can take place to reduce the severe damage and losses seen in the 1994 Northridge Earthquake. Successes and failures in the extraction of information can help evaluate the value of the California Strong Motion Instrumentation Program, and also helps prioritize the necessary upgrades to the program.

Chapter 2 summarized the various full-scale wood-frame tests that have taken place in the past. The case studies collectively demonstrated amplitude dependence of the fundamental frequency and the substantial role of nonstructural elements in providing lateral stiffness. Unresolved issues include the role of the diaphragm and the wide range of reported damping estimates.

Chapter 3 introduced the seismic records and experimental data used for analysis. The seismic records were significant because they displayed some of the highest peak structural accelerations recorded for wood-frame structures. However, due to the limited locations of the instrumentation, utilizing the data to analyze the full structure can be challenging. Recent experimental data from CUREE Tasks 1.1.1 and 1.3.3 were used to validate the extraction process.

Chapter 4 employed a modal identification routine MODE-ID to study significant amplitude dependence of the modal frequencies (which decrease for higher amplitude of shaking) and damping values (which increase for stronger motion) from the seismic response of wood-frame buildings. A 25% to 50% drop in frequency during the stronger earthquakes examined in this dissertation was common. A damping ratio at about 15% to 20% was also typical. Nonlinear behavior of the structure can be inferred from the frequency drop and increased damping.

Chapter 5 outlined a process to retrieve the hysteretic characteristics of wall and diaphragm components. The extraction process worked well for experimental data, but was less successful for field data. Error inherent in the process was the double integration of acceleration records. The chapter listed several measures to resolve this issue and also found that hysteresis loops in wood-frame structures were very susceptible to errors introduced in tilting of sensors and phase delays from filtering. Additionally, the nonlinear behavior of the diaphragm due to the shearing from bidirectional ground motions was also a factor in tampering the integrity of the extracted curves when insufficient instrumentation is available.

By obtaining more accurate hysteresis curves, damping estimates can be calculated from an equivalent elliptical area. The results have shown that low damping estimates inferred from experimental tests are due to structures never reaching or only momentarily exhibiting significant nonlinear behavior. Instantaneous damping estimates can also be obtained with this method. With the presence of energy dissipation from hysteretic behavior, equivalent viscous damping estimates can be as high as 15%-20%, which reaffirms the estimates from MODE-ID. Without the presence of nonlinear behavior, 5% - 10% damping can still be expected in wood-frame structures. The damping estimates should be carefully chosen base on the type of model being used. Furthermore, reports on damping estimates should always be supplemented with the methodologies used, since these values can be easily misrepresented without proper context.

In Chapter 6, different nonlinear models were created to simulate the relative accelerations at the Parkfield school building. Model updating techniques were used to obtain representative parameter values. Bayesian updating and model selection provides an excellent framework for dealing with ill-conditioned problems like the system identification of hysteretic structures. The framework also complements the strong motion database, as both old and new data are available to provide continual updates to the model. Furthermore, the presentation of posterior samples of parameter values and model selection aids human interpretation.

The calculated response of the selected numerical model resembled the recorded data. Displacement time histories from the model were consistent with the anticipated response of the building and suggest that the diaphragm was flexible. By using the damping estimation technique in Chapter 5, the model showed that most of the energy dissipation is from the east and west walls. The diaphragm also contributed by showing flexible behavior.

Goals for future work should focus on the application to building code design and a seamless integration of the Bayesian framework with the CSMIP database. Other objectives include adding a hysteresis degradation parameter in the current numerical model, studying the effects of openings and eccentricity, and refining the hysteresis extraction process.

In conclusion, without significant changes in the current instrumentation program, a substantial amount of new information can be obtained by using the methodology covered in this dissertation. By accurately extracting hysteresis curves, structural deformations and dissipation of energy in wood-frame structures can be inferred. The extraction process can certainly benefit from upgrading to multi-axial sensors and placing sensors strategically. These improvements help account for tilting and bias in sensors, study the nonlinear effects of diaphragm induced from multi-directional ground motions, and characterize the full structure with sufficient amount of records. Furthermore, an integration of the database with a Bayesian updating framework can increase the overall value of the CSMIP program by making better use of each seismic record.