CHAPTER 1

Introduction

In recent years, much of the focus and resources in earthquake engineering have shifted towards a preemptive approach aimed at minimizing life and economic losses. In order to effectively mitigate the damage caused by seismic activity, the dynamic characteristics of buildings must be well understood. This knowledge provides the basis for building code updates for new construction, identifies old structures that need retrofitting, and enhances numerical modeling for building collapse predictions. This process seems straightforward, yet it requires gathering data from buildings stirred by large seismic motion (magnitude 6.0 and greater) – which on average occurs only about 150 times annually around the world (USGS 2008). To further complicate matters, recording instruments are not always readily available as they become increasingly expensive to deploy and maintain. As a result, many of the existing building codes rely primarily on laboratory tests, engineering judgment, and experience.

One case in particular is the design of wood-frame structures. It has been observed that wood-frame construction performs well during earthquakes as it is flexible, light-weight, and stiff considering its density. Large amplitudes of motion are absorbed by the ductility of the structure and dissipated by the friction of connections. Confidence in these structural properties led many to believe that the existing building code was sufficient (Diekmann 1994). However, the 1994 Northridge Earthquake exposed the engineers' lack of understanding of wood-frame structures. Damages and property loss in the amount of $20 billion raised doubts over the reliability of wood-frame construction (Reitherman 1998). While 99% of all residences in California are constructed of wood (Malik 1995), engineers understand less about the behavior of these wood-frame structures compared to those of their concrete and steel counterparts (Cobeen, Russel and Dolan 2004). Therefore, testing of wood-frame structures has attracted a lot of government and research attention in the past decade. Advancement in wood-frame research has been made through the collaboration of agencies such as the Federal Emergency Management Agency (FEMA) and the Consortium of Universities for Research in Earthquake Engineering (CUREE). The CUREE wood-frame project covered five main areas: testing and analysis, field investigations, building codes and standards, economic aspects, and education and outreach (CUREE 2008). The ultimate goal of such work is to make the basis of building codes more applicable and reliable.

1.1 Instrumentation Program

No matter how established are the theories in structural analysis, engineers are unable to improve building codes without proper instrumentation and records. A major contributor of these records is the California Strong Motion Instrumentation Program (CSMIP), which was established by California legislators to obtain vital earthquake data for the engineering and scientific communities through a statewide network of strong motion instruments (CSMIP 2006). In 2003 and 2004, CSMIP was able to measure some key records on one-story wood-frame structures during the San Simeon and Parkfield earthquakes.

Despite the availability of data and records, a recurrent problem in the instrumentation program is how to assess the inherent value of current instrumentation (Sutoyo and Hall 2006). If the current data are limited in the amount of information they provide for structures, what necessary improvements must take place? What resources must be committed in order to establish and maintain an instrumentation network that obtains meaningful data? Another way to approach this question is to determine the extent to which the records are being used. What exactly can be extracted and learned from the data records? Is the amount of data sufficient to make conclusions on the design of wood-frame construction?

1.2 Overview of the Thesis

This dissertation extends the work in *Dynamic Characteristics of Wood-frame Structures* (Camelo, Beck and Hall 2002) by investigating wood-frame records at higher shaking levels and explaining many of the discrepancies raised in reported modal parameters. A proposed methodology to process the CSMIP records is presented to help maximize the value of information gained. The analyses and numerical models presented in the dissertation will also assist in evaluating the CSMIP instrumentation program and in updating the wood-frame construction building codes. The dissertation is divided into the following chapters to address each facet of this data interpretation project.

Chapter 2 highlights many of the advances in understanding of wood-frame construction from the CUREE Wood-Frame Project. This literature review will focus specifically on the dynamic characteristics of wood-frame construction on a full-scale test specimen. The chapter will also identify any unresolved issues, such as high damping estimates.

Chapter 3 presents the time histories used in this investigation and explains the significance of each record. Chapter 4 presents the results of the system identification on these data sets. Results will reaffirm the amplitude dependence of frequency and damping estimates. Chapter 5 connects the quantitative analysis in Chapter 4 to the physical characteristics in wood-frame construction. The chapter will also dispel some of the confusion in the overestimation of damping by explaining hysteretic behavior in wood-frame structures.

Chapter 6 introduces the finite element models that will simulate the measured responses. The models will validate the hysteresis extraction procedures and the component identification process. It will also discuss common model updating routines used in selecting parameters for the models and offer a Bayesian framework for simulation and model selection as a better alternative for this type of data interpretation. Finally, Chapter 7 presents conclusions for the data interpretation project and reviews the methodology, analyses and models presented in this dissertation.