CHAPTER 3

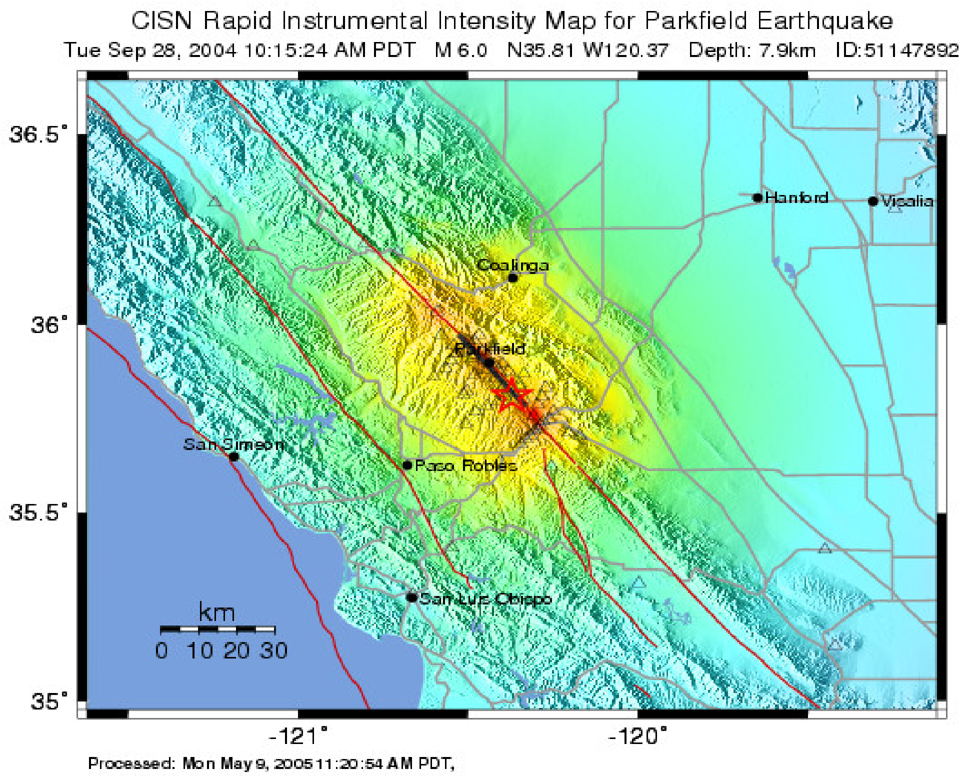
Seismic Records from Wood-frame Structures

Many of the full-scale shake tests used recorded ground motions for excitation. Seismic records provide intense ground motions to structures and can cause serious damage and possibly structural failure. With proper seismic instrumentation, engineers can also characterize structural behavior of wood-frame buildings during strong seismic motion. The California Strong Motion Instrumentation Program (CSMIP) is one of the pioneers in providing seismic records for the engineering and scientific communities over the last few decades. Aside from data processing and delivery, CSMIP also seeks to gain understanding in earthquake ground-shaking and its effect on structures. This chapter will introduce the records that CSMIP has provided for investigation along with additional data sets from other sources. These records are used to reinforce hypotheses and support conclusions presented in this dissertation.

3.1 Parkfield and San Simeon Earthquake Records

The primary data set used in this dissertation is the 2004 Parkfield Earthquake, also coined the Best Recorded Quake in History by the USGS (Michael 2006). Prior to the most recent major quake in 2004, moderately-sized earthquakes of about magnitude 6 have occurred on the Parkfield section of the San Andreas fault at fairly regular intervals – in 1857, 1881, 1901, 1922, 1934, and 1966. This observation has led to the Parkfield Experiment – a long term research project analyzing the San Andreas Fault (USGS 2008). Seismograms were installed at over 100 near-field sites in the area, making the 2004 Parkfield earthquake one of the best recorded earthquakes for seismic engineering purposes (Bakun, et al. 2004).

Instrumented wood-frame construction sites are typically fewer in number than concrete and steel construction sites. The large number of available records in the 2004 Parkfield Earthquake also meant that available wood-frame records were more numerous than average (Figure 3.1 shows an instrumental intensity map; Figure 3.2 shows a contour of near-fault ground accelerations; Figure 3.3 shows particle displacement motions). The 2003 San Simeon Earthquake, on the other hand, provided as its distinguishing mark, the record exhibiting the highest peak structural acceleration for wood-frame structures ever recorded. Previous recorded highs were approximately 60% g, whereas those recorded in 2003 were as high as 125% g. Due to the high dependence of wood-frame structures on the amplitude of motion, these data sets are invaluable to understanding the non-linear behavior and peak amplitudes of these types of construction. CSMIP was particularly interested in two of its wood-frame instrumented sites, one of which was studied by Camelo for the 1993 and 1994 Parkfield Earthquake (Camelo 2003). Comparing the results from these two sites will also be a point of interest of this paper.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	8.1-16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Figure 3.1: Rapid instrumental intensity map for the Parkfield earthquake (CSMIP 2006).

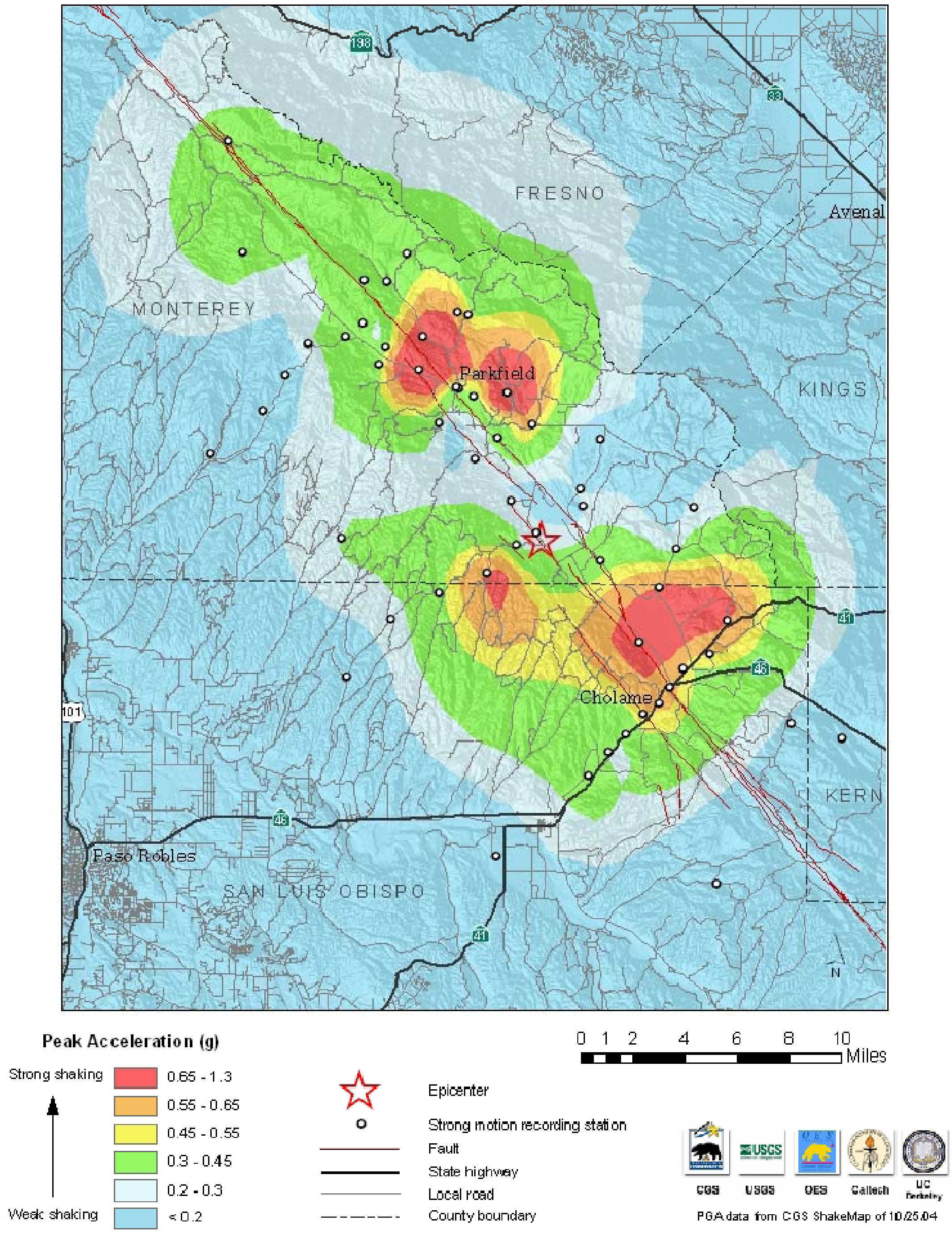


Figure 3.2: Contour map of near-fault peak ground accelerations (CSMIP; Shakal, et al. 2005; Graphic generated by Pete Roffers at CSMIP).

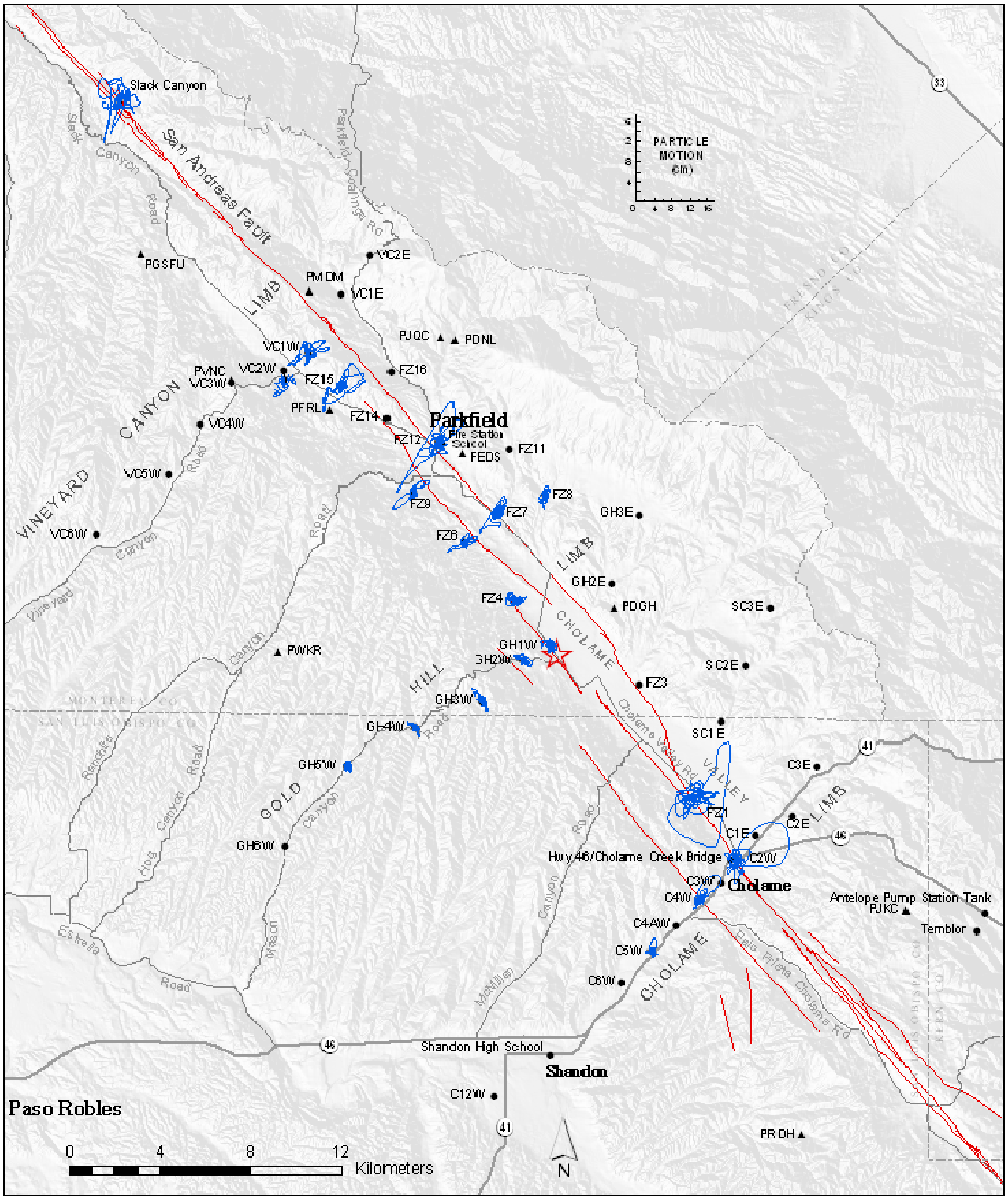


Figure 3.3: Particle displacement motions of Parkfield Earthquake of 28 Sep 2004 (CSMIP 2006).

3.1.1 *Parkfield School Building*

The Parkfield school building is a one-story rectangular building built in 1949, with plywood shear walls installed in the longitudinal direction. The base dimensions are 48’ × 30’. Figure 3.4 shows the location and photograph of the station. The instrumentation was installed in 1987 with a total of 6 accelerometers in place. There were three channels in the N-S (transverse) direction and three in the E-W (longitudinal) direction. The hypocenter of the 2004 earthquake was 13 km away (CISN 2006).

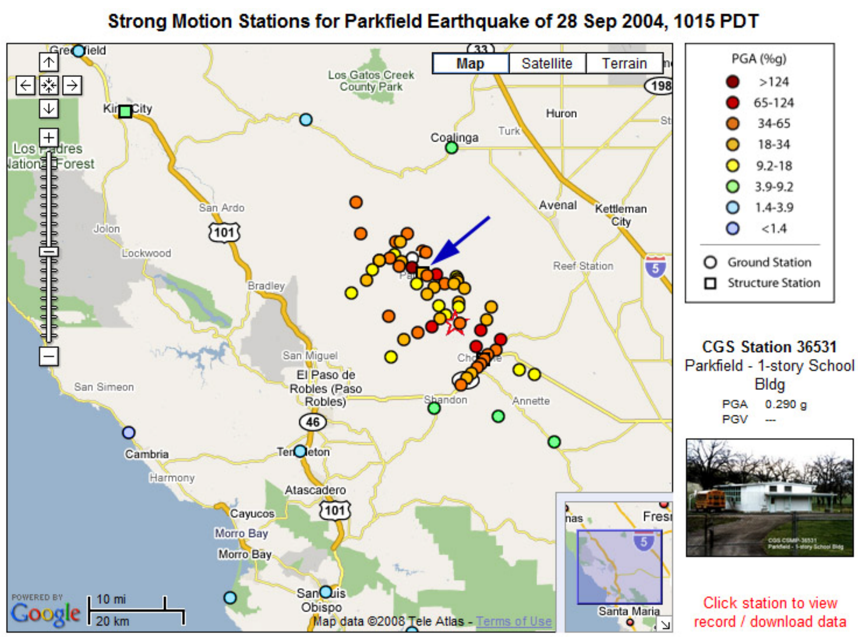


Figure 3.4: Location and photograph of the Parkfield school building strong motion station.

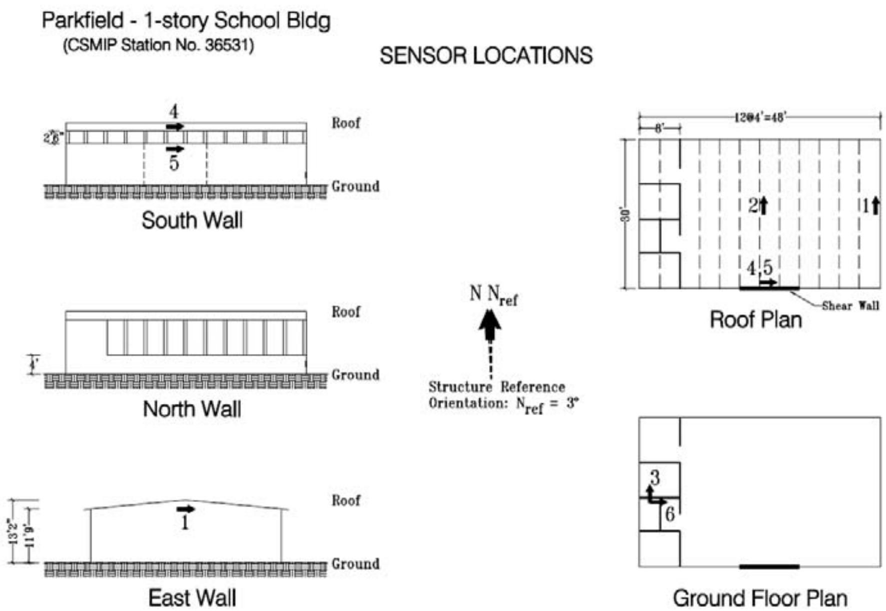
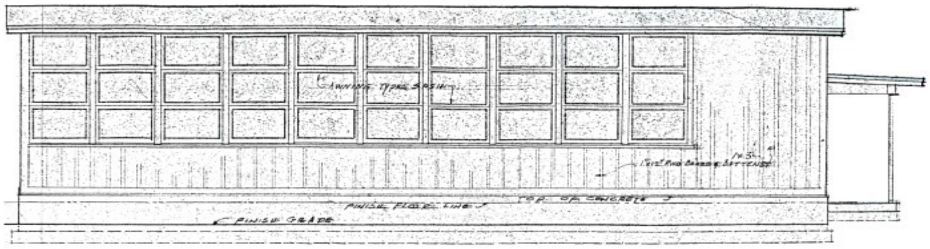
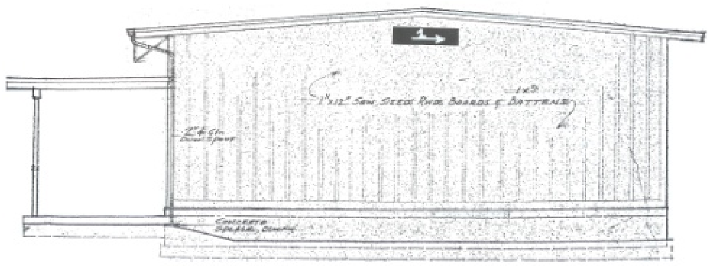


Figure 3.5: Instrumentation layout of the Parkfield school building.

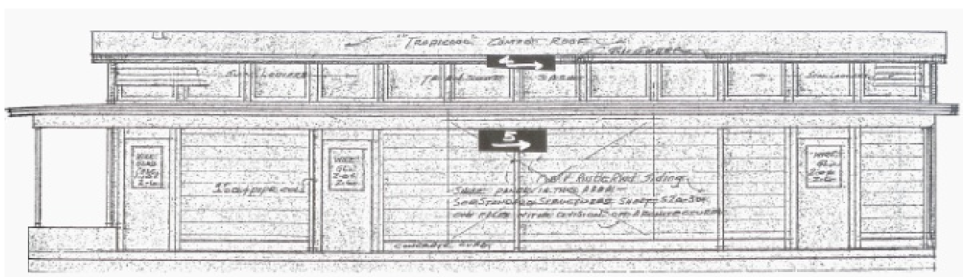
The instrumentation schematic layout is shown in Figure 3.5. Two channels (3 and 6) are situated on the first floor, and three (1, 2, and 4) are located on the roof. Channel 5 sits on the main lateral force resisting system which is a shear wall (12' long) in the long direction on the south wall. Recording with only four channels may seem limited compared to the numbers used in a shake table test in a laboratory setting. However, the symmetry in the building's rectangular structural plan simplifies many of the analyses. For example, it is safe to assume that the motion on the west of the building will be similar to the motion experienced on the east side of the building. However, it is important that symmetry be used with care. From the structural sketches (Figure 3.6) one can notice that the north wall and the south wall differ greatly in their equivalent stiffness. Most of the surface area of the north wall is comprised of windows, and the gaps in these window frames will greatly lower the lateral force resistance on the north side of the wall.



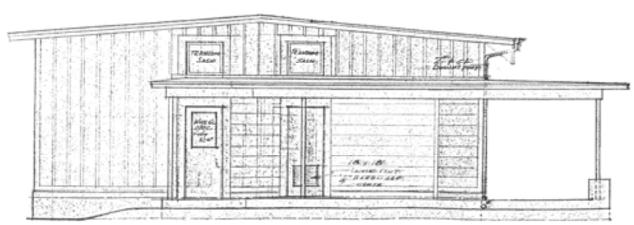
North Wall



East Wall



South Wall



West Wall

Figure 3.6: Elevation views of the Parkfield school building (CSMIP).

Figure 3.7 and Figure 3.8 plot the acceleration time histories from the Parkfield school building. Peak structural acceleration is approximately 35% g. The records in 2004, along with data from 1993 and 1994, can be downloaded from the CSMIP website (http://www.strongmotioncenter.org). Included are raw time histories, calculated velocities and displacement time histories, and response spectrum analyses.

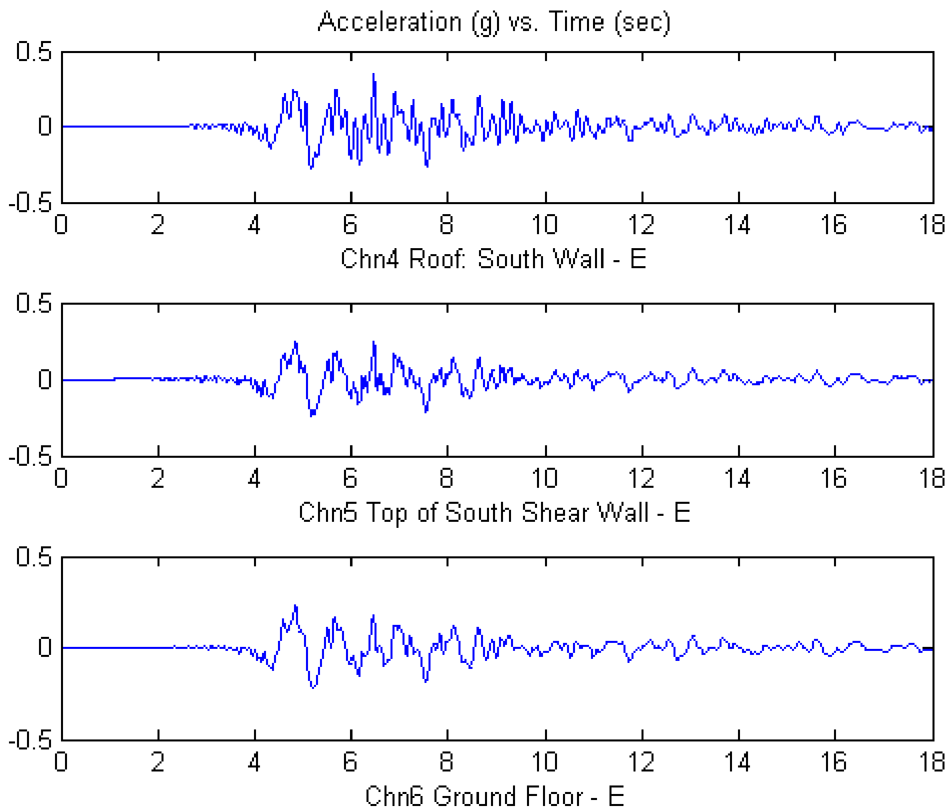


Figure 3.7: Acceleration strong motion time histories (East/West direction) of the Parkfield school building.

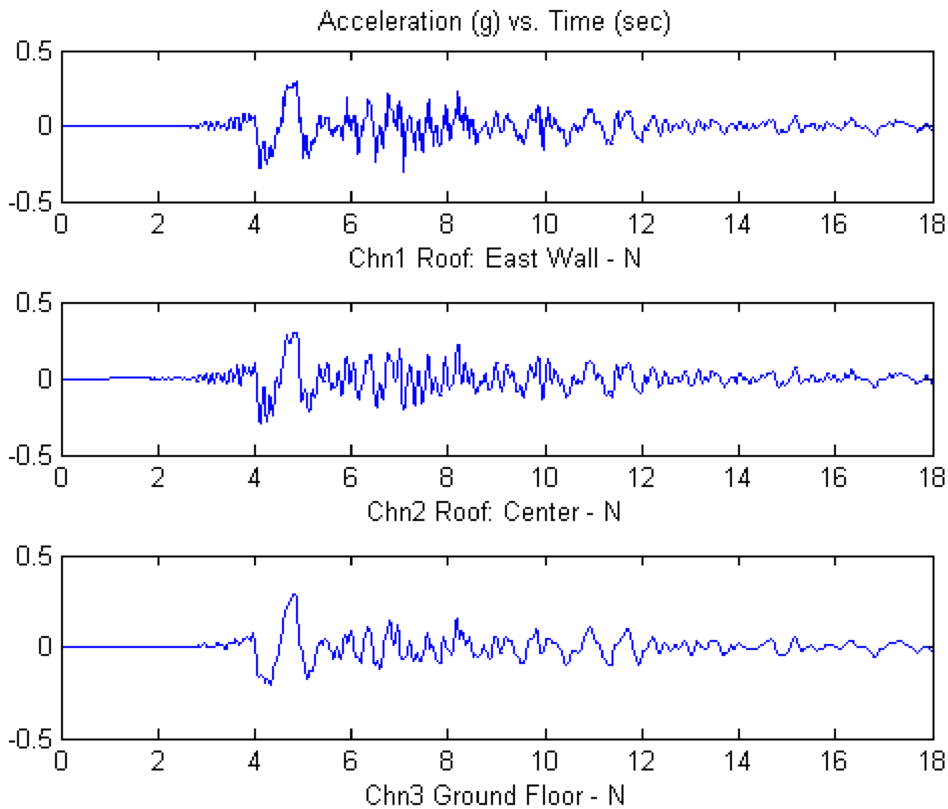


Figure 3.8: Acceleration strong motion time histories (North/South direction) of the Parkfield school building.

3.1.2 *Templeton Hospital*

The Templeton Hospital, built in 1975, has an irregular plan shape and measures 336’ × 277’. Figure 3.9 shows the location and photograph of the station. In 1994 nine accelerometers were installed in the building. Plywood sheathed shear walls are installed in both directions. The hypocenter of the 2003 earthquake was 40 km away (CESMD 2006).

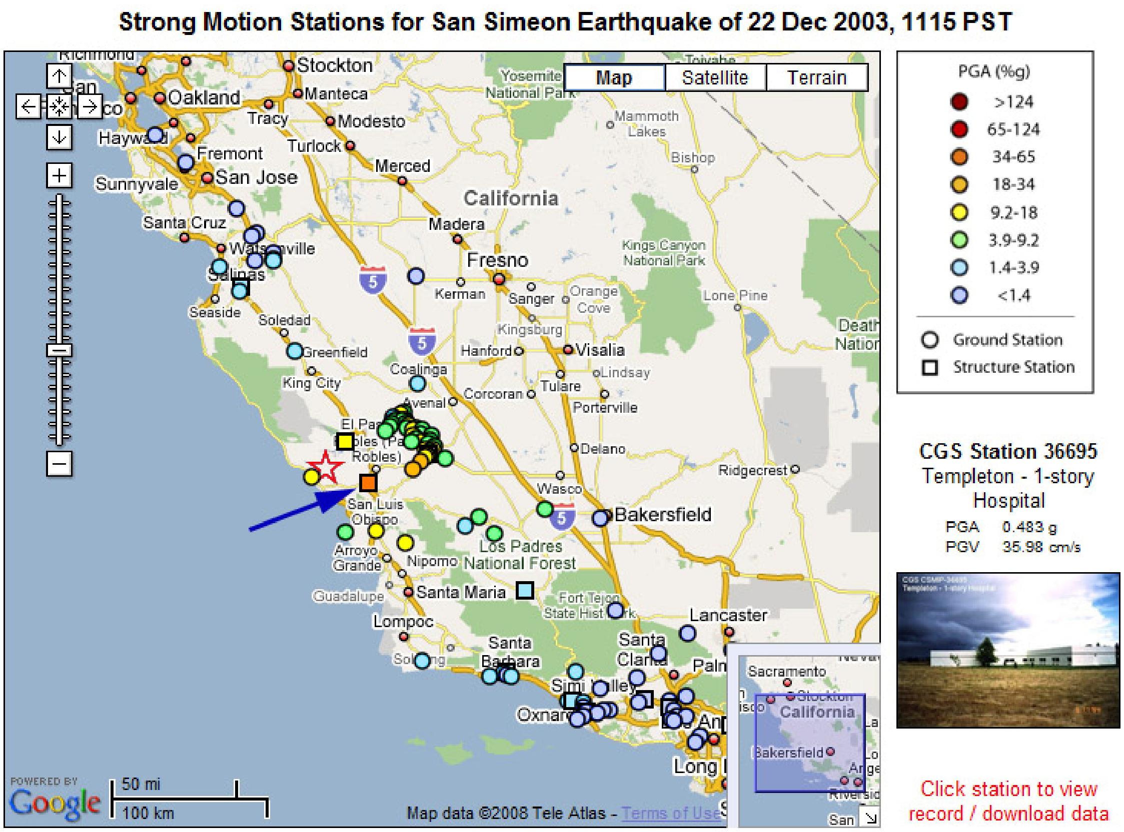


Figure 3.9: Location and photograph of the Templeton hospital.

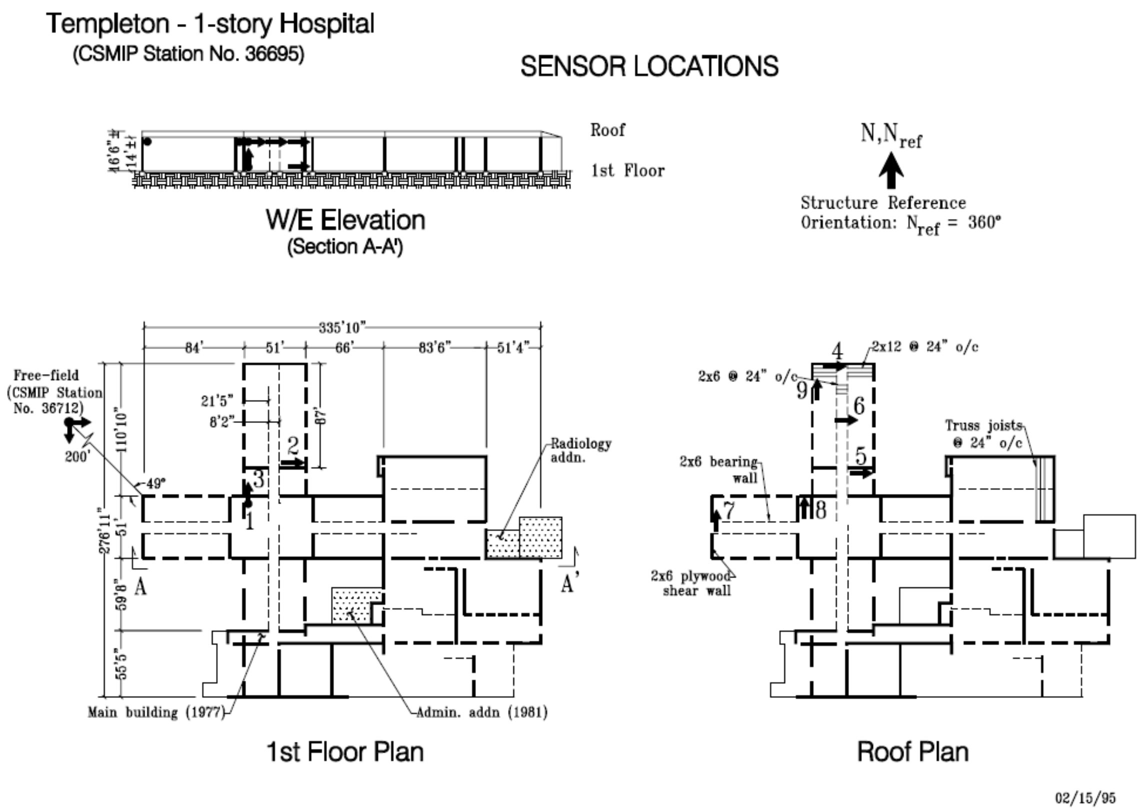


Figure 3.10: Instrumentation layout of the Templeton hospital.

The instrumentation schematic layout is shown in Figure 3.10. Three channels (1, 2 and 3) are situated on the first floor. Channel 1 measures the vertical acceleration of the building, whereas Channels 2 and 3 measure the ground motions in the longitudinal and transverse directions, respectively. The remaining channels are located on the roofs of the North and West Wings. The irregular floor plan and concentration of sensors present a challenge to the modeling effort of the entire structure. There is not much information regarding the rest of the building aside from the North and West Wings. As an alternative, one can model just the North Wing and make some assumptions regarding the inertial force transmitted to this wing from the rest of the building. Therefore, this dissertation will present only the modeling efforts for the Parkfield school building and not for the Templeton hospital.

Figure 3.11 and Figure 3.12 depict some of the channels having more than 100% g for its peak structural acceleration. Prior to this record, it was unknown if low-rise wood-frame structures could reach such peak structural accelerations.

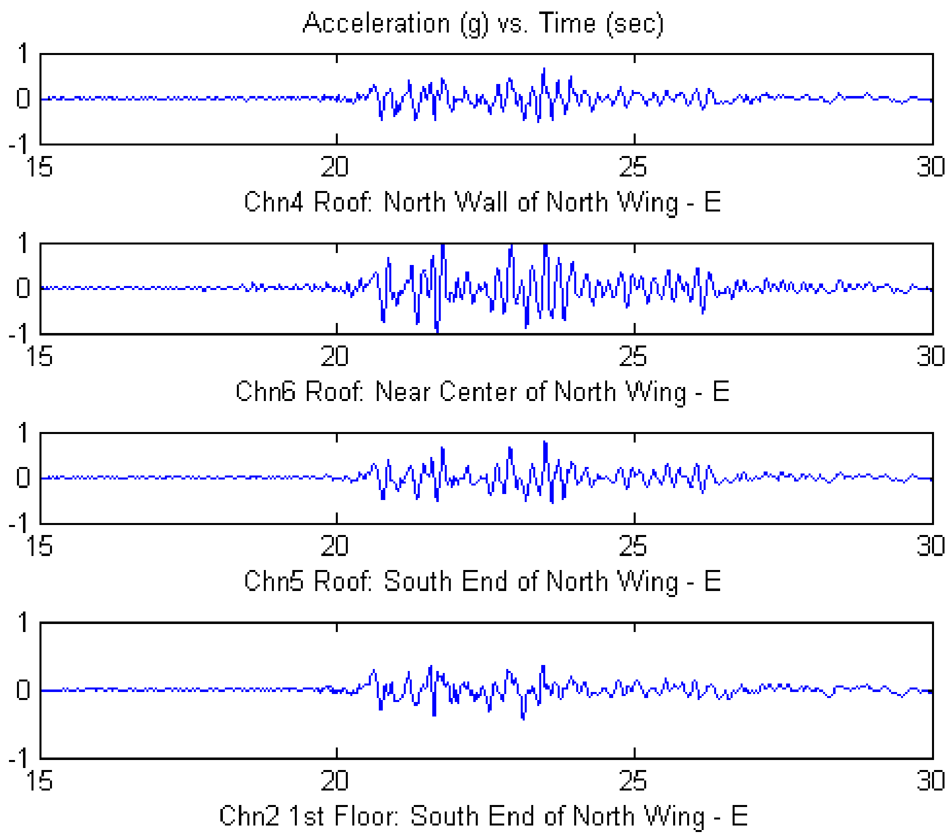


Figure 3.11: Acceleration strong motion time histories (East/West direction) of the Templeton hospital during the 2003 San Simeon Earthquake.

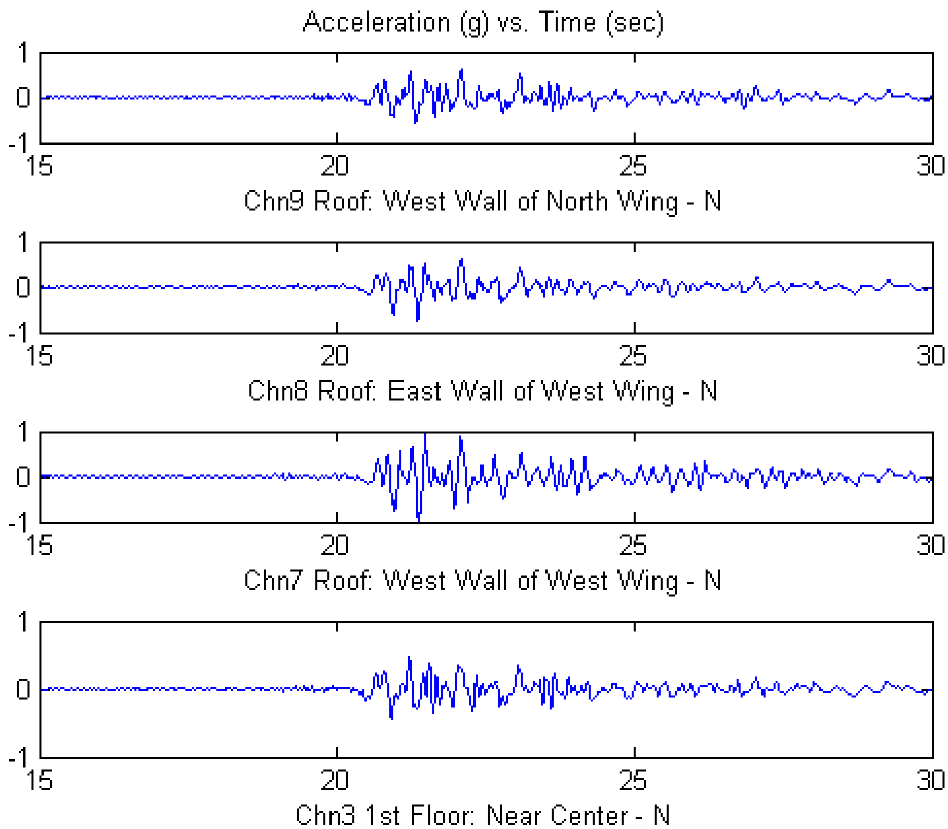


Figure 3.12: Acceleration strong motion time histories (North/South direction) of the Templeton hospital during the 2003 San Simeon Earthquake.

3.2 Experimental Records

Although this dissertation focuses on the interpretation of seismic response records, it was necessary to employ some experimental records for comparison. The advantage of using experimental records is the abundance and variety of available instrumentation on the test specimen, as well as the ability to control environmental and structural settings.

3.2.1 Shake Table Tests – University of California, San Diego (UCSD)

The UCSD shake table tests were part of Task 1.1.1 of the CUREE-Caltech Wood-frame Project. The test structure was a simplified full-scale two-story house. The testing occurred in several phases, each with different structural configurations. Quantifying the dynamic response during these tests will lead to a better understanding of the behavior of full-scale structural wood-frame systems.

The test structure has a 16’ × 20’ floor plan and is situated on the UCSD uniaxial shake table. The structural components of the test structure are full-scale, but plan dimensions are smaller due to restrictions of the shake table (Fischer, et al. 2001). The test structure was instrumented with nearly 300 displacement, acceleration, and force measuring devices. Since there have been so few full-scale shake table tests, the experimental results from this task will be a benchmark for interpreting field records. Having both acceleration and displacement histories, double integration on acceleration records used for field records is not necessary.

3.2.2 Forced Vibration Tests – Vanessa Camelo

The forced vibration tests included in this dissertation were part of Task 1.3.3 of the CUREE-Caltech Wood-frame Project. Multiple tests were performed on a three-story and two-story wood-frame buildings, which were all owned by the California Institute of Technology.

These tests measured harmonic vibrations induced by a shaking machine. The shaking machine generates forces through the centrifugal acceleration of spinning weights. Sensors are mounted on the building to measure the building response at each driving frequency, and will in turn map out the frequency response of the building. These forced vibration tests provide an alternative method in calculating the system's frequency and damping estimates, and are invaluable for comparing with results from shake table tests and field records.

3.3 Remarks

Several records were mentioned in this chapter. Data were obtained in full-scale whole buildings for both field records and lab experiments. These data sets help formulate an understanding of the structure as a whole. In the next two chapters, system identification and hysteretic analyses are performed on the data set to fully extract all the information available in the record.