

PRELIMINARY REPORT ON DECEMBER 22, 2003 SAN SIMEON EARTHQUAKE

By

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A strong earthquake of magnitude 6.5 (M_w) struck the Central Coast of California at 11:15:56 AM PST (19:15:56 UTC) on Monday, December 22, 2003. The epicenter (Figure 1) was 11 km (7 mile) NE of San Simeon, at a depth of about 8 km (5 mile). Two people were killed and about 40 buildings collapsed or severely damaged at Paso Robles which is located about 39 km (24 mile) from the epicenter. At least 40 people were reported to be injured in the Paso Robles-Templeton area. This preliminary report presents basic information on the epicenter location, intensity of shaking, and performance of buildings in the Central Coast region of the California.

Epicenter Location and Shaking Intensity

The Central Coast of California has several active faults (Figure 2). Although exact location of the earthquake of December 22, 2003 is still being determined, this earthquake occurred somewhere on the northern end of the San Simeon/Oceanic/HosGri Fault System. Early analysis by USGS and UC Berkeley indicates that it had a thrust (reverse faulting) mechanism; reverse faulting occurs when compression stresses push the fault block up the fault line “reverse” to the gravity (Figure 3). The last major earthquake in this area was the Bryson earthquake in 1952 with a magnitude of 6.2.



Figure 1. Location of the December 22, 2003 San Simeon earthquake (USGS).

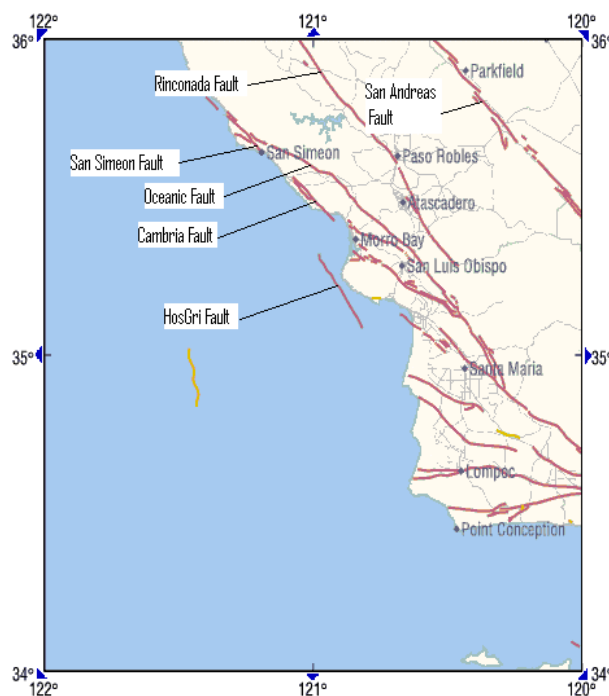


Figure 2. Faults in Central Coast of California (Adapted from a USGS map).

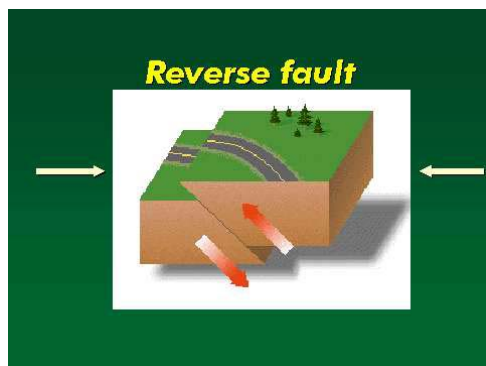
Figure 3. Reverse fault mechanism¹.Figure 4. Map of San Luis Obispo County².

Figure 5 shows the shaking intensity map of the San Simeon earthquake. The intensity was about VII in Atascadero, Cambria, Cayucos, Los Osos, Morro Bay, Nipomo, Oceano, Paso Robles, San Miguel, San Simeon, Shandon and Templeton (see map of the San Luis Obispo County in Figure 4 for locations of various cities). Further south, the intensity reduced to VI in Arroyo Grande, Grover Beach, Guadalupe, Pismo Beach, San Luis Obispo, Santa Margarita and Santa Maria.

CISN Rapid Instrumental Intensity Map Epicenter: 11 km NE of San Simeon, CA
Mon Dec 22, 2003 11:15:56 AM PST M 6.5 N35.71 W121.10 Depth: 7.6km ID:40148755

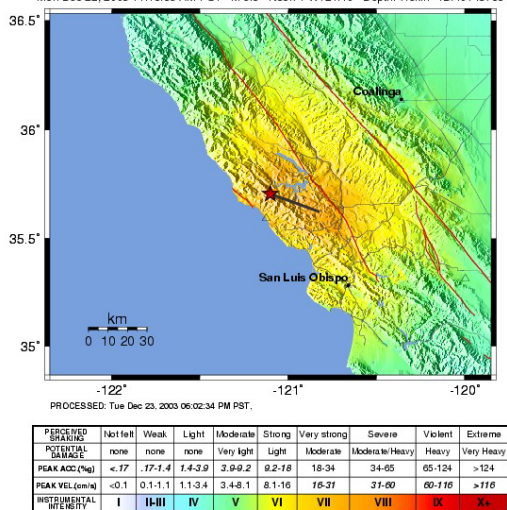


Figure 5. Intensity map (CISN).

CISN Peak Accel. Map (in %g) Epicenter: 11 km NE of San Simeon, CA
Mon Dec 22, 2003 11:15:56 AM PST M 6.5 N35.71 W121.10 Depth: 7.6km ID:40148755

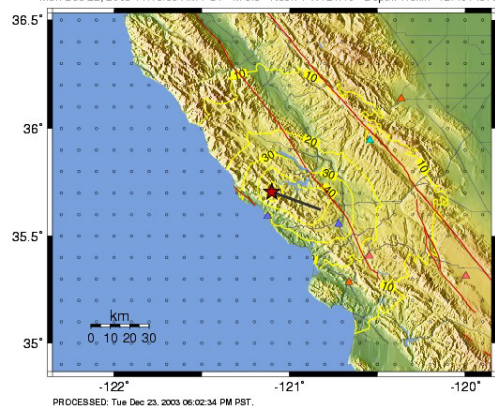


Figure 6. Peak ground acceleration map (CISN).

The largest shaking observed was at a CGS-instrumented 1-story hospital in Templeton, about 38 km (24 mile) from the epicenter (though much closer to the projected southern end of the rupture). The hospital recorded about 50%g horizontal motion and 30%g vertical motion at the ground level³. Templeton is about 10 km (6 mile) south of Paso Robles, where significant damage occurred during the earthquake (see Figure 4 for city locations). Therefore, it is likely

¹ Adapted from <http://www3.uakron.edu/geography/lrb/physf97/lectures/platetect/sld031.htm>

² Adapted from http://www.slocoupons.com/maps_1.htm

³ Second Internet Quick Report: CISN Strong-Motion Data from the M6.5 San Simeon Earthquake of December 22, 2003

that Paso Robles experienced horizontal accelerations in excess of 50%g. The station closest to the epicenter was near Cambria, 12 km (8 mile) from the epicenter, near a Caltrans bridge on Hwy 1. Though the station is much closer, it only recorded 18%g. This early data indicates apparent strong directivity in the direction of the rupture propagation toward Templeton. Another record was recovered from the San Luis Obispo, about 61 km (38 mile) to the south of the epicenter, where 17%g was recorded at a USGS station downtown. A contour map of the peak horizontal ground accelerations during the earthquake is shown in Figure 6.

Performance of Buildings in Paso Robles

Downtown Paso Robles, located about 39 km (24 miles) from the epicenter, suffered the most damage during the San Simeon earthquake. The damage was concentrated in the three-block area of the historic downtown district of the city (see sketch in Figure 7). Summarized first is the overall observations on the damage pattern in the downtown area followed by more detailed description for selected buildings.

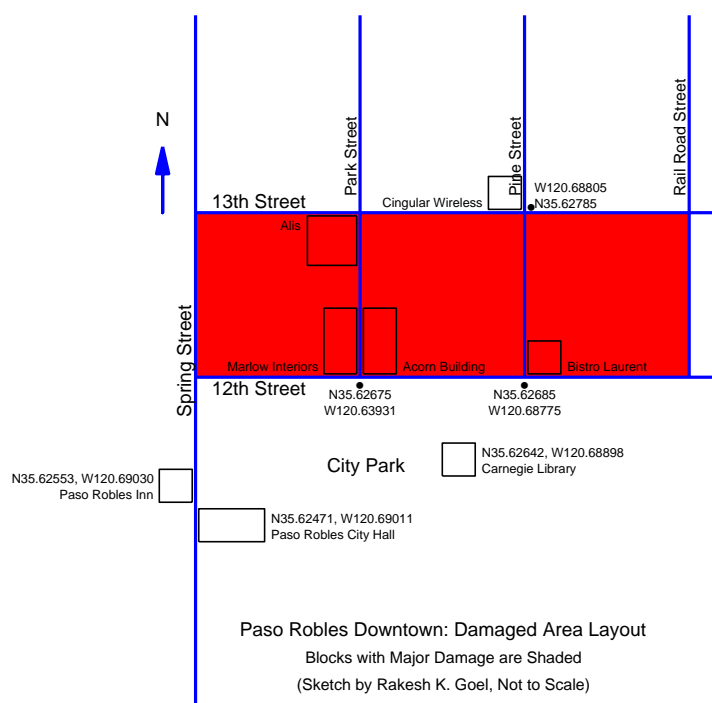


Figure 7. Damaged area in downtown Paso Robles.

Overall Damage Pattern

The largest damage was observed to buildings on both sides of the Park Street between 12th and 13th Streets, and on 12th Street between Park and Vine Streets (see Figure 7 for locations). The Acorn building, located on the corner of 12th and Park Streets, collapsed killing two people. Although the building housing Marlow Interior located on the corner of 12th and Park Streets but opposite to the Acorn building did not collapse, it suffered extensive structural and nonstructural damage. Most other buildings on these streets suffered minor to major structural and extensive nonstructural damage. At the time of this report, access to these buildings had been restricted to building officials for evaluation purposes.

Most buildings in the downtown Paso Robles business district area are very old, some more than a century ago, constructed of unreinforced masonry. Unreinforced masonry construction is known to be especially vulnerable to earthquakes and it is not surprising that such buildings suffered extensive damage during the San Simeon earthquake. Most of these buildings were not designed for seismic loads and lacked proper seismic detailing. A few had been upgraded by tying the floor diaphragm to the walls. The damage level was much higher in buildings that were not retrofitted compared to those that had been retrofitted. None of the buildings with some kind of seismic retrofit scheme implemented collapsed indicating that even basic seismic retrofit can prevent collapse and resulting loss of life.

In general, buildings on the street corners performed poorly. For example, Acorn, Marlow Interior, Bistro Laurent, Cingular Wireless, and Ali's buildings that suffered the largest damage were all located on street corners (see Figure 7). Configuration of these corner buildings with windows on the street sides and solid opening-less walls on the two other sides created extreme plan asymmetry, i.e., large eccentricity between floor center of mass and center of rigidity. The resulting torsional motions during the earthquake shaking imposed much larger demands on these buildings, compared to buildings with symmetric plans, leading to much larger damage.

Unreinforced masonry buildings even without seismic retrofit located mid-block did not suffer catastrophic failure that occurred in the Acorn building. Most buildings in the affected area, especially on the Park and 12th Streets, are constructed without any gap between them. It seems that the adjacent buildings provided confinement to each other, except to those on the corner, and prevented collapse.

Finally, the damage pattern indicates a much stronger shaking in the east-west direction, the direction normal to the fault rupture, compared to the north-south direction. This observation is consistent with the observation in the previous earthquakes that the shaking may be strong in the fault-normal direction compared to the fault-parallel direction.

Acorn Building

The Acorn building is one of the oldest buildings in the downtown district of Paso Robles. A two story unreinforced masonry building constructed more than a century ago, it housed a Clock Tower on the corner of 12th and Park Streets and several small businesses on the ground floor on 12th Street and Park Street sides. This building collapsed resulting in the only two fatalities during the San Simeon earthquake (Figure 8).

The lateral load carrying system of this two-story building appears to be unreinforced masonry walls, which support the timber floor and roof with additional metal sheet on the roof. Both the floor and the roof appear not to be properly tied to the walls. During the earthquake, the clock tower on the Park and 12th street corner of this building collapsed. Furthermore, the second story wall on the Park Street side appeared to have collapsed out-of-plane. As a result, the roof slid to the Park street side leaving a big gap in what appears to be collapsed roof of the second half of the building on the 12th Street side.

The major shear resistance of this building appears to be in the north-south direction, with much smaller shear capacity in the east-west direction. As noted previously, the strong shaking was in the east-west direction. The wall on the west side (on the Park Street side) of the building collapsed out-of-plane due to much smaller resistance.



Figure 8. Collapsed Acorn building on the corner of 12th and Park Streets in downtown Paso Robles (Picture by Rakesh Goel).

Marlow Interior Building

Located on the corner of 12th and Park Streets, the south and east elevations of this two-story building – the two sides facing the streets – have large window openings in the first story and some windows in the second story (Figure 9). The other two sides, which face away from the streets, have only a few window openings in the second story and solid wall in the first story without openings. This configuration led to significant eccentricity between the center of mass and center of rigidity. The damage pattern described next for this building is consistent with that expected due to torsion.

This building suffered major structural damage and was red-tagged after the earthquake. Large cracks appeared on the south-east corner – the corner farthest away from the center of rigidity – of the building (Figure 10). Apparently, this corner experienced large drifts due to torsion of the building during the earthquake. Significant diagonal shear cracks appeared in the first story wall on the east as well as the south sides; both these sides of the building face the streets (Figure 11). This appears to be consistent with the expected large drifts in this wall of the first story. Much less cracking is visible in the second story wall (Figure 12). Drifts are expected to be much smaller in this wall of the second story because of much fewer openings compared to the first story. No cracks were visible in the north and west walls of the building.

Ali's Persian Rugs Building

This two story building located on the south-west corner of Park and 13th Streets suffered extensive loss of its cladding. The brick façade peeled off from near the roof level from faces on both the Park and 13th Street. It appears that the brick façade was attached to the wall with cement mortar. No ties were noticeable on the open face of the building or the rubble below. The other external structural damage appears to be minimal in this building.



Figure 9. Marlow Interior building located at the corner of 12th and Park Streets in downtown Paso Robles (Picture by Josh Marrow).



Figure 10. Large cracks at the corner of the Marlow Interior building (Picture by Sam Vigil).



Figure 11. Crack pattern in the first story of the Marlow Interior building on the Park Street face (Picture by Sam Vigil).



Figure 12. Crack pattern in the second story of the Marlow Interior building on the Park Street face (Picture by Sam Vigil).

Bistro Laurent Building

Located on the corner of Pine and 12th Streets, this one-story masonry building suffered minor structural damage (Figure 14). A few bricks separated and fell from the decorative parapet. This masonry building appears to have been retrofitted by tying the roof to the walls. The anchor bolts are clearly visible along the roof-line of this building. Clearly, this basic retrofit scheme appears to have prevented major damage to this building.



Figure 13. Peeling of the brick facade in the second story of the Ali's Persian Rug building on the corner of Park and 13th Streets in downtown Paso Robles (Picture by Sam Vigil).



Figure 14. Minor peeling of bricks from the decorative parapet of the Bistro Laurent building on the corner of Pine and 12th Streets in downtown Paso Robles (Picture by Rakesh Goel).



Figure 15. Damage to the Cingular Wireless building on the corner of Pine and 13th Streets in downtown Paso Robles (Picture by Sam Vigil).



Figure 16. A close-up view of the seismic retrofit anchors in the Cingular Wireless building (Picture by Rakesh Goel).

Cingular Wireless Building

Located on the corner of Pine and 13th Streets, this one-story masonry building suffered minor structural damage (Figure 15). The brick façade on the south-west corner of the building separated and fell. This masonry building also appears to have been retrofitted by tying the roof to the walls. The anchor bolts are clearly visible along the roof-line of this building (Figure 16). As noted previously for the Bistro Laurent building, this basic retrofit scheme appears to have prevented major damage to this building.

Paso Robles Inn

Paso Robles Inn is located a short distance south-east of the historic downtown district. This Inn consists of a main restaurant with a three-story tall observation tower and several two-story buildings that house the guest quarters. The observation tower consists of a frame supporting the brick façade. Very little damage was noticeable in the observation tower (Figure 17). The attached restaurant suffered moderate nonstructural damage: a few clay roof tiles came loose and a glass broke in a few windows in the first and second stories (Figure 18).



Figure 17. Observation tower of the Paso Robles Inn on Spring Street in Paso Robles (Picture by Rakesh Goel).



Figure 18. Loss of windows and roof tile in restaurant of the Paso Robles Inn (Picture by Rakesh Goel).



Figure 19. Two-story guest quarter building at the Paso Robles Inn (Picture by Sam Vigil).



Figure 20. Cracks in the brick walls of the guest quarter building at the Paso Robles Inn (Picture by Rakesh Goel).

The two-story brick building housing the guest quarters in the front of the Paso Robles Inn (Figure 19) suffered significant cracking in the masonry walls (Figure 20). This portion of the Inn was closed. Other parts of the Inn were open for business as the damage was minor and mostly non-structural in nature.

Performance of Atascadero City Hall

Built in 1918, the Atascadero City Hall (Figure 21) is located about 63 km (39 mile) from the epicenter. Discussion with the city engineer indicated that the structure consists of reinforced concrete space frame with brick façade. The exterior damage primarily consisted of cracks and severe spalling of the brick façade on the rotunda (Figure 22). Falling bricks from the façade took out a sky-light and fell on the tables of a room located at the rotunda office level. No one was injured because this room was unoccupied at the time of the earthquake. The reinforced concrete space frame supporting the dome roof was found to have suffered no damage.



Figure 21. Atascadero City Hall (Picture by Rakesh Goel).



Figure 22. Peeling of brick façade from the rotunda of the Atascadero City Hall (Picture by Rakesh Goel).

Internal damage consists of severe cracks in the walls and plaster throughout the building (Figure 23). The damage was more severe in the first story. Rotunda office where the city council meets experienced spalling of plaster from the roof and the ring beam (Figure 24). Closets in the kitchen outside the city council chambers at the rotunda level opened and spilled their contents during the earthquake (Figure 25). Contents of the display cases in the lobby were tossed around during the earthquake. Several glass display pieces fell to the ground and broke (Figure 26).



Figure 21. Atascadero City Hall (Picture by Rakesh Goel).



Figure 22. Peeling of brick façade from the rotunda of the Atascadero City Hall (Picture by Rakesh Goel).



Figure 23. Typical cracks in the walls of Atascadero City Hall (Picture by Rakesh Goel).



Figure 24. Peeling of plaster from ring beam of the rotunda of the Atascadero City Hall (Picture by Rakesh Goel).



Figure 25. Damage in the kitchen of Atascadero City Hall (Picture by Rakesh Goel).



Figure 24. Damage in the lobby of the Atascadero City Hall (Picture by Sam Vigil).

Performance of Buildings in Downtown San Luis Obispo

Although downtown San Luis Obispo has a large stock of unreinforced masonry buildings, very little structural damage was observed in the city. The lack of damage in San Luis Obispo may be attributed to relatively large distance from the epicenter – the city is about 61 km (39 mile) from the epicenter of the San Simeon earthquake – and low levels of ground accelerations in the city – the peak horizontal ground acceleration recorded during the earthquake was about 17%g at a USGS recording station.

Ah Louis Store (Figure 25), a two-story unreinforced masonry building located on the corner of Palm and Chorro Streets, is designated as a historic landmark in the city. No noticeable change in cracks on the south-west wall, which has been retrofitted, was observed after the earthquake (Figure 26). However, new cracks appeared on the north-east wall of the building

(Figure 27). The building was temporarily closed for inspection and subsequently cleared for occupancy.

Several vulnerable buildings in San Luis Obispo are located on the campus of the Mission San Luis Obispo de Tolosa. This adobe structure survived the earthquake without damage. The only noticeable damage was widening of existing hair-line cracks at the junction of the Bell-Tower building and the adjacent building (Figure 28). The mission was open for business in the afternoon of December 22, 2003.



Figure 25. Ah Louis Store in downtown San Luis Obispo (Picture by Rakesh Goel).



Figure 26. Cracks existing prior to the earthquake and attempt to retrofit on the south-west wall of the Ah Louis Store building (Picture by Rakesh Goel).

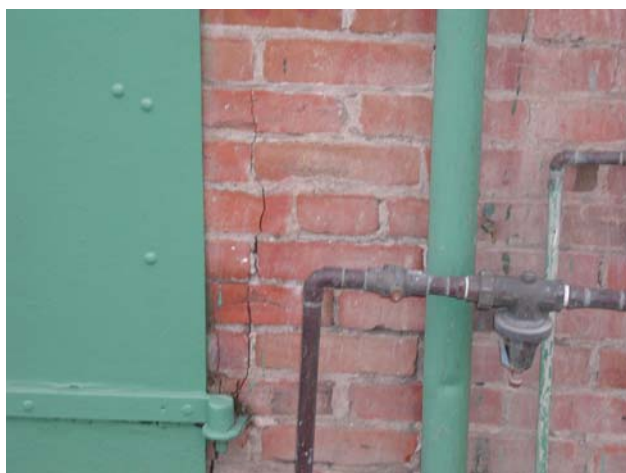


Figure 27. New cracks on north-east wall of the Ah Louis Store building (Picture by Rakesh Goel).



Figure 28. Widening of cracks at junction of the bell tower and adjacent building in the Mission San Luis Obispo de Tolosa in downtown San Luis Obispo (Picture by Rakesh Goel).

The campus of California Polytechnic State University houses numerous buildings of various ages and types of construction. There was no reported structural damage on this campus. The only significant nonstructural damage was to a light fixture in the Recreational building; one of the vertical rod supporting the light fixture pulled out from the roof due to insufficient thread length (Figure 29).



Figure 29. Damage to a light fixture in Recreational building on the Campus of California Polytechnic State University, San Luis Obispo (Picture by Rakesh Goel).