

The Resistance of American Pioneer Masonry and Mexican Adobe Buildings to Shaking in the 1868 Hayward Earthquake

The 1868 Hayward earthquake generated the strongest ground shaking that the Californios and American pioneers in northern California had ever experienced. The earthquake represented the first seismic test of the adobe and masonry buildings in Alameda, Santa Clara, and Contra Costa Counties, and changed masonry practice throughout northern California. As a result, the built environment that suffered the 1906 earthquake was significantly more seismic resistant. To correctly evaluate Modified Mercalli Intensities for the 1868 earthquake, it is necessary to gauge the fragility of the Mexican and early American buildings.

For the American masonry structures, built in the 20 years following the annexation of California in 1848, this calibration is relatively simple. These brick and concrete buildings were built to withstand fire, not seismic shaking: Richter (1958) would grade them as Masonry D. But our interpretation of the MMI 6-8 intensities is more readily described by considering the damage to a few localities than by referring to Richter's grading system.

The best description of shaking came from Vallejo: "We felt the ground moving beneath our feet in the street, heard a building creak and groan, heard bottles fall from shelving, saw the wares suspended in a tin store vibrating many minutes after the shock, hear that water slopped from buckets and pitchers, clocks stopped, trees swayed as in a gale of wind, houses careened until strong nerved men thought they must surely fall; yet all our buildings, including one, -two, and three story bricks, are entirely unharmed; while in Suisun, Petaluma, Benicia, Martinez, and Pacheco, buildings were cracked from top to bottom; ..." (*Solano Advertiser*, Oct. 22, 1868).

This extensive report is unusual: newspaper reports for most towns are brief and give incomplete summaries of damage. Suisun, Fairfield, and Santa Cruz appear to have only suffered cracked buildings and no damaged chimneys. In Vallejo, one fallen chimney was reported, and in Stockton “some plaster fell; water spilled from buckets; bells rang; some windows were broken; some chimneys thrown down.” (*Daily Evening Herald*, Oct. 21, 1868). We take the Vallejo and Stockton reports as characteristics of MMI 6 effects.

The next half intensity level, MMI 6-7, made manifest the weakness of the pioneer masonry. In Santa Rosa, “nearly all the brick buildings in town are more or less injured. Many chimneys were thrown down, the Court House sustaining the most damage of any building” (*Alta California*, Oct. 22, 1868). In Napa, there were “six chimneys thrown down; many brick buildings cracked; large amounts of plaster knocked off.” (*The Napa Register*, Oct. 24, 1868). In Benicia, “every brick building was more or less damaged ...” (*Solano Sentinel*, Oct. 22, 1868).

“Half the chimneys down” is the benchmark that Boatwright and Bundock (2005) used to assign MMI 7 at many locations shaken by the 1906 earthquake. No newspaper report similarly quantified chimney damage for the 1868 earthquake. The extent of chimney damage must be gauged from the tone of the reports. Fortunately, the damage to pioneer masonry is also well marked at MMI 7: gables and unbraced walls start to separate and fail, and stone buildings can be more severely damaged.

Three sites typify MMI 7 intensity. “At Martinez, many chimneys were thrown down. Two of the walls of the new stone building at the Alhambra Hotel were partially thrown down.” At the John Marsh house, “the heavy [stone] tower ... was partially destroyed, ... and all the chimneys were also thrown down, ...” (*Contra Costa Gazette*, Oct. 24, 1868). In Petaluma, “a great many chimneys in different parts off the city were broken off at the

roof, and many entirely destroyed. One large stone residence had the entire front thrown down.” (*San Francisco Morning Call*, Oct. 22, 1868). These three localities typify MMI 7 intensity.

The next half intensity level, MMI 7-8, is marked by most or all chimneys damaged, and many masonry and concrete walls damaged, but usually no buildings collapsed. On Broadway in Oakland, there was “an avalanche of bricks and mortar from falling chimneys and fire-walls” (Wollenberg, 1993). Brooklyn and Alameda suffered similar damage to chimneys and masonry buildings. In Pacheco, the serious damage was “confined to the brick and concrete structures, though most of the frame buildings lost the chimneys above the roofs,” (*Contra Costa Gazette*, Oct. 24, 1868).

Damage to pioneer masonry buildings begins to saturate above MMI 8. That is, at these higher levels of shaking, all brick and concrete buildings are damaged to some extent and some have collapsed. Fortunately, few communities were shaken so severely by the 1868 earthquake. In Alvarado, a brick warehouse was destroyed, and “T.F. Meyers’ Hotel went off its foundation and was wrenched out of shape considerably.” (*Alameda Democrat*, Oct. 28, 1868). In San Francisco, some of the masonry buildings downtown, on “made-land,” suffered partial collapse. Both of these localities were assigned MMI 8. We note, however, that this is the highest intensity assigned in San Francisco: other localities in the city were assigned MMI 5-6 to MMI 7-8.

Estimating the shaking intensity from damage to Mexican adobe buildings is significantly more difficult. The first problem is that only two adobe buildings (the Davis-Estudillo house in San Leandro and the church at Mission San Jose in Fremont) were reported as damaged by the American newspapers. Fortunately, this circumstance has been remedied by searching other historical sources, including Hendry and Bowman’s (1945) remarkable compilation of Spanish and Mexican adobes in the Bay Area. Where the

other historical sources describe six adobe buildings as damaged by the earthquake, Hendry and Bowman (1945) describe 11 more adobe buildings as damaged by the earthquake and provide grounds to suspect that 17 other adobe buildings were also damaged, by documenting that the buildings were razed within ten years after the earthquake.

The second problem is the great range of fragility of adobe buildings. Adobe buildings performed poorly at many locations that the 1906 earthquake subjected to moderate shaking (Boatwright and Bundock, 2005). On this empirical basis, adobe buildings should be graded as the weakest masonry. But a well-constructed adobe building is as strong or stronger than an unreinforced brick building: the walls are usually thicker and there is less rigidity contrast between the bricks and the mortar (Tolles et al., 2000). So why did adobe buildings perform so poorly in the 1906 earthquake?

As Tolles et al. (2000) point out, a new adobe building is jointless or monolithic. Intact adobe brickwork is relatively strong, but brittle. When an intact adobe building is subjected to moderate shaking, it develops cracks: if it is shaken strongly enough, these cracks coalesce and reduce the structure into “an assemblage of adobe blocks.” The resulting cracked adobe building is significantly weaker than the original building. If it is shaken again, the “jointed” pieces can shift relative to each other, so that wall sections can fall out or corners can fail, causing partial collapse.

Thus, to understand the fragility of an adobe building, it is necessary to know both the construction type and seismic history. On the face of it, this requirement appears insurmountable. However, our effort is aided by the similarity of the adobe buildings we evaluated and the relative lack of large earthquakes before 1868. Most of these one and two-story structures were built in the 1840's to establish settlement of the ranchos, the large land grants given out by the Mexican government. Adobe buildings continued to

be built through the 1850's, but by the 1860's, adobe construction had given way to wood-frame construction, even among the remaining Californios.

The adobe buildings damaged by moderate shaking in the 1906 earthquake were relatively old (> 50 years). In addition, these buildings had been damaged and weakened by the large earthquakes in the Bay Area that preceded the 1906 earthquake, so they could be damaged by MMI 6-7 shaking (Boatwright and Bundock, 2005). This baseline estimate for adobe damage is corroborated by Tolles et al.'s (1996) survey of historic adobe buildings shaken by the 1994 Northridge earthquake: they found that MMI 6-7 shaking was sufficient to damage these historic buildings if they had not been retrofitted.

There are two documented examples of previously weakened adobe buildings damaged by the 1868 earthquake. The first is the abandoned Mission building or hopsice at San Mateo, which was "badly damaged" by the 1868 earthquake. This building was damaged and weakened by the 1838 earthquake, and abandoned. The shaking in San Mateo is estimated to be MMI 6-7. The second is the Jose Domingo Peralta adobe in Berkeley that "was cracked by the earthquake of 1856 and was so badly injured by that of 1868 that it was razed soon thereafter" (Bowman, 1951). The shaking in northwest Berkeley is estimated to be MMI 7.

Unfortunately, we have no guide to estimating the seismic resistance of intact adobe buildings. The simplest approach is to consider historic adobe buildings that were strongly shaken by the 1868 earthquake but not reported as damaged. The Encarnation Bernal adobe in Lafayette, the Jose Joaquin Moraga adobe in Orinda, and 1841 adobe mill built by Jose de Jesus Vallejo at the mouth of Niles Canyon all survived MMI 7-8 shaking without reported damage. We assume that these buildings were cracked and weakened by the 1868 earthquake, however.

At other sites, specifically, Vicente Peralta's residence in Temescal, Antonio Maria Peralta's residence in Fruitvale, and near the town of Alamo, MMI 7-8 shaking severely damaged one adobe building and left a second adobe building habitable, but weakened. In Warm Springs, two Higuera adobes were damaged while three other Higuera adobes were still habitable: this locality was also estimated to suffer MMI 7-8 shaking.

Finally, MMI 8 shaking appears to be sufficient to strongly damage and partially collapse intact adobe structures. In Mission San Jose, MMI 8 shaking damaged the Church, the Priest's House, the Tienda, and the Mission building itself. We note, however, that Jose de Jesus Vallejo's residence at Mission San Jose was not severely damaged (Hendry and Bowman, 1945). West of San Leandro, Ignacio and Francisco Peralta's adobe houses were severely damaged by MMI 8 shaking. In San Leandro itself, MMI 8-9 shaking entirely collapsed the Davis-Estudillo residence and partially collapsed the well-built Estudillo House.

Because most or all adobe buildings are damaged, estimates of intensity from adobe structures saturate above MMI 8, similar to estimates determined from pioneer masonry. It is hard to compare the strength of American pioneer masonry and Mexican adobe because few of the towns in Alameda County had mixed populations in the 1860's. San Leandro, which began as a "sobrante" town situated between the Peralta and Estudillo ranchos, may have been the most integrated: adobe, masonry, and wood-frame buildings were all damaged there.