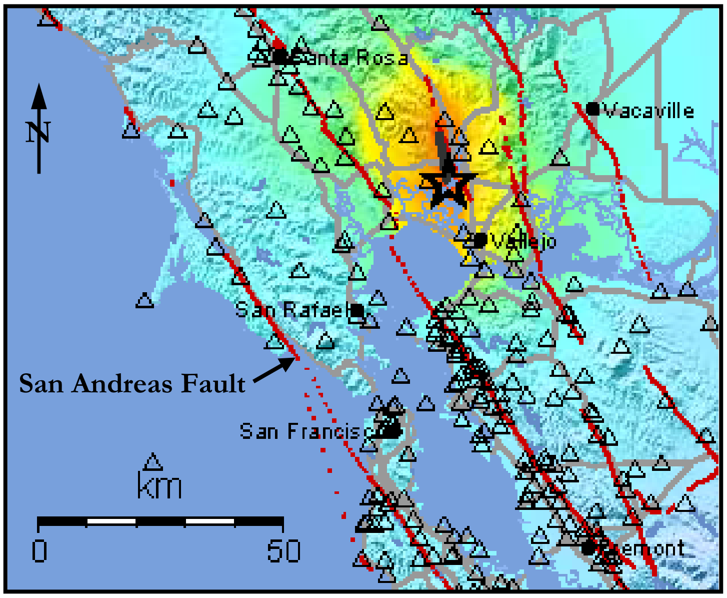
M6 SOUTH NAPA EARTHQUAKE
August 24, 2014

MRP Engineering Summary Report **September 2014**



Shakemap with recording stations and faults. Source: USGS

On August 24, 2014, at 3:20am, a M6.0 earthquake struck an area in northern California, about 50 kilometers north-northeast of San Francisco. The earthquake originated near the West Napa fault, at a depth of 11 kilometers. The regional seismicity is associated with a system of northwest-trending active faults that define this broad boundary between the Pacific and North American tectonic plates. Major regional faults include the San Andreas, which last ruptured in 1989 in the vicinity of Santa Cruz, California (M7.2 Loma Prieta earthquake), resulting in over $20 billion in losses. The South Napa event affected the local residents, communities, and industry, with economic losses estimated to exceed $1 billion. This report summarizes MRP Engineering observations of earthquake impacts conducted August 24 through 26, 2014.

NAPA CITY CENTER

The city of Napa (with a population of about 80,000) is located approximately 10 kilometers north of the earthquake epicenter. The region is home to over 500 wineries and attracts three million visitors annually. Napa County annually contributes over $25 billion to California's economy. Ground shaking affected historically significant buildings, residential structures, government facilities, critical utility operations (water distribution and telecommunications), as well as wine storage sites. The recorded horizontal peak ground accelerations near the epicenter approached values used for seismic design of modern structures. The region was recently affected by earthquakes in 1989 and 2000. Proactive structural and bridge upgrades lessened the impacts of this earthquake. However, significant damage was observed to unretrofitted and some retrofitted unreinforced masonry structures, as shown below.

This three-story structure includes an unreinforced masonry façade, a portion of which collapsed onto the sidewalk below. The close-up photo shows remaining wall anchorage connections below the roofline.

UNREINFORCED MASONRY (URM) BUILDINGS

Low-rise unreinforced masonry (URM) structures typically consist of brick or stone bearing walls and an interior wood frame. These pre-1930s structures are known to be vulnerable to earthquake damage, with safety implications. Typical weaknesses include: brittle wall construction, lack of structural connections between walls and interior framing, weak mortar, slender walls, extensive storefront openings (weak story), and heavy parapets (walls extending above roofline). Seismic retrofits typically tend to focus on occupant safety or preventing collapse. In 2006, the City of Napa passed an ordinance requiring retrofits of its 44 URM structures, though reportedly not all of these were in compliance at the time of the South Napa earthquake. We observed structural damage to both retrofitted and unretrofitted URMs, as shown below. URM structures are common in earthquake-prone areas such as western Oregon and Washington states, where seismic upgrades are typically voluntary, unless a change in use or a major renovation is proposed. The recent series of earthquakes that impacted Christchurch, New Zealand, has demonstrated that such "passive" upgrade policy may not be adequate in preserving communities with URM building stock. Landmark URM structures require retrofits beyond life-safety. Implementation of structural upgrades for URM buildings may require financial incentives.

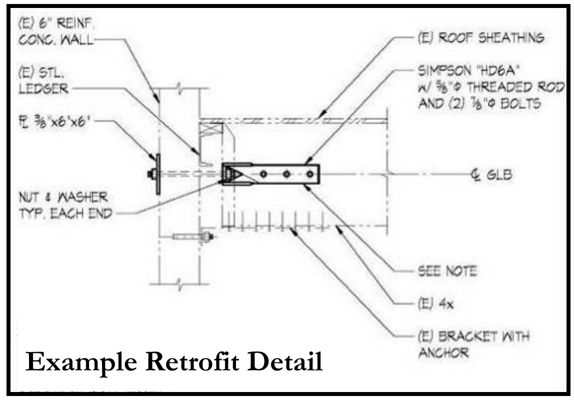
Damaged 1875-vintage stone masonry building in Napa.
Note wall anchorage (through bolts with steel plates) in the close-up photo

Masonry wall failure in a building retrofitted with wall anchors at roof and floor levels.

Retrofitted URM building that survived the earthquake. Upgrades included wall anchors and a steel braced frame at storefront.

GENERAL OBSERVATIONS

The Napa region is dominated by low-rise construction of various vintage. Limited structural damage was observed to structures designed according to modern seismic design criteria. Structural retrofits to vulnerable structures, such as pre-1990s reinforced concrete tilt-ups, lessened the earthquake impacts. However, significant losses are likely from damage to in-building nonstructural components, utilities, or piping that lacked seismic restraint.



Proactive upgrades of reinforced concrete tilt-up structures can be effective in preventing roof and wall separation. This building in Napa that survived the earthquakes was retrofitted with wall-to-roof thru-bolt connections.

Ground rupture in an elementary school parking lot south of Napa resulted in fracture of underground water piping.

Precast concrete wall panel connections failure at a local telecom hub damaged HVAC system at this critical facility.

Residential wood-framed structures that predate modern seismic design consideration can shift from their foundations when short wood-framed walls are present surrounding the crawl space below the main floor. These common failures can lead to a fire-following-earthquake hazard from severed natural gas piping and nearby electrical components. Correcting this condition involves installation of plywood sheathing with floor and foundation connections.

EARTHQUAKE IMPLICATIONS AND LESSONS

The M6.0 South Napa earthquake serves as another reminder that even moderate events can result in major impacts on local communities and significant losses for key business operations. A similar daytime event would have likely resulted in more injuries. Implications for this region and other earthquake-prone areas are:

- The recorded horizontal peak ground accelerations near the epicenter approached values used for seismic design of modern structures. The ground rupture passed very near a school campus.
- For earthquake-prone regions with URM building stock, active URM upgrade policies with funding incentives are needed. Retrofits of landmark structures need to go beyond "life-safety" considerations.
- Functional regional lifelines are critical to rapid post-earthquake recovery. The local highway system performed well. The bridge retrofits included foundation upgrades and proved successful.
- Wine barrel warehousing practices in California and the Pacific Northwest need to be updated to provide safe and stable storage.
- Early earthquake warning systems should be funded. Advance warning from seconds (California) to minutes (Pacific Northwest) can save lives. In this event, the prototype early warning system provided 12-seconds advance notice to the San Jose area.
- Earthquake losses can be dominated by in-building equipment damage. For critical operations, in-building power backup systems should be redundant and tested to provide reliable performance.

MRP ENGINEERING

MRP Engineering is a structural engineering and risk analysis firm (based in metropolitan Seattle, Washington) and provides proactive risk analysis for natural hazards, damage investigation, and upgrade design. We assist clients in protecting their business operations from risks to physical assets resulting from extreme events such as earthquakes and hurricanes. We provide high-quality technical expertise in evaluating the risks and structural issues, and recommend to you the appropriate risk-mitigation strategies. In providing these services, we balance innovation with tested approaches that result in practical and cost-effective structural engineering-based risk reduction solutions that contribute to your safety and success as an organization. We have also performed investigations of structural damage following the recent earthquakes in Haiti (2010), Chile (2010), New Zealand (2011), and Japan (2011). Lessons learned from these earthquake investigations are then applied in serving our clients.

Services include:

- Earthquake and wind risk evaluation
- Structural benefit-cost analysis
- Upgrade design
- Independent design review
- Damage (root cause) investigation
- Expert witness and claim support