OBSERVATIONS OF STRUCTURAL PERFORMANCE NEAR STRONG-MOTION STATIONS DURING THE ITALY L'AQUILA EARTHQUAKE

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Abstract

The deployment and retrieval of strong motion records over the past 80 years has provided new insight into the intensity, distribution, and character of strong motion. Gathering, processing, and interpreting the records has also become a key aspect of understanding building response and damage patterns. Specific inspections of the buildings around the 2009 L'Aquila Italy Earthquake strong motion recording stations offers yet another glimpse of how well buildings seem to be responding to strong shaking that appears to exceed the design levels. The observed damage pattern beyond the instrumented locations also offers some indication of the variation of shaking and once again demonstrates the need for significantly more instruments.

Background and Observations

L'Aquila is located in central Italy, about 60 miles northeast of Rome in the mountainous Abruzzo region. Construction in the region dates back hundreds of years and includes a rich collection of stone, masonry and concrete buildings. Italy's design standards for the expected earthquakes have been developing since the early 1900's and are similar to those used in California. The magnitude 5.8 earthquake that occurred on April 6, 2009, damaged thousands of buildings, collapsed several dozens, killed just over 300 people and left nearly 70,000 homeless. Italy's 2006 Seismic Hazard map indicates that the region is in the second highest seismic region with an expected PGA of .25g to .275g for the 10/50 earthquakes.

Italy's Rete Accelerometrica Nazionale (RAN) has deployed hundreds of strong motion instruments throughout Italy. Dozens recorded the April 6, 2009, event with four stations located within 6 km of the epicenter. Three of those stations were a part of a five-station array deployed to capture the variation of motion across a valley. The fourth was located near the ancient city and located at the base of the bluff on the north side. The records are posted on the Center for Engineering Strong Motion Data (www.strongmotioncenter.org) as well as from the RAN web site. Extensive documentation for each station site is also available from RAN.

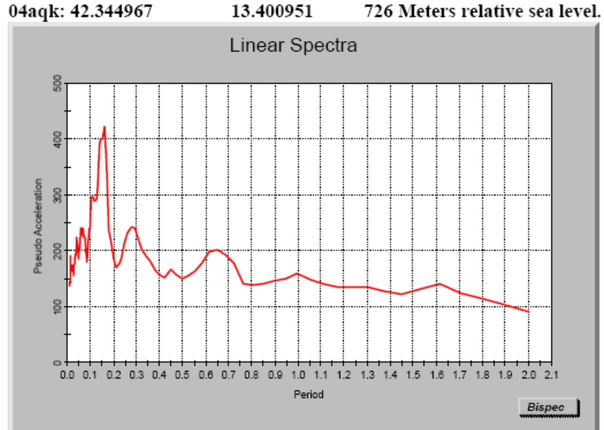
The four strong motion stations near the epicenter recorded peak ground accelerations that varied from .36g to .67g with the strong shaking lasting about 10 seconds. The instrument located at the northeast end of the array reportedly went off scale at 1g, though the record has not been published due to quality concerns. It appears that the earthquake produced ground motions considerably larger than expected for the regions 10/50 earthquake. The response spectra for the recordings show the expected variation due to the local site conditions.

Figure 1 includes a single, sample response spectrum for the record taken nearest the ancient city and a cluster of buildings located nearby. None were seriously damaged. Figure 2 includes three of the five instruments in the valley array along with buildings located in the immediate vicinity. In all cases, damage to the adjacent buildings was light to not visible, even for those in the area of the instrument that went off-scale. The buildings observed included many of the styles of construction in the region and ranged in height from one to six stories. The strength of these records and the lack of damage suggest that acceleration alone is not a good indicator of damage potential.

In an effort to catalogue the variations in the intensity of shaking throughout the region, the extent of damage to reinforced concrete frame/infill buildings was catalogued throughout the region. Four damage states from “Extreme” to “Mild” were defined and assigned based on visual inspection from the street. The GPS coordinates of each building were determined and plotted with an indicator of damage level on a Google Map image of the region as shown in Figure 3. The location of the strong motion instruments is also shown on the figure along with the zones of intensity inferred from the individual building observations. These zones represent the general damage patterns observed within each zone and not the worst-case occurrences.

Initial reports for the region suggested that the city was destroyed and blamed inadequate design standards and poor construction for the outcome. The reality is that the shaking appears to have far exceeded what was expected and the buildings, in general, performed amazingly well. The strong motion records provide the opportunity to better understand the damage and lack of damage that occurred. They also provide the opportunity for earthquake professionals to improve the design, evaluation and analysis techniques used to predict building performance and better account for the effects of variations in the geology and site conditions.

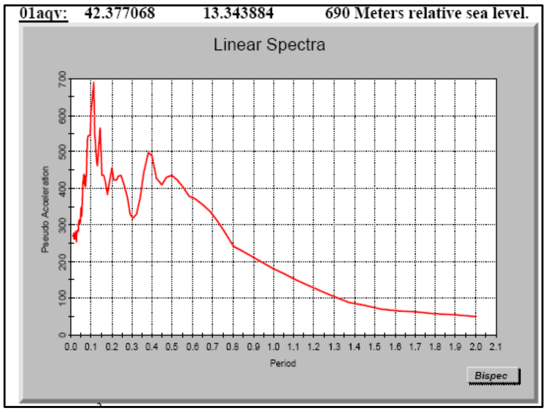
04aqk: 42.344967 13.400951 726 Meters relative sea level.



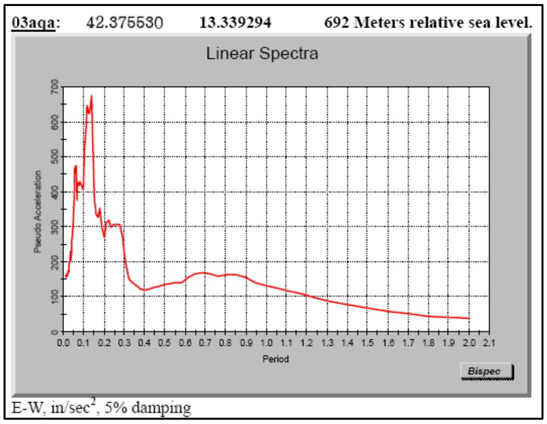
E-W, in/sec^2, 5% damping

Figure 1. Strong Motion record near the Ancient City, .36g PGA

Station AQV, Valley location, .67g PGA



Station AQA, Edge of Valley location, .44g PGA



Station AQG, Rock location beyond valley edge, .51g PGA

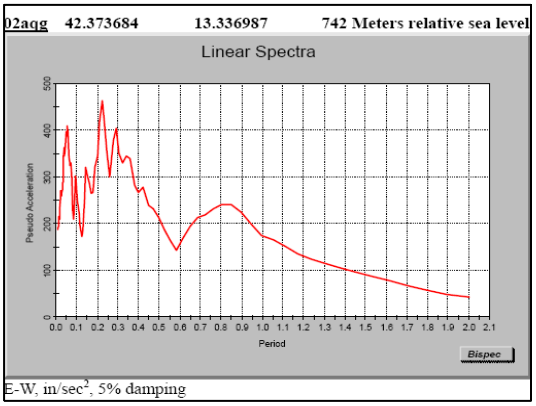


Figure 2. Response Spectra and nearby Sample Building Performance

Figure 3. Inferred Intensity from Damage Observations