L'Aquila Earthquake, Abruzzo. Italy May. 06, 2009 M_w=6.3 – Lifeline Performance

by

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Executive Summary

The overall performance of lifelines was reasonably good when compared with the performance of the structures (excluding the failures of the URM buildings) in this earthquake. Some areas were very heavily damaged resulting in more than 30,000 residents being displaced.

A few areas within the earthquake impacted area were designed as the 'red zone' due to the extensive structural damage. No unauthorized people were allowed in the 'red zone' and military guarded all entrances and fire fighters controlled the access within the 'red zone'. This restricted access might have reduced the impact of lifeline failures within the 'red zones'.

Electric power systems sustained damage of bus connections to transformers in substations, and of fallen poles and terminal pedestals in the distribution system. The network control building was severely shaken and damaged, and so the network control equipment was relocated to a temporary shelter next to the building. The essential part of the operation was completed in less than 12 hours. In some areas the electric power was out for a period of three days.

Underground facilities such a telecommunication cables, and gas pipelines suffered as yet unknown levels of damage in areas hardest hit, and minor damage with minimal service disruption in areas that are still occupied. The reason for the insignificant service disruption was the fact that in the heavily damaged areas the citizens were not allowed back to their houses or apartments. One water transmission pipeline was severed and disrupted service for a short period of time. Many damaged distribution water pipelines could not be identified as water was shut off going into the areas, where major structural damage occurred.

A new wastewater treatment plant did not suffer any structural damage to the aeration tanks and the digester tanks. However, some minor damage to the control equipment and the pumps occurred. The plant ran on the backup power generation plant for three days due to power outage in this area. The older wastewater treatment plant serving L'Aquila had the aeration tank wall collapsed, which rendered half of the treatment plant not functional. Since the citizens were not allowed to go back to their damaged houses and apartments, the usage of the plant was reduced by about 40%.

Only one bridge had collapsed, which was far off the major roadways, and therefore the transportation system performed quite well. There were a few landslides and developing

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landslides on mountain roads near L'Aquila, but this damage did not affect the transportation system in any significant way.

Lifeline Performance

This section will provide details of the damage observed by lifeline.

Electric Power

It was reported that two substations serving the greater L'Aquila had damaged connections between a rigid bus and insulator, Figure 1. That was due to shifting of the un-anchored transformers during the earthquake. Also due to sloshing of the cooling oil within the transformer, cooling oil pressure increased, and actuated the safety shut off feature to avoid costly damage. One of the transformers moved about 14 cm.

In the distribution system, 30 posts were damaged causing severed links that resulted in service disruption. More than 180 pedestal type connection boxes (Figure 2) were dislocated and severed cable connections at the termination lugs that resulted in localized power failure.

The Electric Power Control Center at L'Aquila sustained sever damage (Figure 3), both building and equipment, and it had to be moved to a temporary building in the yard of the building premise. It took three days to complete the move, while the essential part of the system was functional by 9 AM the day after the earthquake (Figure 4).

Transformers in substations were not anchored. We noted that steel angles were welded on the tracks that the transformers were supported to stop sliding, Figure 5. This was done after the earthquake. However the steel angles seemed to be under sized.

In the control house of substations, the batteries were not anchored or tied to the racks, Figure 6. There was no batteries damage reported at these substations.

Some locations were without power for three days, e.g. wastewater treatment plant.

Telecommunications

Telecommunication service performed reasonably well. It went off air for a couple of hours right after the earthquake. Cellular phones seemed to be the main means of telecommunication in this small community. Although there was no reported damage to the physical equipment and equipment building, we saw a number of temporary cellular sites deployed within the earthquake impacted areas, Figure 7. The increase of cell sites might have reduced the circuit overload that commonly occurs after an earthquake.

Both Fire Fighters and Police used their own radio system as the primary communication tool. Cellular phones were also used to compliment the radio system. With a good backup power generation plant, their communication was not interrupted. The Fire department had three repeater stations, which were not damaged.

A number of landlines were damaged or severed, as repairs were evident during our investigation, Figure 8. Since tenants were not allowed back to their houses or apartments, most landlines were not used. Hence the demand on this circuit became much lighter.

Transportation

The only significant damage to the transportation system was the widely reported bridge collapse with one span unseated from the abutment. One bridge in the 'red zone' had a slight abutment shifted and some localized cracking, and one bridge outside of the rural town of Onna had some damage to the girders and evidence of movement. It was still open.

We did not observed any other significant damage that would impair the transportation system of the region. On highway SS80 leading to the Lake Campotosto where we planned to inspect the three dams of this lake, we came across a couple of sections of slumping damaging about 30% of the width of the south bound lane, and a failed retaining wall of the abutment of a bridge, Figures 9 and 10.

The region has many tunnels, they all performed well with no service interruption.

Water and Wastewater

The information regarding water pipe breaks was not available. In order to identify leaks the system had to be charged. Since water is turned off in the 'red zones', there was no means to find out how many breaks were existing in the system.

When visited Paganica, through a trail of water running down hill, we met a repair crew was working on a shut off valve in the manhole, Figure 11. While on the other side of the town, there was a new transmission pipe along a small slope replacing a damaged one. This transmission pipeline was still exposed.

We visited the main water supply tunnel and storage system in the mountain and it had no damage.

Water consumption was reduced by 30% as a result of water shut off leading into the 'red zones'.

In addition to bottled water, mobile water tankers were also used to serve the relief camps.

There were two wastewater treatment plants serving the greater L'Aquila area. The older treatment plant had sustained significant damage to the aeration tank wall spilling unpleasant liquid, Figure 12. It was cleaned up and part of the facility was closed. The affluent intake pipe joint was also damaged during this earthquake, Figure 13.

At the newer treatment plant, power was off for three days. This site ran on its own backup power generator for the three days to deal with wastewater in the area. A pipe connected to the pump in the control room was damaged due to shifting (about 15 cm) of the unanchored pump, Figure 14.

One of the facility managers told us that the total capacity was reduced to about 60%. Luckily with large number of building damage and residents not allowed to return to their homes, the demand was much reduced.

Dams

There were three dams that created the reservoir called Lake Campotosto. There was no apparent damage to any of the dams. The area did experience some strong ground

motion, as there was some building damage. A small relief campsite was set up for the victims in this area.

Reservoir Water level was reduced as safety precaution.

Gas

We visited a location close to the town called Onna where a small gas pipeline crossed a small creek. The pipeline was damaged and was replaced with a new pipeline. There were two new concrete abutments on either side of the crossing that supported the pipe. The pipe was rigidly connected to the abutment with no flexible connection between the pipe and the bridge foundations, Figure 15.

We did not come across any gas storage facility in the region.

Schools

There were 57 Primary and Secondary Schools sustained various degrees of damage in this earthquake. There are six classes of structural conditions that the post earthquake inspectors can assign to the buildings. Classes A and B are acceptable to return to after minor fixes, while classes C, D, E, and F ranges from structural fixes to demolition.

The University of L'Aquila had several buildings damaged, classes were moved to temporary sites around the city. A portion of a university student residence collapsed with the remaining portions severely damaged, Figure 16.

Emergency Services and Shelters

The Italian government organizations and NGOs (Non-Government Organization) were to be commended on a great effort providing the victims with relief services and care. The military and fire brigade set up service camps to provided needed services to the victims.

Some of the relief campsites provided the victims with Internet services in addition to daily necessities such as medication, food, and water. In general the victims were very satisfied with the relief service. Many residents were afraid to get back to their houses even when their houses (marked as class A or B) were not condemned, due to their fear of future earthquakes and the potential for damage to their homes.

Temporary housing is scheduled to be completed by September 2009 (before winter arrives) for the victims, Figure 17. These houses will be on a base isolation system to protect residents from future earthquakes.

There were more than 30,000 victims settling in more than 160 campsites, Figure 18.

Observations and Recommendations

The military and the fire brigade along with the Civil Protection Agency had done an excellent job coordinating the emergency response effort. Managing more than 160 sites dealing with health, food, water, and daily necessities was not an easy task. An in-depth study to find out the how and what of this effort will benefit other emergency response service groups in being able to respond effectively.

Anchoring equipment should be the priority in securing lifeline equipment. Even in cases where there was no damage from this event, it is still important to positively secure equipment, both functional and non-functional.

Flexible joints of pipes at transition points should also be a common practice.

More details will be provided in the ASCE post earthquake monograph to be composed by the investigation.

Acknowledgment

We really are very grateful of the support that Professor Gianfranco Totani, and Professor Iunio Iervolino provided. Without their kind and dedicated effort we would not be as successful in obtaining the lifeline information. Professor Iervolino was instrumental in setting up the necessary contacts for us prior to our arrival. Professor Totani took time off from his teaching to accompany us throughout the whole period when we were in Italy. When he really could not skip his job he made special arrangements for us so that we can get what came for and were continually introduced to local people that were intimately involved in the response and recovery efforts. His hospitality was unsurpassed.

We also like to thank Professor Andrei M. Reinhorn of University of Buffalo who introduced us to the contacts in Italy.

Figures

Figure 1. The rigid bus connection at the top of the transformer was damaged during the earthquake.

Figure 2 A lot of this type of low voltage distribution connection boxes was damaged resulting in power interruption.

Figure 3 The electric power network control building was damaged and repaired.

Figure 4 The temporary electric power network control room was set up and operational within 12 hours after the earthquake.

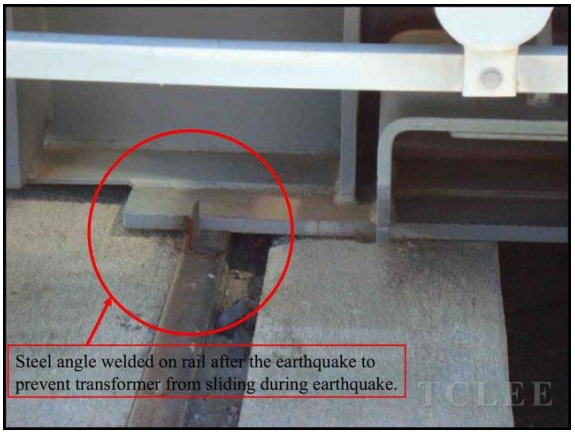

Figure 5 Steel angles were welded to prevent the transformers in substations from sliding after the earthquake.

Figure 6 Unanchored battery racks and the batteries on the racks were not secured were common in substation control rooms.

Figure 7 Many temporary cell sites like this shown were set up to compliment the landline communication service.

Figure 8 Underground telecommunication landlines were damaged and being repaired.

Figure 9 Some part of the State highway SS80 was damaged, this shows the displacement of the retaining wall and surface crack on the road surface. The offset was about 9 cm.

Figure 10 Road surface rupture repair was in progress.

Figure 11 A water valve in a manhole was being repaired in Paganica.

Figure 12 This aeration tank in the old wastewater treatment plant was damaged. Note the wall of the tank collapsed. The dirt water spilled all over.

Figure 13 The waste intake pipe at the old treatment plant was dislocated at the joint, leaking dirt water.

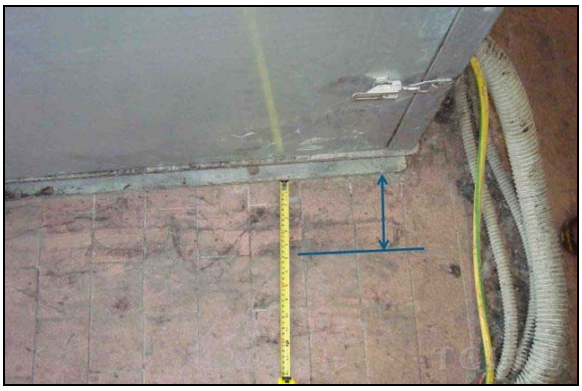

Figure 14 The pump in the control room of the new wastewater treatment plant was not anchored and shifted during the earthquake. It shifted about 15 cm.

Figure 15 This new gas pipeline replaced the old damaged one in Onna. Note that the pipe is fixed on the concrete block.

Figure 16 The student dormitory was severely damaged with one part collapsed.

Figure 17 The base pad for the temporary housing units was being filled with concrete. There were three pads on this site.

Figure 18 This is one of the many shelter areas organized by Civil Protection Agency, the Red Cross, the military and the fire brigade.