2.12 Emergency management for lifelines and rapid response after L'Aquila earthquake

M. Dolce[1-3], S. Giovinazzi[2], I. Iervolino[3], E. Nigro[3], A. Tang[4] ■

2.12.1 Introduction

Performance of lifelines during the April 6 event may be considered generally good if compared to the extended losses related to buildings (Verderame et al., 2009), nevertheless damages and service downtime, which required recovery and emergency management, occurred. In the following, for each of the main lifelines in the L'Aquila area (i.e., road network, water distribution, gas distribution, power distribution, water distribution and treatment, telecommunications and post-event aid to population), the emergency management strategies adopted to recover the systems and restore their functionality in the shortest possible time are described. Finally, criteria adopted to define priorities and to allocate resources for the temporary housing camps are discussed. From the reported investigations it is concluded that the emergency management of the lifelines networks provided a rapid and resilient response to the earthquake. The emergency management procedures implemented for the physical and functional restoration of lifelines, after a proper codification may become a reference model for the Civil Defence at international level.

2.12.2 Road Network

ANAS S.p.A. is the agency that manages in the Abruzzo Region, as well as in the rest of the national territory, the state road network. The residual functionality and safety investigation of the road network were the first priorities identified by ANAS for the management of the first phase of the emergency. Physical and human resources were deployed to achieve the following goals: 1) rapid survey of the road network to ensure, at the largest possible extent, the regional mobility; 2) activation of emergency contracting procedures ("somma urgenza" agreements) to immediately begin, where possible, activities for the restoration of normal mobility conditions; 3) damage survey of the road-network components; 4) short term planning for the repair of damaged components.

At the same time, physical and human resources were deployed in support of the Civil Defence for a first partial debris removal and for the excavations works necessary for the installation of relief campsites. It worth mentioning that, further to the local resources, additional ones were used to manage the emergency. These resources were available from few ANAS' Regional compartments differently located on the national territory, with an average daily commitment of 80 men and 70 vehicles.

Rockfalls (Fig. 1a) and landslides triggered by the earthquake and aggravated by the heavy rain that hit the area in the days following the event, were identified as the most problematic situations affecting the network mobility. However, the rock falls and landslides occurred mainly in mountainous areas around L'Aquila, while the main road network in the city was not affected by the aforementioned phenomena. In the urban area, mobility limitations were caused by debris following damaged and/or unsafe residential and monumental buildings adjacent to the roads.

Immediate activities for the restoration of normal mobility conditions included: 1) removal of rocks and soil from the roads; 2) rock slope consolidations; 3) enhancement of soil slope stability. These activities were conducted employing, where possible, internal resources or activating, alternatively, emergency contracting procedures with external organisations. Securing of unsafe buildings adjacent to roads was carried out by firemen.

Temporary traffic management measures were extensively implemented in order to minimize road closures; these measures included traffic flow restrictions; alternating one-way; lane and velocity restrictions (Fig. 1b).

The only significant damages occurred to the

[1] Ufficio Rischio Sismico, Dipartimento della Protezione Civile, Roma. www.protezionecivile.it
[2] Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch. www.civil.canterbury.ac.nz
[3] Dipartimento di Ingegneria Strutturale, Università degli Studi di Napoli Federico II. www.unina.it
[4] Technical Council on Lifeline Earthquake Engineering, American Society of Civil Engineers, US. www.asce.org/instfound/techcomm_tclee.cfm

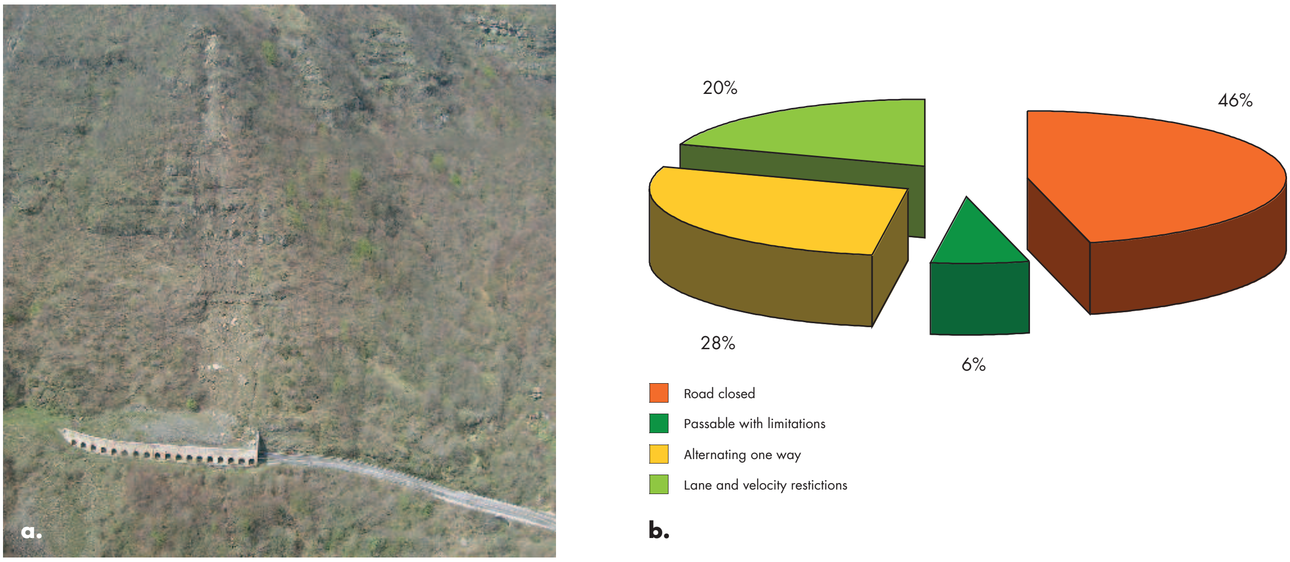


Fig. 1
Impact of the earthquake on the road network: (a) SS80 "Gran Sasso d'Italia" road affected by rock falls, but featuring rock-proof tunnels. (b) Distribution of traffic management solutions (updated to 01/05/09) for the 61 road tracts affected by the earthquake (red = road closed; dark green = passable with limitations; yellow = alternating one way; light green = lane and velocity restictions).

road network components were the structural failure of the viaduct "Corfinio" on the national roadway SS5 and the collapse of a bridge on the main road SP36 "Forconese". No further significant damages were reported to the components of the road networks including the numerous tunnels present in the Region that performed well.
The urgent need for a standardized and structured survey form to report damages and disruptions in the road networks was highlighted while performing safety investigation and damage survey operations. A rapid survey form and an ad-hoc procedure were therefore identified and formalised while the survey work was in progress.
The timely information on the mobility conditions was a key component of the effective emergency management. The Civil Defence issued daily a report summarising road closures, mobility restrictions and repair works carried out in the road network. Using a Geographic Information System, GIS, the technical compartment of the Direction of Command and Control, Di.Coma.C represented this information in a cartographic format. Road closures and other temporary traffic management measures were overlaid to aerial photographs, technical regional maps, etc. providing maps that had a fundamental role in supporting many emergency management operations.
As for the public information, emergency bulletins were regularly issued to update in real-time the end-users about the mobility situation in the Abruzzo Region. Communications and timely news were, as well, posted on the ANAS website.
Once the firth phase of the emergency was managed, efforts and resources were concentrated, on one hand, to handle the modified traffic conditions in L'Aquila city due to the closure of the main road that ran through the city and, on the other hand, to respond to the new mobility requirements created by the relief camps, and by the construction of the provisional accommodation: Temporary Housing Modules M.A.P., and C.A.S.E. project.

2.12.3 Water distribution network

Gran Sasso Acqua G.S.A. SpA is the water provider for L'Aquila city and for 37 municipalities in the earthquake area. The organisation offers an integrated water service including potable water supply, sewerage and wastewater treatment.
The G.S.A. has 3 major supply systems (Chiarino, Gran Sasso, Water Oria) in addition to some secondary ones. The water supplied is transported by a network consisting of approximately 900 km of large diameter pipes and is stored in a huge number of tanks (about 200) that require continuous functional and hygienic monitoring and maintenance. The water is distributed from the tanks to approximately 100000 customers through a 1100 km distribution network made of quite old cast iron and steel pipes. The pressure inside the main pipeline network is quite high, reaching 30-50 atm., as well as in the distribution networks where it can reach 6-8 atm.
Thanks to a remote control service and guided valves connected, through cables or wireless connection, to the main reservoirs and supply systems, it is possible to check the water flow inside the pipeline network and to manage partial or total opening/closing operations directly

Fig. 2
Impact of the earthquake on the water distribution network: (a) Joint slip-off in a main water network pipeline in Paganica. (b) Repair on a cast iron pipe in a Paganica at the moment when some of the evacuated people were returning home.

from the Gran Sasso Acqua headquarters. In particular, electromagnetic sensors, measuring input low pressure, and electromagnetic gauges (or "Clamp on"), measuring output differential pressures, are installed in the tanks. The remote control service allows furthermore the assessment of the water level in the tanks.

The equipment connected to the remote control system revealed, on the morning of April 6, a significant and sudden change in the water flow for a main pipeline in *Paganica*. The immediate closure of the relative shutters for that pipe was operated directly from the GSA headquarters, before the technician team reached the affected site. The cause of the rupture was identified in the fault crossing the Paganica pipe. Because of that, the steel joint of the pipeline (diameter Ø = 600 mm; pressure 25-30 atm) slip-off, causing a violent escape of water (Fig. 2a).

A connection portion at the joint, however, was still grasped for a length of 6cm. In order to quickly respond to the emergency, the repair was limited to the welding of the pipes at the joint.

Exception made for the aforementioned joint slip-off, no significant damage was observed to the main distribution and storage system. Following the repair of the damaged joint it was, therefore, possible to restart the provision of potable water for all municipalities administered by the G.S.A. SpA since the evening of April 6. As a lot of ruptures were expected in the minor water distribution system, in order to prevent flooding and deterioration in the buildings already damaged, the decision was made, not to restore the water distribution in L'Aquila historical centre and in the most affected villages. For these areas, the restoration of the water provision was gradually operated starting from the less affected zones and/or the zones with a strong need for reactivation; priority was given to the strategic services, secondly to the commercial and industrial activities, including the hotels to be reopened for the G8 meeting, and finally to the residential buildings classified safe, after the specific AeDES survey. The partial restoration of the water distribution was possible because of secondary networks and of a shutter system that allowed the exclusion of areas where the water supply was not urgently needed. A few days after the earthquake (19 April), due to a further slip of the fault, the welded joint of Paganica pipe broke, requiring a further repair intervention.

The priorities identified in the second phase of the emergency management were, on one hand, the provision of the water service to the relief campsites and, on the other hand, the management of all the activities for restoring the water provision in L'Aquila City. To carry out the works for the water network connection in the relief campsites, the technical staff of the company (fully operative since the third day after the earthquake) was supported by the "Genio Civile" staff. On the other hand, the works for repairing damages and restoring the functionality of the water service in L'Aquila were operated, where possible, by the G.S.A. SpA technicians, or activating emergency outsourcing procedures for the most demanding operations. Relationships with external organizations have been unfortunately, nowadays, interrupted because of the financial difficulties that the company is undertaking due to the lack of income.

Most commonly observed damages in the minor distribution system were the slippage/breakage of the joints and the breaking of cast iron pipes (Fig. 2b). It is important to emphasize, however, that in large part of the "red zones" (damaged zones with prohibited access) the water network is still closed. Because of that, it has not yet been possible to completely estimate the extent and

the spread of the damage suffered by the network[1].
Finally, it is worth mentioning that the drinking water purity and quality has been officially tested and certified daily since the early days after the seismic event. Because the G.S.A. official testing laboratory was severely damaged after the earthquake, this service was guaranteed via mobile laboratories of a neighboring water organization, C.A.M.
The third phase of the emergency management focused on the construction of the water distribution network and connections for the sites identified for the construction of the provisional accommodation: Temporary Housing Modules M.A.P., and C.A.S.E project. Both the design and the new construction of the reservoirs and of the distribution network for these areas were committed to external organizations and contractors. The costs for both the design and the construction of the new reservoirs and networks for the temporary accommodation were covered by the Civil Defence. The G.S.A. SpA will continue to be in charge of the management of the water provision for the temporary accommodation areas.

2.12.4 Wastewater treatment plant

The technical visits at the wastewater treatment plants serving L'Aquila (AQ), in the resorts of Ponte Rosarolo, Pile and Arischia, and at that located in the City of Corfinio (AQ) have shown that examined systems have similar technical characteristics, as they have the same practical functions (Nigro & Bilotta, 2009). Each plant was equipped both with the structures necessary for the treatment of wastewater (primary clarifier tank, aeration tank, digestion tank, settling tank, thickener, sludge dewatering band press and chlorinator system) and with those for management purposes (buildings used as offices, rooms for technical equipment and laboratories).
The facility in Ponte Rosarolo is located near the historical center of L'Aquila (42°20'18.10"N - 13°23'39.09"E). Structures were built the '60-'70. The reinforced concrete digestion tank suffered partial collapse of a longitudinal wall (Fig. 3a), several vertical cracks on a transversal wall and the separation of orthogonal walls at the edges (Fig. 3b). The partial collapse of the wall also involved the steel pipe adducting wastewater that was connected to it. In buildings used as offices, local technological and laboratory equipment (RC framed structure) were also found cracks of both internal partitions and external walls. However, there were no evidences of damage to structural elements: the cracks detected on non-structural elements did not represent significant damages and did not prevent the use of building. The inspected facilities were therefore useable at the time of inspection, except the digestion tank that was useless. Due to this damage the tank has lost water and the plant were partially closed by reducing the disposal capacity of about 60%. The remaining functionality was still sufficient to face the demand, which was significantly reduced due to the large number of evacuated people (approximately 30,000), housed outside the city.
The structures of facility in Pile (42°21'3.25"N - 13°22'13.41"E), which is situated between the town and the industrial area of L'Aquila being the second plant serving the city, were realized in two different periods ('80 and 2000) with RC walls and slabs. Structural damages were not detected, only some damages to the partitions of local offices occurred. With regard to the older settling tanks, characterized by a circular cross section, a deterioration of the curbing RC beam was detected due to significant corrosion of the steel reinforcements.
The inspected structures, therefore, were viable and fully functional despite the damages (of non-seismic origin), due to degradation of materials descending from a insufficient maintenance of the settling tanks. However, in the control room, a tube connected to the pump (not anchored) was damaged due to a displacement of 15 cm, figure 3c. Finally it should be noted that this plant has been out of energy for three days after the earthquake, so it worked through its own backup generator.
The plant located in Arischia (42° 24'49 .02 "N - 13° 20'25 .48" E) presents reinforced concrete structures with the exception of the circular tanks for leaching, consisting of circular walls of artificial masonry blocks connected with a RC curb at the top of the tank, and a gravity retaining wall. The structures date back to the 70s with the exception of RC curb which was more recently constructed. Cracks on the walls of a distribution trap and damages to the retaining stone wall, which led to the partial obstruction of the

[1] The water consumption was reduced by 30% as a result of water shut off into the 'red zones'. Mobile water tankers were used to serve the relief camps in the first days after the quake.

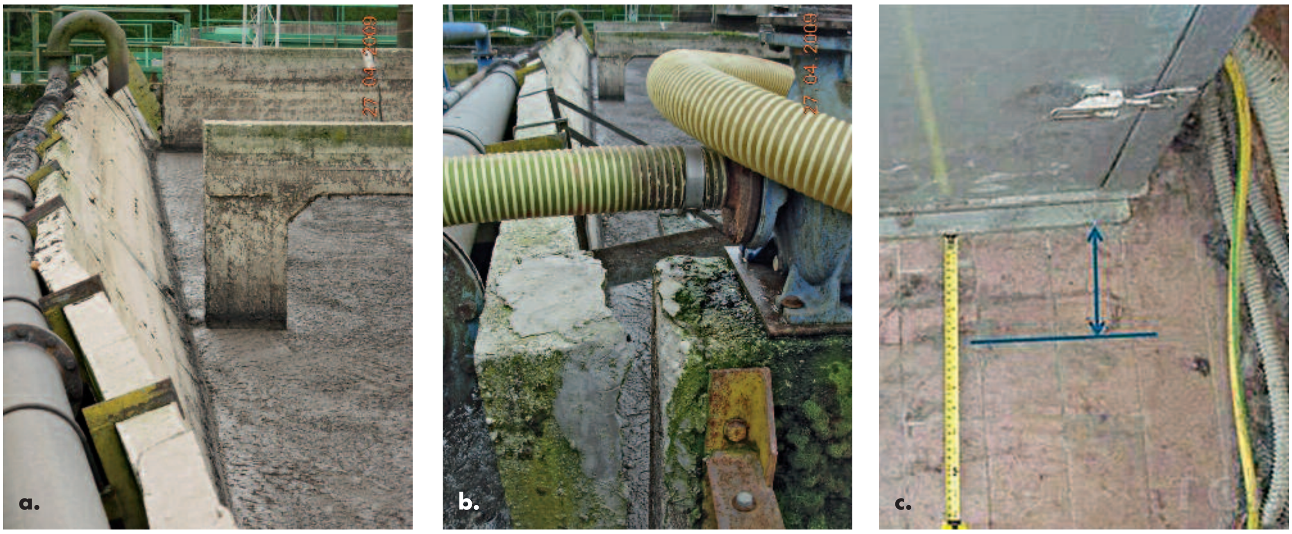


Fig. 3
Ponte Rosarolo Plant. Digestion Tank: (a) partial collapse of a longitudinal wall and of the pipe connected to it. (b) Detail of the detachment of the orthogonal walls at the edges. (c) Displacement of the pump in the control room.

hydraulic groove drain at the base of the tank, were observed. With regard to the circular tanks, one of the two rotating distributors was put out of service for damage to its support; the cracks found on some blocks of the structure were dated before the earthquake. Therefore, the inspected facilities were functional, although the restoration of the full functionality of the hydraulic facility required some minor rehabilitation and repair of the tank distributor. In any case, the age of the plant suggests a constant monitoring even after the remedial action.

The treatment facility in Corfinio (AQ) situated not far from the center of the same town (42°7'25.74"N - 13°50'31.78"E) is a RC construction built in the 90s. The central part of the longitudinal walls of the aeration tank, separated from lateral walls, shows a rotation very probably occurred in large part before the seismic event, as witnessed by the comparison of the positions of monitoring slides before and after the earthquake; such slides were applied two years before the event: the displacements due to the earthquake did not compromise the hydraulic seal of the joint, nor the functionality of the structure.

A comprehensive analysis of the observed damages was carried out in relation to the position of each facility with respect to the epicenter of the earthquake of 6 April 2009 (UTC 01.32 hours) and to the records provided by the National Network Accelerometric (RAN) available (Chioccarelli et al., 2009). It can be observed that:

- Ponte Rosarolo facility is located near the epicenter and close to the AQK accelerometric station, which recorded ground accelerations equal to 3.7 m/s^2 equal to about 50% of the maximum value recorded for the same seismic event (station AGV - 6.6 m/s^2); after the earthquake, the plant has shown damages to the tanks with rectangular walls larger than those found in circular tanks of the Pile plant, despite the geographical proximity. The structural behavior of the circular tanks was essentially better than that of the rectangular ones, mainly because of the lack of structural details ensuring effective connection between the orthogonal walls;
- Arischia plant lies about 5 km from the L'Aquila accelerometric stations AQV, AQG and AQA, which recorded maximum ground acceleration values; even if distant from the epicenter (approximately 10 km), it has shown some structural damages;
- The Corfinio plant was not damaged because distant from the epicenter (approximately 50 km): the maximum acceleration recorded by the accelerometers of Sulmona station (Sul) located near the plant, is indeed equal to 0.34 m/s^2, approximately one-twentieth of the maximum recorded at AQV Station of L'Aquila.

2.12.5 Gas distribution network

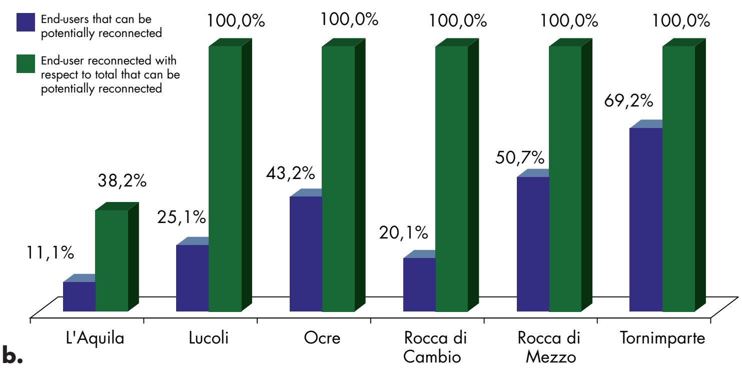
Enel Rete Gas S.p.A. is the gas provider for L'Aquila city and for other 5 municipalities in the earthquake affected area, namely Lucoli, Tornimparte, Ocre, Rocca di Cambio Rocca di Mezzo.

The gas is distributed via a 621 km pipeline network, 234 Km of that with gas flowing at average pressure (2.5-3 bar) and the remaining 387 Km with gas flowing at low pressure (0,025-0035 bar).

The medium pressure network is connected to

the high pressure national one (namely SNAM network) through 3 reduction cabins while, about 300 reduction groups allow for the transformation of the gas transport pressure (2.5-3 bar) into the gas distribution pressure (0,025-0035 bar).
The gas network is mainly made of steel pipes, with an average internal diameter of $Ø_{intenal}$ = 125 mm (external diameter $Ø_{external}$ = 139.7 mm) and the joints are mainly welded.
The first priority identified for the management of the gas network, in the first phase of the emergency immediately after the earthquake, was the timely securing of the network in order to avoid explosions, gas leaks and fires and to allow the emergency vehicles and the USAR teams to act in the safest possible way.
To ensure this priority, the entire network managed by Enel Rete Gas S.p.A. in the affected area was shut off via the closure of the 3 reduction cabins. Thanks to this decision, and to the rupture of a pipeline near Onna (Fig. 4a), it was possible to timely and significantly reduce the gas pressure and to avoid the occurrence of secondary effects. The subsequent closure of the 300 reduction groups ensured the full securing of the network in less than two hours after the earthquake. In the days following the event, the gas valves external to each residential building were as well closed. The pipeline damaged in Onna was replaced with a new one that was too rigidly connected to a reinforce-concrete support. It is worth highlighting that, as a result of the earthquake, the Enel Rete Gas headquarters in L'Aquila resulted unusable. Because of that the chief executive and the staff had to manage the emergency without the support of their data, software and maps. Luckily, the national society Enel Rete Gas has, at a national level, an integrated information system, including a data base and a geographical information system GIS. Making reference to the closest Enel Rete Gas headquarters in Teramo and Pescara, it was possible to reprint the maps and all the documentation necessary to operate.
The second phase of the emergency response was focused on the activation of the physical and human resources in support to the Civil Defence. The timely provision of gas to the strategic structures was the first priority identified and was operated via mobile reduction cabins and gas wagons. H24 shift were organized for the local technical and administrative teams, as well as for the teams coming from other areas of the national territory including the Enel Rete Gas national headquarters in Milan. In the first month after the earthquake, the daily commitment of physical and human resources resulted on average approximately equal to 70 men and 35 vehicles, including equipped trucks, gas wagons and gas-leak detectors.
On the same time, activities for the reactivation of the gas provision were started. The reactivation of the shut gas network required to operate gradually restoring, first of all, the gas flow into the medium pressure network, secondly the gas flow in the low pressure network, up to each external valve pertinent to each residential building previously closed.
Reactivation of the service was managed according to the following four steps: 1) seal verification; 2) nitrogen check; 3) repair of damaged pipes and/or valves; 4) reopening. In the seal verification phase, the detection of broken pipes and/or the possible joint slip-off was made, acting in the first instance, from node to node, and further segmenting the network when necessary.
The material and equipment needed for the repair was immediately available from the integrated logistics system which Enel Rete Gas uses; actually, the material normally in storage in the Battipaglia inter-harbour to perform ordinary repairs and maintenance works, was simply diverted to L'Aquila. The adopted strategy ensured the remediation and testing of more than 90% of the gas network in three month time after the earthquake. The diagram in figure 4b shows how, three months after the quake, it was possible to restart the gas distribution for all the end-users with a safe home, exception made for L'Aquila city.
It is worth mentioning that the reconnection of the individual user supplies required, on one hand, the definition of the priorities to be followed and, on the other hand, the definition of the testing procedures to be carried out to certify the safety of the gas systems that were subjected to the action of the earthquake. As for the priorities, those identified by the Civil Defence were followed; namely, the service was provided first of all to the strategic buildings, secondly to the manufacturing and industrial plants, and finally to the residential buildings identified as safe after the AeDES ispection. As for the testing procedures, in accordance with the procedures used by Enel Rete Gas for routine checks, an ad hoc protocol was defined in collaboration with the Civil Defence and the Firefighter Department. It was decided to reconnect each single user following the fulfillment of four conditions: 1) safe dwelling (classified as A following the AeDES survey); 2) leak-tightness checking; 3)

a.



b.

Fig. 4
Impact of the earthquake on the gas distribution network:
(a) Onna (AQ), damaged pipeline.
(b) End-user gas connections activeted on June 8 2009 (Green = end-users that can be potentially reconnected; Bleu = end-user reconnected with respect to total that can be potentially reconnected).

operative test of the equipment; 4) smoke test. It is worth mentioning that the Civil Defence fully covered the cost of the whole procedure to reconnect the individual users to the gas service and that a dedicated phone line (Line Amica Abruzzo) was specifically set up to facilitate and support the end-users in this operation.
As a final note it is worth remembering that no damages were detected to the gas storage facilities.

2.12.6 Electric power distribution network and telecommunications

It was reported that two substations serving the greater L'Aquila had damaged connections between a rigid bus and insulator, figure 5a. 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 were dislocated and severed cable connections at the termination lugs that resulted in localized power failure (Fig. 5b). The Electric Power Control Center at L'Aquila sustained severe damage, 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 (Fig. 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 6a. 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 6b. There was no batteries damage reported at these substations. Some locations were without power for three days, e.g. wastewater treatment plant.
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. 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. 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.

2.12.7 Temporary housing

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

Fig. 5
(a) Damage to rigid connection of a transformer.
(b) Typical damage to pedestal box.

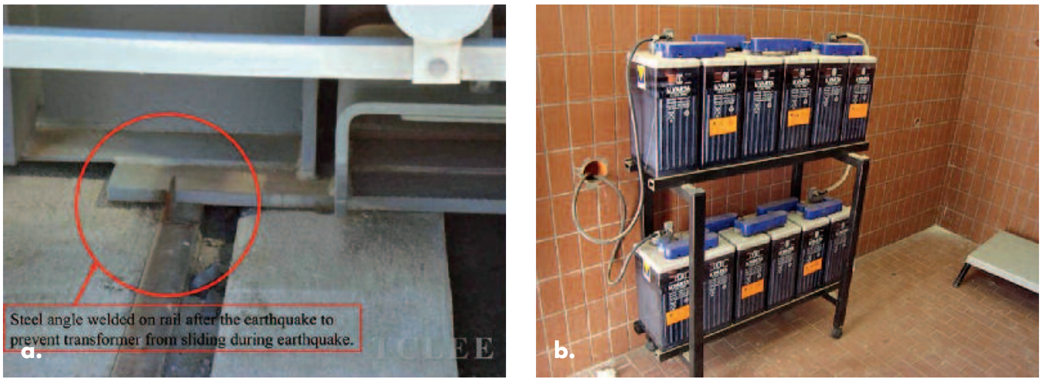


Fig. 6
(a) Steel anchors installed after the earthquake to avoid sliding of transformers.
(b) Unanchored batteries' racks in substation.

Fig. 7
One of the relief campite in L'Aquila set up by the Civil Defence.

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 7. 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.

2.12.8 Conclusions

Performance of lifelines during the April 6 event may be considered generally good if compared to the extended losses related to buildings. This is because: (1) the main damaged areas were evacuated after the earthquake and their access was prohibited; and (2) the emergency management was effective in limiting the downtime of essential services.

Damages to structures of wastewater management plants reduced the service level, but even in this case, the evacuation reduced the demand of about 40%.

Critical element of the transportation network did not suffer any significant damage, experienced only in secondary branches of the network. Reduction of the traffic flow capacity was mainly due to debris from collapsed/damaged structures adjacent to the road in urban areas and to rock falls and landslides in mountainous areas.

From the seismic risk reduction point of view, it was concluded that components in facilities should be anchored and that the use of flexible connections should become a standard practice. As for the emergency management, the Civil Defence effectively coordinated a rapid and effective response. Chief executive and administrators of lifelines networks participated to the strategic decision making process since the very beginning of the post-event emergency-management. The cooperation with the Civil Defence was continuous during all the phases of the emergency management ensured via daily meetings.

Finally more than 160 relief camps were properly managed. It can be concluded that the emergency management of lifelines networks provided a rapid and resilient response to the earthquake. The emergency management procedures implemented for the physical and functional restoration of lifelines network, after a proper codification, may become a reference model for the Civil Defence at international level.

References

Chioccarelli E., De Luca F., Iervolino I. (2009). Preliminary study on L'Aquila earthquake ground motion records V5.2 [Report disponibile a: http://www.reluis.it/doc/pdf/Aquila/Peak_Parameters_L_Aquila_Mainshock_V5.2.pdf].

Nigro E., Bilotta A. (2009) - Rapporto sui danni subiti dagli impianti di depurazione per reflui civili a seguito dell'evento sismico del 6 aprile 2009 – V1.00. [Report disponibile a: http://www.reluis.it/doc/pdf/Aquila/Depuratori_Provincia_Aquila_V1.00.pdf].

Tang A., Cooper T.R. (2009) - L'Aquila Earthquake, Abruzzo. Italy May. 06, 2009 M w =6.3 – Lifeline Performance. [Report disponibile a: http://www.reluis.it/doc/pdf/Aquila/Lifelines_TCLEE.pdf].

Verderame G.M., Iervolino I., Ricci P. (2009) - Report on the damages on buildings following the seismic event of 6th April 2009 time 1:32 (UTC) - L'Aquila M = 5.8. [Report disponibile a: http://www.reluis.it/doc/pdf/Aquila/Rapporto_fotografico_V1.2.pdf].