ITALY

Earthquakes strike gas infrastructure plans

Overview of Pescara del Tronto a) after 24 August 2016 and b) after October 2016 earthquake events

Photo: Geotechnical Extreme Events Reconnaissance Association (GEER)

Italy's hope to become a European gas hub depends on how it rehouses evacuees from last year's earthquakes, writes *Maria Kielmas*.

Almost a year after the first of four earthquake sequences that occurred on the borders of Umbria, Marche, Abruzzo and Lazio along the spine of the central Italian Apennine mountain chain, some residents of Amatrice, one of the most strongly affected towns, returned to what was left of their garden for a lunch on the Ferragosto (15 August) holiday. There was no gas, electricity or water, and they were surrounded by nearly 1mn tonnes of rubble caused by the earthquakes. Rescue and disposal crews had managed to clear less than 10% overall, and 6% in Amatrice, of the total 2.3mn tonnes of rubble because of the need to separate out from it asbestos, public and private property, and remnants of historical buildings and artefacts. Most of the buildings here were of cultural heritage type dating from medieval times to the 20th century.

Residents in the most affected region, 90% of whom were evacuated to temporary housing, may have to wait up to 10 years to return to their reconstructed homes – if ever. Hundreds of evacuees are housed in and around the Adriatic seaside resort of San Benedetto del Tronto, where they are at the forefront of growing popular opposition to a planned natural gas storage facility. This is part of a longer-term plan to make Italy a European gas hub and includes the 'Rete Adriatica' gas transportation pipeline that is scheduled to pass through the area most damaged by the 2016–2017 earthquakes.

Long sequence events

The first, magnitude 5.9, earthquake occurred on 24 August 2016, causing greatest damage in the region around Amatrice, northern Lazio. It was followed by two shocks, on 26 October (magnitude 5.4) and 30 October (magnitude 5.9), with epicentres more to the north near Visso in the Marche region. Four further earthquakes on 18 January 2017 with magnitudes 5.1, 5.4, 5.5 and 5, hit the borders of the Lazio and Abruzzo region north of L'Aquila. These were followed by a spate of bad weather that caused an avalanche near Gran Sasso mountain.

The first earthquake caused 299 fatalities, of which 290 were in Amatrice; the third earthquake caused nine deaths; while the avalanche caused 29 deaths in a nearby hotel. Total economic losses after the earthquake sequence were approximately €25bn, of which less than 10% was insured. The most affected towns were Arquata del Tronto, Accumoli, Amatrice and Pescara del Tronto.

The earthquake epicentres were located in a gap between two earlier damaging events – the 1997 Marche earthquake to the north-west, and the 2009 L'Aquila earthquake to the south-east. This area is dominated by an extensional regime. 'Italian seismicity is predominantly normal fault seismicity,' says Paolo Zimmaro, Research Scientist and Lecturer at the University of Los Angeles (UCLA) in California and one of the leaders of the Geotechnical Extreme Events Reconnaissance Association (GEER) team that surveyed damage following the August and October events.

Characteristics of earthquakes in the central and northern Apennine regions are their long seismic sequences that can last over months and even years. In the year following the 24 August 2016 event there have been over 74,000 earthquakes, according to the Rome-based government agency, Instituto Nazionale di Geofisica e Vulcanologia (INGV). 'This was a typical cluster of earthquakes,' comments Zimmaro. The causative faults were the Monte Vettore and Laga Mountain faults. Only the former displayed surface ruptures, one of which extended 4.8 km after the August event. The peak recorded ground acceleration was 0.9g at Amatrice, but Zimmaro believes that amplification of seismic waves due to geotechnical side-effects may have occurred at this site.

Amplification

In contrast to the 2009 L'Aquila earthquake that hit an urban environment causing major damage to gas and electric distribution networks, the 2016–2017 events did not cause major infrastructure damage because there is little, aside from hydroelectric dams, in this isolated mountainous region. However, this

Aerial photograph of the 2016 landslide that impacted Strada Statale No 4 below Pescara del Tronto

Photo: Geotechnical Extreme Events Reconnaissance Association (GEER)

topography had a major effect on the damage pattern on buildings, approximately 75% of which were unreinforced masonry, says Anastasios Sextos, Reader in Earthquake Engineering at the University of Bristol and a GEER team member.

'The strange topography reflected and refracted trapped energy and, with local site effects, caused the worst damage to focus on Amatrice and surrounding villages,' he says. Although many buildings in Norcia survived the first shock because they had been retrofitted with earthquake protection, they still collapsed after the second and third shocks. The second shock also flattened what remained of Pescara del Tronto. Sextos notes that it was luck that such a sequence of earthquakes had not occurred in a more urban environment. 'Three sequential events in a residential area could have led to a disproportionate level of damage. There is no time to retrofit in between events.'

Hydroelectric infrastructure

Hydroelectric energy infrastructure performed well. The Scandarello dam, closest to the 24 August 2016 epicentre, showed a few millimetres of crest displacement but no slope instability. A turbine at the foot of the dam stopped operating because of power loss, not damage caused by ground shaking. After the January 2017 earthquakes the local council of Lenessa, Abruzzo, ordered schools to be closed for fear the Campotosto dam, one of three dams on a lake of the same name, could be damaged. The dam is located on a fault that could generate a 6.2 to 6.5 magnitude earthquake, according to INGV, but there were no signs of its reactivation. Power utility Enel said the dam was safe. But locals still fear that a landslide could collapse the level of the dam 10 metres into the water and cause a catastrophic spillage, or that a 90-cm fracture opens up in the ground.

However, the combination of topography combined with landslides, rock falls and ground deformation after earthquakes can choke up whatever infrastructure exists in such isolated regions. The GEER team observed how a landslide dammed a river that, in turn, flooded the single highway between Rome and Visso, and required a four- to five-hour detour to get to the town. Utility lines were impacted by landslides. Retaining walls around towns and villages built on cliff edges were often of poor quality and collapsed. Some man-made fills beneath the walls were not as strong as the natural basement below, causing the wall to rotate upwards and cause land settlement that in turn damaged buried pipelines. Some modern concrete walls had no drainage measures installed in the back fill. This kind of deformation impacted on various buried pipelines.

Pipeline integrity

Sextos stresses that it is important to remember that the integrity of pipelines is sensitive to permanent ground deformation. This is caused by fault displacements, landslides, lateral spreading and liquefaction of sandy soils, and is especially dangerous for buried pipelines. It is important to avoid stiff connections at welds in pipelines and make the structure as flexible as possible.

'We try to make networks more redundant and have more ways for gas or water to flow,' he says. But there is no European legislation in designing pipeline systems as networks in a holistic manner. The design aims to satisfy localised integrity criteria using rather simplified approaches to quantify seismic demand, he adds. It is for the designer to ensure the release of secondary flow. Eurocode 8, that stipulates the seismic design of buildings, only provides general principles for earthquake protection of surface and buried pipelines.

Soil/structure interaction should be considered for buried pipelines, while for surface pipelines the important features are mainly about the loss of the support of the structure and of differential movements. Hydraulic dynamic effects due to the filling levels inside the pipelines are considered negligible except for wastewater pipelines. Apart from energy generation and transmission systems, critical infrastructure in the event of earthquakes, notes Sextos, are schools, hospitals and public buildings such as police and fire stations, and public administration. Due to their large length, gas pipelines are not considered critical in their entirety unless they lead to other strategic facilities such as nuclear power plants.

Local opposition

Such ambiguous gas infrastructure regulation combined with public distrust of government in the aftermath of any catastrophe poses problems for Italy's hopes to be a seasonal hub for European gas storage. The planned Rete Adriatica gas transportation pipeline between Sulmona, Foligno, Sestino and Minerbio, first proposed in the early 2000s, will pass along the western border of the Gran Sasso and Monte Sibilini National Parks, not far from L'Aquila, Amatrice, Visso and Norcia. The project has triggered major local opposition as these are the zones of greatest central Italian seismic risk and those most affected by the 2016–2017 and 2009 earthquakes.

There are also fears that withdrawal and filling at planned gas storage facilities at San Benedetto di Tronto and San Martino sulla Marrucina could induce earthquakes. These facilities are located at depleted gas fields, will hold gas at just above atmospheric pressure, and are unlikely to induce major seismic events. But local opponents remain unconvinced.

Engineers stress that there has been lots of research into the response of gas pipelines and other lifelines in regions of major seismic hazard, such as the Trans Adriatic Pipeline (TAP) bringing gas from Azerbaijan via Greece to Italy. These include detailed studies of their path, about crossing faults, avoiding areas of known landslides, and burying the line to avoid surface hazards. But the pipelines have to be cost-effective and sophisticated methods of burial using, say, horizontal drilling techniques rather than trench excavation, could be too expensive.

Secondly, what engineers and risk analysts recommend on seismic hazard may not always be understood or accepted by political decision makers. Italy's endemic problem with illegal construction is caused in large part by the reluctance of local and national politicians to enforce existing building regulations, especially ahead of elections. Consequently, public distrust of authority soars in the aftermath of every earthquake. Planned gas infrastructure in central Italy is unlikely to be completed if last year's evacuees have no homes to return to. ●