Living with Landslides: the Ancona Case History and Early Warning System

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On 13th December, 1982, Ancona city, an historical and capital region of Le Marche – Italy, located on the East coast of the Adriatic sea, was involved in a large and deep landslide.

An intense landslide affected the northern area of the city, the "Montagnolo" hill started to slide towards the sea. The event involved about 180 m³ during the movement.

Fig. 1: 1982 event.

It damaged structures and infrastructure and some important public and strategic buildings, among them the Faculty of Medicine, the Oncological Hospital, the Geriatric Hospital and the Tambroni retirement home. All the older people and the patients were moved to the nearest Hospitals for first aid.

The National Railway MI-LE (Adriatica) and regional Highway Flaminia slid down 10 meters towards the sea. The movements started from the lower border of the landslide and came up the slope. At the end of the event the movements surveyed were: on the base, max. 8 metres in horizontal and 3 meters in height, while on the top, 5 meters in horizontal and 2.5 meters downwards.

In the morning of 13th December, after a night of uninterrupted movements and noises due to the opening fractures of buildings, the residential districts named "Posatora" and "Borghetto", were evacuated (Figure 2).

Fig. 2: The National Railway MI-LE (Adriatica) and regional Highway Flaminia.

The landslide damaged private houses and infrastructures and about 3000 people were evacuated. 1562 people were moved to hotels and other residences by Municipality and they remained in that situation for a long time. Gas and water supplies were interrupted too and the city remained for some days without the necessary services.

The more significant damages can be resumed as follows:

- 220 hectares extension (affecting 11 % urban area of Ancona)
- 3661 people evacuated (1071 families)
- 1562 people moved to hotels and other residences by Municipality
- 280 buildings destroyed or damaged (a total of 865 residences)
- Faculty of Medicine, Oncological Hospital, Geriatric Hospital, Tambroni retirement home, were irreparably damaged
- 31 farms damaged
- 101 SME
- 3 industries
- 42 shops
- 500 people lost their jobs
- National Railway MI-LE (Adriatica) and regional Highway Flaminia blocked
- Gas and water supplies interrupted
- Luckily, no people died during the event!

The dynamic of the landslide of Ancona can be explained in two steps:

A gravity slide happened at great depth, probably induced by some dislocations activated during the 1972 earthquake, then re-activated by the intense rain infiltration (some days before the event, it rained for almost 6 days without interruption).

After the first step, we had an activation of superficial and medium landslides. These started to move after about 10 minutes, with consequent damages to buildings and infrastructures (this second step continued for some hours).

The superficial geomorphology of the Ancona landslide is influenced by many and complex movements. The colluvial soils, in some places of the landside, where their thickness is about 10 m, have flown down as a mudslide. This dynamic was helped by the high rate of saturation.

Taking into account all the researches and investigations over the last 25 years spent in the site and in laboratory, we can conclude that the Great Landslide of Ancona city is a Deep-seated landslide (complex, composite according to CRUDEN & VARNES, 1996), reactivated after a long period of precipitation; new fractures were opened by a long period of earthquakes 10 yrs before (6 months duration) (Figure 3).

The landslide involves clay and silty clay layers (Pliocene–Pleistocene), fractured with different OCR parameters, alternated with thin sand levels.

Overlapped sliding zones are active (maximum depth: 100–120 m, maximum depth 1982 event is 75 m bgl).

Across the entire body of the landslide, in horizontal direction, parallel to the coast, there are two natural trenches that cross the slope. These trenches are upstream of old landslides slid down and now they are filled with heterogenic and plastic soils. These soils involve clay and silty clay, mud and thin sand levels with some fragments of calcarenitic layers.

These trenches together with a complex structural system of fracture and discontinuity, influenced the system of underground water.

All the geological and geotechnical analyses of the landslide mechanisms aimed at the consolidation preliminary design in 2000; but this plan concluded that a consolidation was impossible, both due to very large expenses and to a very strong environmental impact, which would have totally changed the site appearance with a severe socio-economical impact.

Ancona Administration decided then to live with the landslide, nevertheless, reducing the risk for the people living there.

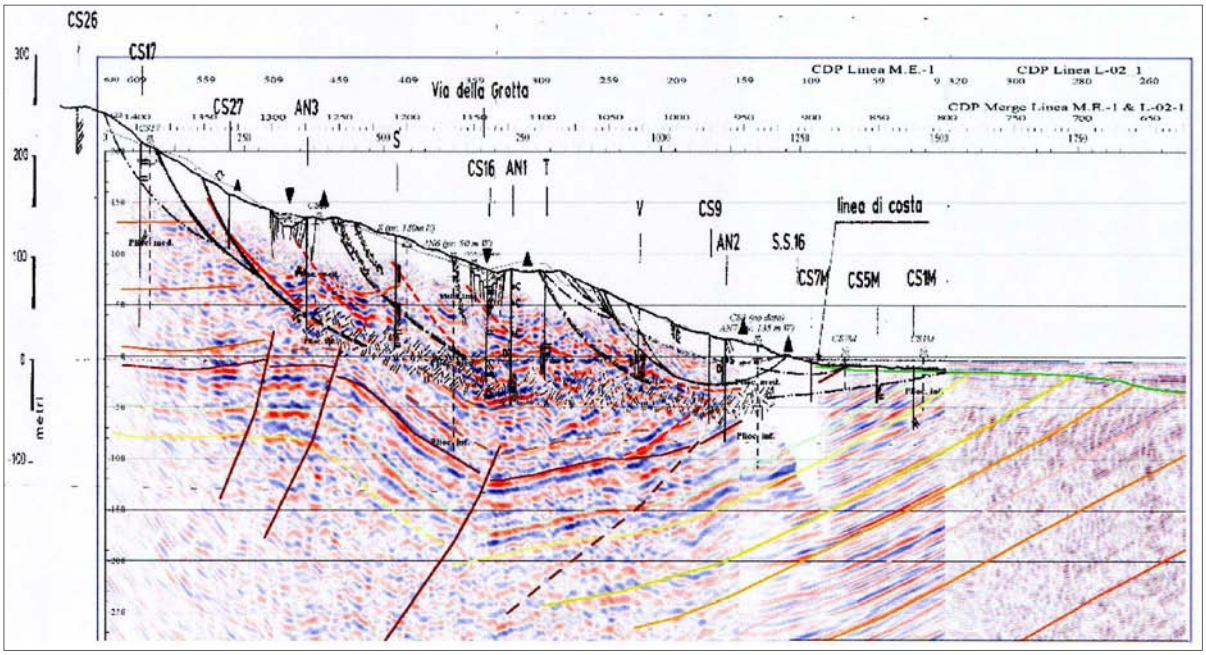

Fig. 3: Geomorphological and seismic section.

During the last years, some partial interventions of the total preliminary design for the consolidation stroke have been made. Two drainage systems were put in place, a deep one based on trenches and wells, and a more superficial one with canals. Reinforced bulkheads were built and in some part of the area reforestations were made.

Ancona Administration decided to continue both drainage systems both superficial and deep.

In 2002, the Regione Marche passed a law for the people that still today live inside the landslide area, giving Ancona Administration the responsibility of creating an Early Warning System and an Emergency Plan for people. The whole project has the aim to issue the population a certification to live safely in their homes and to check the landslide movements.

The projected Early Warning System consists of the integration of continuous surface and borehole active monitoring.

The first phase of the monitoring system, concerning the control of the surface, has been working since 2008. The Geotechnical in Place Continuous monitoring system (II phase) has been activated also.

Surface Monitoring

The surface monitoring system is based on 7 Automatic Robotic Stations, 230 reflector points (installed partly on the 64 inhabited houses and on the structures and infrastructures), 26 geodetic GPS, 8 geodetic GPS (dual frequency), 7 high precision clinometric sensors for the stability control of the main stations of the I and II level of the net. The combination of the different instruments: GPS, Automatic Robotic Stations and the clinometric sensors allows us to monitor a great number of points previously identified, to keep them under supervision with different measuring techniques and from different control positions in the three coordinates (3D, X, Y, Z). The adoption of the geodetic GPS at dual frequency assures a high quality of the GPS measures, and a greater versatility of the whole system.

Geotechnical Monitoring (DMS)

Recently, the Geotechnical Monitoring Systems DMS (patents and trade mark CSG-Italy) have been installed inside n°3 boreholes (100 metres depth).

Each DMS column is formed by n°85 Biaxial Inclinometric modules (range ±20°, resolution 0.01°), n° 2 Piezometric Sensors (range 100 psi, resolution 0.01 m), n°85 Temperature Sensors (range 0–70°C, resolution 0,1°C) for a total active vertical of 85 metres controlled. Digital compasses are on board, accuracy 1° azimuth.

DMS has been preassembled in the factory and installed in place by a DMS reeler, forming an instrumented column, like a spiral cord, connecting the required number of modules, each containing one or more geotechnical-geophysical sensor and the electronic boards for data collection and transmission.

Fig. 4: Surface and geotechnical DMS-systems (Via delle Grotte site).

This monitoring system is studied to try to determine every surface movement both in the area and in the inhabited houses and to produce some alarms managed by a Control Centre H24 placed in the Town Hall, where a staff of technicians have to estimate the alarms. Only whenever the situation requires the Coordinator does the Civil Protection Plan come into action.

The measuring cycle is set up on 30 minutes, but in emergencies or after a long rainy period, the system can operate on every point of the dual frequency GPS net also in Real Time RTK, and with the 7 Automatic Robotic Stations.

The modules are linked by special 2D/3D flexible joints that allow strong, continuous adaptability to bends and twists of the borehole, whilst maintaining rigorously the orientation with respect to a reference system defined during installation.

Fig. 5: DMS installation stroke.

The data from the DMS instrumentation column are sent through RS485 protocol to the control unit, which compares them with threshold values (set by the user) and stores them in a circular buffer.

In case of movements larger than threshold values, the control unit sends a warning SMS/direct call to the staff on duty of the Ancona Monitoring Centre.

The same is the case of rapid change of water-table levels. Warning levels are counted from 1 to 4, in a order of hazard.

In the monitoring centre, the GeoMaster and Guardian software take care of downloading the data stored in the control unit memory buffer.

The DMS Early Warning is the software that visualizes the subsurface data at the monitoring centre and wherever an Internet or GSM connection is possible. The software in a compact check panel allows the contextual control of displacement (E–W, N–S, Module diagrams, on Polar and Azimuthal plots), as well as the variations of the level of the water table and temperature; time history of each multiparametric module, and displacement-velocity are also displayed at selected intervals.

Transmission System

The transmitted data coming from the different sensors, are collected according to the two following procedures:

a. I and II Level Net: data transmission in real-time through a WiFi Standard HyperLan to the Town Monitoring Centre. The system is based on a main radio line (spot to spot) between the Automatic Robotic Stations and the Ancona Municipality Monitoring Centre. Data transmission in real-time works through some free frequencies radio links of 5.4 GHz (HyperLan). It realizes a strong transmission and a low environmental impact thanks to their noise control system.
b. III Level Net: data transmission through periodic GSM with data acquisition/6 h.

Preliminary Data

After some months of observation and data analysis of the surface monitoring system, apart from any ordinary variations connected to the days and seasons, some small movements have been located inside the landslide. Some geodetic GPS at single frequency L1 installed on 26 inhabited houses inside the landslide area (third network) have monitored displacements 0.5–1.5 cm towards N. This area is located where the landslide shows the maximum depth (100–120 m), trenches are also mapped, filled by soft clays.

But the movements examined are not worrying, because they happen in a restricted area and during seasons changes (summer – winter), when the clay soils lose their humidity and reduce their volume.

These data have permitted the verification of the monitoring system sensibility also for what concerns the smallest movements in the colluvial soils.

In this way, the Ancona administration has chosen to "LIVE WITH THE LANDSLIDE": this new concept implies that the safety of the population is achieved through a high-quality and comprehensive early-warning system. This – in contrast with the more static concept of standard engineering remediation – works which is clearly impracticable so far, in our case.

This project is the result of the best conjunction between human resources and a more reliable technology in the Early Warning monitoring field, put in use for a best safety and peacefulness for the people living on the Ancona landslide.

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