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Recent large-scale mass movements in the Northern Apennines: the reactivation of the Ca' Lita composite landslide system (Northern Italy)

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Introduction

In the Emilian sector of the Apennines (Northern Italy), the lithological and tectonical features, together with the geomorphological evolution of the mountain chain, have triggered a great variety of landslides, which cover extensive areas. The 80% of the 30.000 landslides known in the Emilian Apennines (Garberi et al., 1999) show a complex and composite styles of activity (Cruden and Varnes, 1996) and, in most cases, consist in multiple rotational or roto-translational phenomena at the crown and translational slides in the lowermost portion of the slopes. At present, nearly all the slope movements are partial or total reactivations of ancient landslides. When reactivations occur, large rotational slides are triggered in the source area and each reactivation causes a regression of the main scarp. Then, the mechanical properties of the displaced material undergo a physical degradation and when a saturation up to the liquid state of consistency is reached, earth flows are triggered.

The evolution of this type of landslides is related to inherited factors, either geological or climatic. On the one hand, the rock masses involved in the movements are made up by flyschoid and chaotic weak rocks (Bieniawski, 1989), litologically and/or structurally complex (A.G.I., 1985). On the other hand, it is ascertained that during the Holocene, these phenomena have undergone distinct instability phases, that can be related to humid phases (Bertolini, 2003). It is also believed than within the present morpho-climatic context, the reactivation of these landslides is mainly connected to hydrogeological factors (Bertolini & Pellegrini, 2001), while other triggering causes, like earthquakes, play a secondary role (Castaldini et al., 1998; Genevois et al., 2000).

The interaction between such phenomena and anthropogenic activities is frequent, resulting in considerable hazards. In fact, many of the civil emergencies occurred over the last few decades have been caused from either partial or entire landslide reactivations, which resulted after decades or even centuries of dormancy.

In this context, the study of the Ca' Lita landslide system here described is relevant for the understanding of the triggering mechanism and the evolution of this kind of large scale mass movements, thanks to the relatively fast development undergone by the phenomenon. In fact, many of the components making up the landslide system have resumed activity between 2002 and 2004, during periods of intense and prolonged rainfalls, threatening a village, some houses and an important motorway.

Ca' Lita landslide system

The Ca' Lita landslide is a large, active slope failure involving a hilly area of the northern Apennines, in the Secchia River Valley (Northern Italy). It consists of a composite landslide system of prehistoric origin, that has developed into Cretaceous to Eocene flysch deposits and chaotic complexes. From the geomechanical standpoint, the arenaceous flysch rock masses are characterized by a marked lithological and structural complexity, that imply heterogeneity and anisotropy, both at a mesoscopic and macroscopic scale. The chaotic materials ascribed as mélanges are characterised by disarranged layers of competent rocks and clay shales, jointed up to sheared. In this case, the primitive condition of weak rock masses (Bieniawski, 1989) is lost because of weathering processes and the rock mass behaves like a clayey soil aggregate. These formations are characterised by low to extremely low hydraulic conductivity. This is due to the pervasive presence of an important pelitic fraction, even in the flysch rock masses. At the same time, the frequent stratigraphic and/or tectonic superposition of flysch plagues on clayey basal complexes makes up permeability thresholds, that have an important role either in the triggering first-time failures or in supplying ground water to landslide bodies, thus generating subsequent reactivations. In this case, besides the high values of cumulative rainfall and snowfall in periods of various lengths prior to the movements, also the snow accumulated in the period preceding reactivation has had a paramount importance. In fact, the most significant movements occurred in spring 2004, after the rapid melting of the snow cover.

Geomorphological features

The landslide extends from an elevation of 650 m at the crown, to 230 m a.s.l. at the tip of the earth slide. Its total track length is approximately 3 km from the crown to the toe and its maximum width is about 1.4 km, in the rear scar area, with a maximum depth of about 50 m.

The main landslide components can be described as follows:

- an extensive and deep process of rock-block sliding involving the uppermost mountain ridge;
- a large complex and composite landslide, that in the upper sector includes rotational slides evolving into a rock-block slides and then in a wide earth slide;
- soil slips and earth and mud flows, that affect the whole catchment area.

As far as the process of rock-block sliding is concerned, the locations and shapes of scarps and trenches suggest a deep slope gravitational deformation mechanism, with a very slow down slope movement of the entire rock mass. This mechanism depends upon the fact that stiffer flysch rock masses overlap clayey materials and that, probably, deep fracturing of the rock mass occurs, in some cases, along structural discontinuities that could be conjugated faults to the main fault line crossing east to west the landslide area.

The landslide which develop down slope shows considerable evidence of activity. The morphological evolution of the marginal portion of the arenaceous plague involves the accumulation of huge amounts of debris, containing coarse-grained material and blocks. This debris is then involved in a large slide, which is continuously moving since two years with surge phases, that cause damages to infrastructures and private properties.

Investigation programme

After the April 2004 events, the landslide system has undergone an extensive investigation programme, financed by the Civil Protection Agency of Emilia-Romagna Region and aimed to understand the possible future evolution of the phenomenon and to gain knowledge elements on the basis of which to properly design structural mitigation actions. In particular, the investigation phase has until now led to the production of:

- a new aerial photo coverage at 1:14.000;
- a detailed landslide map at 1:5000 scale;
- refraction seismic on 14 cross and longitudinal sections, elaborated with tomography techniques;
- cores of landslide masses and bedrock from 5 boreholes 40 to 80 m deep;

- a set of monitoring data obtained from 5 inclinometer casings, 2 large diameter TDR cable and 4 piezometers, 2 of which equipped with electric pressure transducers and dataloggers for continuous acquisition.

The quantification of the spatial and in-depth magnitude of the 2002-2004 series of events has been achieved on the basis of a GIS-based comparative analysis of digital elevation models of the slope (obtained by photogrammetric treatment of pre- and post-event aerial photo coverage), and from geophysical and borehole investigations that, in association with monitoring data, have allowed quite reliable cross-sections of the landslide to be outlined.

On the basis of the surveys and monitoring data so far collected, it is believed that the mechanisms and times of reactivation of the landslides are governed by the hydrogeological setting of the study area and, in particular, by a circuit of groundwater directed from the uppermost plague into the lowermost clays, in which several sliding surfaces develop. Concerning groundwater circulation, the area display numerous small springs with seasonal discharge. These springs lie in correspondence with permeability boundaries between the flysch plague and the clayey substratum, which by now is covered by a thick debris deposits. The depletion zone of the landslide unit acts as a basin that keeps the debris in a saturated state, thus promoting movements.

Structural mitigation strategy

In the first emergency phase, the consolidation works have consisted in the rearrangement of displaced materials, in order to avoid the formation of water impoundments and to restore drainage networks. Permanent consolidation works have then been carried out by means of draining trenches, check dams, draining wells and subhorizontal drains. Structural works and rigid containment structures have been proposed with foundations reaching the bedrock at 10 to 15 m of depth, on the basis of the monitoring data and the numerical modelling results.

References

A.G.I. - Associazione Geotecnica Italiana, 1985. Geological outline of Italy: bearing of the geological features on the geotechnical characterization on the example of some typical formations. In: A.G.I. (ed.), Geotechnical Engineering in Italy. Tip. L. Chiovini, Roma, pp. 159-184.

Bertolini G. (2003). Frane e variazioni climatiche nell’Appennino emiliano. Unpublished PhD Thesis Università degli Studi di Modena e Reggio Emilia, Modena.

Bertolini G., Pellegrini M. (2001). The landslides of Emilia Apennines (Northern Italy) with reference to those which resumed activity in the 1994 - 1999 period and required Civil Protection interventions. In: Bertolini G., Pellegrini M., Tosatti G. (eds.), Le frane della Regione Emilia-Romagna, oggetto di interventi di Protezione Civile nel periodo 1994-1999, Quaderni di Geologia Applicata 8(1), pp. 27-74.

Bieniawski Z.T. (1989). Engineering rock mass classification. Wiley Interscience Publ., New York.

Castaldini D., Genevois R., Panizza M., Puccinelli A., Berti M., Simoni A. (1998). An integrated approach for analysing earthquake-induced surface effects: a case study from the Northern Apennines, Italy. J. Geodynamics, 26(2-4): 413-441.

Cruden D.M., Varnes D.J. (1996). Landslides Types and Processes. In: Turner A.K., Schuster R.L. (eds), Landslides: Investigation and Mitigation. Transportation Research Board, Special Report 247, National Academy Press, Washington D.C., pp. 36-75.

Garberi M.L., Palumbo A., Pizziolo M. with the contribution of Baldelli C., Barchiesi P., Bertolini G., De Nardo M.T. (1999). I numeri sulle frane. Regione Emilia-Romagna, Servizio Cartografico e Geologico, Bologna.

Genevois R., Berti M., Ghirotti M., Romeo R., Simoni A. (2000). Rapporti tra frane e sismi: risultati preliminari della ricerca nell’area appenninica centro-settentrionale. 1986-1995 Report, CNR-GNDCI Line 2, GNDCI Pubbl. 2142, pp. 397-406.