Geophysical Research Abstracts
Vol. 16, EGU2014-14584, 2014
EGU General Assembly 2014

Landslide risk mitigation through integrated monitoring and modelling

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In winter 2008-09, exceptional prolonged rains triggered numerous landslides in Calabria (southern Italy). Among these, a large rock slide was triggered on 28 January 2009 in weathered metamorphic rocks at San Benedetto Ullano (CS), involving fractured and altered migmatitic gneiss and biotitic schist. A detailed geomorphological survey was carried out during the entire phase of mobilization, allowing to recognize the evolution of the phenomenon. A series of benchmarks was promptly placed in correspondence of fractures on the body and along the sides of the landslide, allowing for frequent measurements of surface movements. In addition, a network of real-time monitoring extensometers were implemented at the surface of the landslide, combined with a meteorological station. The survey site and the data of the monitoring system allowed, from the early stages of activation of the phenomenon, to implement a support system to handle the emergency.
In the following months, a clear retrogressive distribution could be identified, coupled with a tendency towards the enlargement of the flanks. In early May, the first crisis ended up.
After the arrest of the phenomenon, a geological-technical scheme of the slope could be drawn, also based on data collected through a set of 5 exploratory wells (equipped with 4 inclinometers and 1 piezometer). The landslide mobilized a thickness from 15 to 35 meters along the longitudinal profile.
To examine the stability of the slope affected by the landslide, and to quantify the role of fluctuations of the water table in destabilizing the slope, a parametric limit equilibrium analysis was conducted. The analysis confirmed the first interpretation of the process: the first activation of the landslide was expected, in fact, in the central portion of the slope in case, in the same area, the groundwater levels are close to ground level.
Between 31 January 31 and 1 February 2010, following a further period of exceptional rainfall, the network of strain gauges promptly evicenced the beginning of a new phase of mobilization of the landslide, accompanied by the opening of cracks along the local and provincial roads. On 10 February, the slope movement led the Civil Protection Authority to issue new evacuation orders and closing the roads. On 11 February, following further rains, a further movement of the landslide body occurred, with severe damage to roads and infrastructure. Overall, this new phase of activation replied the one observed during the crisis started in January 2009, confirming the results of the limit equilibrium analysis.
Based on the results of the parametric analysis, the surveillance system could be refined, thanks to a better understanding of the physics of the slope instability. The limit equilibrium analysis was followed by the calibration of a hydrological model, thanks to the availability of dates of activation of the landslide and of rains recorded in the vicinity of the study area.
The latest activation of the slope instability took place during the night between 15 and 16 March 2013, again confirming the results of the limit equilibrium analysis and of the hydrological model “SAKe”. It should be noted that this activation occurred as a result of rain amounts that are less abundant and prolonged than those of the previous two activations, despite the realization of some engineering works and drainages had been started in the study area to improve slope stability. Further works are still to be made, and a refinement of the stability analyses is in progress to understand the apparent increasing fragility of the considered slope.