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Rockfall and deep-seated rockslide modelling in the Cinque Terre UNESCO World Heritage site

Paolo Frattini (1), Will Moody (2), Andrea Tettoni (1), Federico Arlati (1), Federico Agliardi (1), Riccardo Castellanza (1), Andrea Cevasco (3), Elena Valbuzzi (1), Andrea Valagussa (1), Claudio Margottini (4), Daniele Spizzichino (4), and Giovanni B Crosta (1)

(1) Universita' degli Studi di Milano - Bicocca, Earth and Environmental Sciences, Milano, Italy (paolo.frattini@unimib.it), (2) University of Portsmouth, School of Earth and Environmental Sciences, Portsmouth, United Kingdom, (3) University of Genova, Dipartimento di Scienze della Terra dell'Ambiente e della Vita, Genova, Italy, (4) ISPRA - Institute for Environmental Protection and Research, Roma, Italy

The Ligurian coast between Cinque Terre and Portovenere is a UNESCO cultural landscape site. Human settlement in this region over the past millennium have been developed by shaping a steep, uneven terrain, which is highly prone to landsliding. Rockfalls, shallow landslides, debris flows and deep-seated landslides have seriously affected the site during the last centuries, with serious damages and injuries to population. This site has been selected as a case study for the PROTHEGO (PROTection of European Cultural HEritage from GeO-hazards) research project. Two main processes have been analysed within the project: rockfalls along the well-known Via dell'Amore (Lover's Lane), a 500 m long portion of the Cinque Terre coastal path between Manarola and Riomaggiore; and a deep-seated rockslide at Punta Persico, south of Campiglia. Since its construction in the 1920's, the Via dell'Amore played an important role in the local history and more recently as a popular hotspot for tourists visiting the region. The walkway has been closed since 2012 when a rockfall severely injured 4 tourists on the path causing the local authorities to close the walkway since this event. Hazard and risk assessment along the closed portion of the path have been performed. Terrestrial Laser Scanning (TLS) was used to image the inaccessible rock faces and slopes, in order to characterize the discontinuities and perform kinematic feasibility analyses. The resulting susceptibility values were used, along with other inputs (i.e. DEM, block sizes, coefficients of restitution), to run rockfall simulations by 3D numerical modelling software Hy-Stone. The simulation results were used to attain a hazard zonation along the walkway. The individual risk of being killed by a rockfall while on the path on any given day is about one in every 200.000 people. The Punta Persico deep-seated landslide involves many houses inside the landslide, which can be subdivided in several sectors with different behavior. The landslide appears to be active from Ps-InSAR data available from the Italian Special Plan of Remote Sensing of the Environment (Costantini et al, 2017), with surface displacement rates in the order of 10 to 20 mm/a during the period 1992-2008. Following field activity, geomechanical survey, and photo-interpretation, a geological and geotechnical model of the landslide were developed, to be used as a basis for the construction of a 3D Finite Element model of the slope with GTS-NX. The simulation has been calibrated by fitting the observed PS-InSAR displacement rates, in order to constrain the landslide behavior and to trace the potential evolution of the phenomenon. The results show that the landslide is slowly deforming through time without serious treats for the buildings and the population.