An integrated approach for the assessment of ground instabilities-induced damage on critical structures

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Ground instabilities can be responsible for a progressive damaging which acts on civil infrastructures, habitat, and, in extreme cases, human life, due to simultaneous population growth, urban expansion, and climate change. Specifically, the occurrence of combined geohazards (e.g., heavy rainfall and earthquake occurring simultaneously) in a changing climate scenario, highlighting the need for the evaluation of adaptive technologies and the development of innovative approaches for the assessment of ground instabilities and their effects on built and natural heritage. In Italy, landslides, rapid sinkholes, liquefaction and subsidence occur in different natural and anthropogenic environments and may have detrimental impacts on infrastructures and in terms of social and economic losses. As such, occurrence of ground instabilities represents a serious issue to investigate, especially as concerns their predisposing, preparatory and triggering factors.

The research concept presented here aims at developing an integrated multi-hazard approach for quantifying the cumulative effects related to ground instability over time, as a consequence of ongoing deformational processes (i.e. related to soil- or rock mass- creep) as well as of sequence of event occurrence, as in case of rainfalls, earthquakes or subsidence settlements and evaluate the possible damages on existing structures and infrastructure.

As it regards rainfalls occurrence, the sequences of rainfalls play a dual role in the landslides triggering since they can be regarded firstly as preparatory factor and ultimately as triggering actions whose efficiency is subordinate to thresholds related to the previous cumulative rainfalls. Both preparatory and triggering actions depend on changes in pore water pressures distribution and/or soil saturation. Extended field investigations, geotechnical characterisation and the adoption of advanced numerical analyses will allow to highlight the dependence of the time evolution of the horizontal displacement of a rainfall-induced landslide on the pore water pressure variation. Moreover, the implementation of monitoring programmes to measure rainfall, pore water pressures, and deep and superficial displacements will be crucial to back-analyse relevant and well documented case histories, as for the deep ground instabilities (e.g., the Cerda Landslide in Rosone et al., 2018) occurred along the basin of Imera river in northern Sicily, where the reactivations of the Scillato landslide broke down two pillars of the "Imera" viaduct causing the interruption of the A19 motorway (Martinello et al., 2022).

On the other hand, the use of more sophisticated constitutive model for soils and rocks will shed new light on the mechanics of landslides by embracing the role of soil inelasticity throughout the stages of initial triggering of movement from an initially stable condition and eventual propagation. This can also benefit of a series of continuum mechanics numerical analyses aimed at underlining the consequences on propagation of assuming an all-at-once release or a multiple-time release from the many triggering areas spread on the slope, as for the two catastrophic debris-flows occurred in Sarno, Campania region, and Giampilieri, north-eastern Sicily (La Porta et al., 2023). In this perspective, special care will be devoted to the rheology selection and the calibration of the model parameters.

Moreover, long periods of drought make several portions of the territory susceptible to wildfires with detrimental effects on landslide activation and the rheological behaviour of the post-fire debris flow as compared to similar mechanisms happened in the unburned surrounding basins, while anomalous temperature variations play a relevant role in mountainous regions where significant anthropic presence and the dense infrastructure network further worsen the hazard. If one also considers that Italy is characterised by severe seismicity, an even more complex picture emerges that requires a multi-hazard approach of analysis. High and low-magnitude earthquakes have been revealed capable of increasing the number of landslide reactivations in the post-seismic stages, by reducing their pluviometric triggering threshold. For instance, the Molise case study in southern Italy (Martino et al., 2022) revealed that seismic shaking could enhance of about 120% the landslide reactivations during the rainy season following the earthquake, and boost the activity of earthflows, under similar and ordinary pluviometric regime. Such legacy could significantly reduce the safety of strategic infrastructures and existing buildings. For these reasons, the proposed methodology will employ both simplified mechanics-based methods and refined numerical modelling for the vulnerability assessment of existing constructions to earthquakes and landslides. For each considered natural hazard, building-level fragility relationships will be derived in line with the state-of-the-art methodologies for large-scale risk assessment. The synergic collaboration between the Spoke's components will provide essential information/data on the hazard elements, such as expected intensity for both earthquakes and flow-type landslides (e.g., flow density and depth, impact flow velocity). Moreover, the effects of cumulative damage in the case of concatenate events (e.g., earthquake-triggered landslide) will be investigated, building on the recent developments for damage-state-dependent fragility estimation (e.g., Pedone et al. 2023). Such an approach could represent an important step toward an effective evaluation of the resilience of the built environment to seismic and landslide risks.

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