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# Failure susceptibility assessment under dynamic conditions of man-made underground caves in soft rocks

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The Apulian region (south-east of Italy) is extensively characterized by the presence of old underground cavities used in the past for the extraction of calcarenite rock, a very soft carbonate rock, and then abandoned over time. The assessment of the stability conditions for such caves is a very challenging problem, especially where the interaction of cavities with overlying structures or infrastructures is possible. The role of environmental factors in the triggering of cave failure processes has been widely studied in the literature, for instance by Parise & Lollino (2011), Castellanza et al. (2018), Perrotti et al. (2018) to mention a few. However, the instability processes related to dynamic loads are often underestimated. In fact, very few literature works exist in the specific field: Genis & Gercek (2003) have firstly demonstrated the role of dynamic waves in the enlargement of the yield zone around the cave; Genis & Aydan (2007; 2008) have carried out some studies applied to real cases, specifically focusing on the pillar behaviour. The effects of the interaction between adjacent cavities has been also investigated by Gercek (2005) and Landolfi (2013), all highlighting that the presence of cavities at short distance induces larger risk conditions under dynamic conditions.

This work is aimed at investigating the effects of dynamic loads, in accordance with regional seismicity, on the evolution of plasticity within man-made underground cavities in soft calcarenite. Both the seismic behaviour of single ideal caves and that of twin adjacent caves have been analyzed. In order to investigate the evolution of the stress-strain state of the cavity under dynamic loading and the corresponding equilibrium conditions, a parametric analysis was carried out. The parametric analysis was performed by varying both the geometrical features of the ideal cavity, in accordance with the typical values observed for the Apulian underground cavities system, and the seismic input characteristics. An elastic-perfectly plastic Mohr-Coulomb model, integrated by viscous damping according to the frequency-dependent Rayleigh formulation, has been adopted.

The numerical results highlight appreciable widening of the rock zones at yielding caused by the dynamic input, especially in the case of wide cavities. Also, the overburden roof thickness plays a significant influence, since a clear increment of the difference between the static and dynamic behaviour of the rock mass is observed when the roof thickness increases. The numerical results also indicate that the dynamic cavity stability depends on the energy content of the dynamic input.

In addition, the numerical model implementing the interaction between twin cavities under

dynamic conditions shows the tendency to plastic failure in the septum, which is enhanced in the dynamic phase compared to the static one, and again dependent on the width of the cavity, the thickness of the roof and the energy content of the dynamic load.

Lastly, the research has also proposed a methodology to calculate the factor of safety with respect to the occurrence of a general failure of underground cavities under dynamic conditions, which allows to quantify the change of the stability conditions from static to dynamic conditions.