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A three-dimensional back-analysis of the collapse of an underground cavity in soft rocks

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Anthropogenic sinkholes have recently occurred in built-up areas of Sicily (southern Italy) and are generally associated with the presence of ancient underground quarries for the extraction of soft calcarenite rock, used as building material. These quarries were poorly excavated and then were abandoned in the following decades; urban expansion has recently enlarged to involve the areas affected by presence of the cavities, so that the likely collapse of the underground systems poses serious risks to people, buildings and infrastructures.
The present work focuses on the case of the town of Marsala, where in 2003 a sinkhole opened at the outskirts of town, near peri-urban buildings. Field surveys, structural analysis of the joint networks in the rock mass and numerical modeling were carried out in order to investigate the most significant factors responsible of the instability processes of the underground quarry.
In particular, a geotechnical three-dimensional model has been defined based on in-situ measurements and surveys. The FEM analyses have been performed with the code Plaxis-3D, by using initially the Mohr-Coulomb elasto-plastic model and then assessing the influence of the joint systems on the rock-mass stability with a jointed rock anisotropic model. Discrete planar bands have been also used to simulate the effect of specific joints, as an alternative to the jointed rock model. The results are in good agreement with the failure mechanism generated during the 2003 sinkhole event, and confirm that reliable analyses of these problems requires 3-D sophisticated tools.