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# Geoengineering problems and solutions in the Murge karst (Apulia, SE Italy)

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The Murge area extends for about 6000 km$^2$ and is represented by a NW–SE karst plateau whose elevation decreases by means of fault-bounded displaced blocks toward NE, from about 680 m a.s.l. (High Murge) down to the Adriatic sea (Low Murge and Apulian Adriatic shelf). Geologically, it consists of a 3 km-thick Cretaceous carbonate succession of well-bedded limestones and dolomites, locally covered by thin Late Pliocene-Quaternary deposits, namely calcarenites and subordinate sands and clays. From the end of Cretaceous up to Pliocene, the Murge area experienced a long period of exposure which favored the development of karst processes responsible for the genesis of surface and underground features, like swallow holes, dolines, dry valleys, poljes and caves. In particular, the main cave and conduit systems develop in the first tens of metres from the ground, involving entirely the epikarst or subcutaneous zone.

Many are the geoengineering problems in this area due to complexity of the karst landscape and of the underground drainage system. Some of them regard the hydrogeological and hydrological aspects, involving aquifer pollution and groundwater contamination, or flash floods related to clustered rainfall and the related sudden runoff; other problems result from rock or soil failure mechanisms through occurrence of collapse and suffosion sinkholes. In the Murge karst, collapse sinkholes occur both as natural phenomena, linked to karst caves, but they can be also induced by anthropogenic cavities, consisting of excavation by man for shelter, cultural proposes or where rocks were mined to be used as building material. In particular, the occurrence of sinkholes results typically from sudden collapses of the roof of underground voids, and have been at the origin of casualties and severe damage. Subtle and gradual suffosion sinkholes develop where seepage erosion occurs in sandy soils whose grains settle into voids in the underlying carbonate rocks. This mechanism induces differential settlements and rotations of foundations, leading to instability of buildings and other structures.

Numerous remedial and preventive solutions dealing with geoengineering aspects in karst can be adopted due to the complex peculiarities and high variability of the Murge landscape. Thus, the selection of appropriate measures to predict and remediate future damage scenarios becomes very important and require i) the development of detailed geological and engineering geological models, and ii) careful understanding of the geological hazards, and of their likely effects.

The main difficulties for planning and monitoring actions are linked to the implementation of integrated methods capable of exploring and modeling carbonate rock masses and their structural uncertainty in the karst environment. Multi-technique geophysical methods, integrated with geotechnical surveys (including borehole drillings) can be adopted for passing from a conceptual geological model to an observational engineering-geological model, constrained by data from site-specific ground investigation and laboratory tests. The next step is then constituted by assessing analytical and numerical models which usually require considerable simplifications of the engineering geological model and can be used as general guidelines for designing mitigation and remediation measures.