Geophysical Research Abstracts
Vol. 12, EGU2010-9726, 2010
EGU General Assembly 2010

Numerical analysis of instability processes in underground cavities and of the related effects at the surface

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Natural and anthropogenic caves may represent a potential hazard for the built-up environment, due to the occurrence of underground instability processes, that may propagate upward and eventually reach the ground surface, thus inducing the occurrence of sinkholes. Especially when the caves are at shallow depth, the effects at the ground surface may result extremely severe. In the Apulia region of southern Italy, there are many sites where underground quarrying developed in the past, due to presence at a certain depth of rock of good quality for building purposes. Development of underground quarries, rather than open pit mines, was also favoured by the preservation of the terrains on the ground surface for agricultural practices. The Pliocene-Pleistocene calcarenite (a typical soft rock) was therefore quarried underground, by digging extensive networks of galleries in those levels within the local geological succession most suitable for the quarrying activity. With time, these underground activities have progressively been abandoned, and later on many quarries were used for other purposes, including illegal discharge of solid and liquid wastes. Many Apulian towns are nowadays located just above these caves, due to urban expansion in the last decades and loss of memory of the presence of the underground quarries. Thus, a serious risk exists for civil society, which should not be left uninvestigated.
The present contribution deals with the analysis of the main factors at the origin of the instability processes described, also including those causing weathering of the soft rock wihich induces gradual decay of the physical and mechanical properties of the rock mass. Aimed at exploring the evolution with time of the stability conditions within the cavities, numerical analysis have been implemented by using finite element methods with respect to ideal situations which are representative of typical case studies in Apulia. Both the effects of local instability processes occurring within the underground case and the effects of the progressive enlargement of the caves have been explored. Sensitivity analyses have been carried out to evaluate the influence of the rock properties on the cave stability. Moreover, decay processes of the mechanical properties of the rock mass as a consequence of wetting and weathering phenomena in the areas surrounding the caves have been simulated. The results achieved from the numerical analyses have been then compared to what has been observed in situ during several field surveys and a satisfactory agreement between the numerical simulations and the instability processes detected in the field has been noticed.