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The neglected role of karst features in rock mass characterization and stability assessment

Lidia Loiotine[1,2], Gioacchino Francesco Andriani[2], Marc-Henri Derron[1], Michel Jaboyedoff[1], Piernicola Lollino[3], and Mario Parise[2]

[1]University of Lausanne, Institute of Earth Sciences, 1015 Lausanne, Switzerland (lidia.loiotine@unil.ch; marc-henri.derron@unil.ch; michel.jaboyedoff@unil.ch))

[2]Department of Earth and Environmental Sciences, University of Bari Aldo Moro, 70125 Bari, Italy (lidia.loiotine@uniba.it; gioacchinofrancesco.andriani@uniba.it; mario.parise@uniba.it)

[3]CNR – IRPI, Istituto di Ricerca Protezione Idrogeologica, Bari, Italy

Stability analyses in karst settings, whether to assess the equilibrium conditions of natural slopes or to design engineering interventions, coexist with a significant uncertainty related to difficulties in modelling karst features. As a matter of fact, most of the rock mass classification systems do not directly take into account the presence of karst structures such as voids, conduits or caves, which can strongly influence the mechanical behaviour and the water flow in rock masses.

In the last decades, the identification and characterization of discontinuity systems for rock mass characterization, aimed at stability analyses, have been intensively investigated by means of remote sensing techniques. However, semi-automatic or automatic methods for the extraction of discontinuities from point clouds are not easily applicable in karst because surface and subsurface features produce irregular surfaces, which are difficult to classify even using the most-advanced algorithms. This occurs even more heavily in the case of soft rocks, such as calcarenites.

In this study, a demonstration of the influence of karst features in rock mass characterization and slope stability assessment is presented. First, the results of the Discontinuity Set Extractor (DSE) software used on an appropriate case study show that the irregular surfaces produced by carbonate dissolution, further enhanced by weathering, caused an incorrect classification of the discontinuity sets. Second, a high-resolution Digital Outcrop Model (DOM) was used to generate a very fine mesh (average element size = 35 cm, to take into account the large-scale karst structures) and to carry out 3-D numerical stability analyses by means of Finite Element Method, using a continuum-based approach. Although in the current conditions the examined slope is stable, the results illustrate that the maximum shear strain is localized in correspondence of the karst features (e.g. caves and voids) and at the sea level. By applying the Shear Strength Reduction method, it was found out that weathering processes can cause the same structures to be under yield and lead to localized failures.

In addition, the key role that the discontinuities (extracted using an *ad-hoc* procedure) play on the rock mass mechanical behaviour was investigated using a 2-D FEM, based on a discontinuum

approach. The results, which are in agreement with field observations, point out that karst processes, which features are characterized by the highest values in pervasiveness and aperture of the discontinuity systems and tend to reduce the rock bridges over time, need to be implemented in the rock mass classification systems and in numerical modelling techniques to avoid incorrect results.