PERFORMING GEO-MECHANICAL CHARACTERIZATION OF CARBONATE ROCK MASSES IN UNDERGROUND CAVES THROUGH LASER SCANNER TECHNIQUE

Poster · April 2018

DOI: 10.13140/RG.2.2.21947.11047

3 authors:

Biagio Palma
Idrogeo

M. Parise
Università degli Studi di Bari Aldo Moro

Anna Ruocco

European Geosciences Union General Assembly 2018 Vienna | Austria | 13 April 2018
Session NH8.2/GM7.5/HS11.35/SSS13.42 - Speleogenesis, Geomorphology and Hazards in Karst

PERFORMING GEO-MECHANICAL CHARACTERIZATION OF CARBONATE ROCK MASSES IN UNDERGROUND CAVES THROUGH LASER SCANNER TECHNIQUE

M. Parise
University Aldo Moro, Bari, Italy;
National Research Council, IRPI, Bari, Italy

B. Palma
Idrogeo s.r.l., Vico Equense, Italy

Anna Ruocco
Idrogeo s.r.l., Vico Equense, Italy

INTRODUCTION

Knowledge of the geometrical and structural setting of rock masses is crucial to evaluate the stability and to design the most suitable stabilization works. The traditional survey techniques are often expensive and present great difficulties related to logistics in accessing the sites, to the high hazards for the operators, and to the height of the rock faces, or simply because of the wide extent of the rock walls to be examined. To solve such problems, and with the aim to characterize rock masses from both the structural and geo-mechanical standpoints, in recent years' innovative survey techniques including the use of the Terrestrial Laser Scanning (TLS) have been introduced. In this work we present the results of a study carried out in one of the most famous karst sites of southern Italy, the Castellana Caves.

Figure 1. Location of the study site

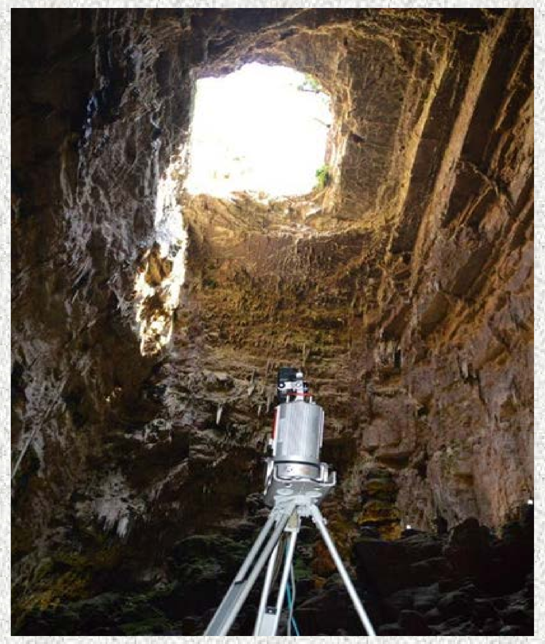
1. CASTELLANA CAVES

The Castellana Caves is a famous karst site located in Apulia, S Italy (Fig. 1). This remarkable karst system, discovered in the 1930s by Franco Anelli [1], and soon became show cave [2], represents karst and its wonders to thousands of visitors. The most spectacular view of the system is the Grave, produced by the collapse of the cave roof, a very common situation in Apulia [3]. Local bedrock is represented by stratified Cretaceous limestones [4], belonging to the palaeo-geographic domain of the Apulian Carbonate Platform, the foreland during the building-up of the Southern Appennininic Chain.

2. 3D LASER SCANNER SURVEY AT THE GRAVE OF CASTELLANA

Grave was analysed through a survey carried out by means of the laser scanner RIEGL VZ400 (Fig. 2). Laser scanner techniques have been recognized since several years as a powerful tool for investigating rock masses [5, 6, 7], especially when these present difficult logistic conditions.

During the survey, a geo-referenced point cloud of 430.000 million of points was obtained (Fig. 3); each point is characterized by the geographic information (X,Y, Z), the chromatic ones (RGB), and by the characters of reflectivity. The survey consisted of 42 scans (20 scan-positions, 8 out of these located outside the Grave). By the elaboration process, from the original point cloud (Fig. 3) a solid surface (mesh in fig. 4) was obtained, which is able to represent the geometry of the Grave at high detail.



Main features of laser VZ 400:
- *Class 1 Laser.*
- *Distance > 500 mt.*
- *Metric photocamera with optical features calibrated at high.*
- *definition (>6 Mpixel).*
- *First and last impulses.*
- *Ability to reduce the shadow areas due to vegetation.*
- *Integrated inclinometric sensor.*
- *Integrated GPS antenna.*
- *High acquisition speed: min. 122.000 pts/sec.*
- *Scan angles: 360° horizontal – 360° vertical.*
- *Precision: ≤ 5mm.*
- *Integrated compass.*

Figure 2. Laser scanner RIEGL VZ400 and its main features

3. GEOLOGICAL-STRUCTURAL ANALYSIS ON POINT CLOUD

The geo-structural analysis of the Grave was performed through innovative methodologies which considered the measure of the discontinuities directly from the point cloud. The procedure consists in analysis of the normals, associated with the plans that make up aggregates of points, with the aim to identify those sectors showing similar orientation. These values were later characterized by assigning to the point cloud a new attribute, computed by associating the attitude (Dip/Dip Direction) to the value of the normal. Eventually, all points showing similar attitudes, were grouped along the geological lineation of interest, to better interpolate the planes which adapt in the best way to the identified point distribution.

This is a semi-automatic method, with manual control and validation, since the computational phase of identification, computation and conversion of the normals in geological datum, is proceeded by a process of manual selection of the elements to be modeled, guided by experience of the operator, who is in this way able to fully control the output. The planes so identified (Fig. 5) were portrayed in stereographic projections (Fig. 6), by ranking the data in families of discontinuities: 113 discontinuities were taken along the walls, and 3 main families identified, in addition to bedding (Fig. 6).

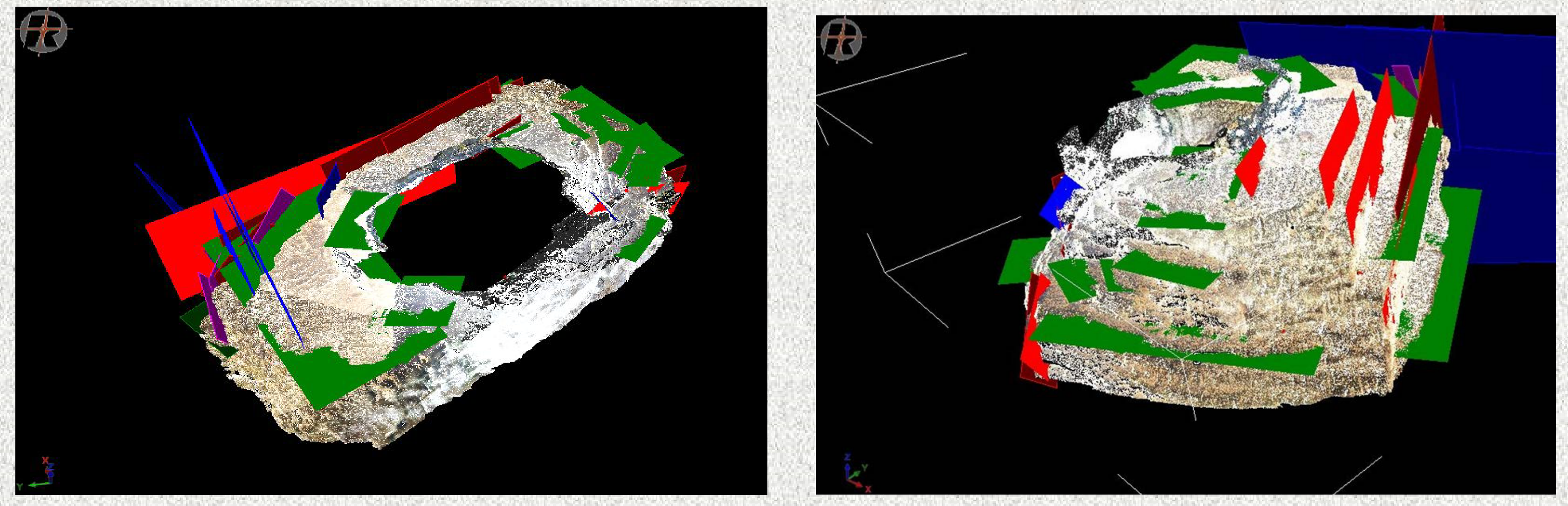
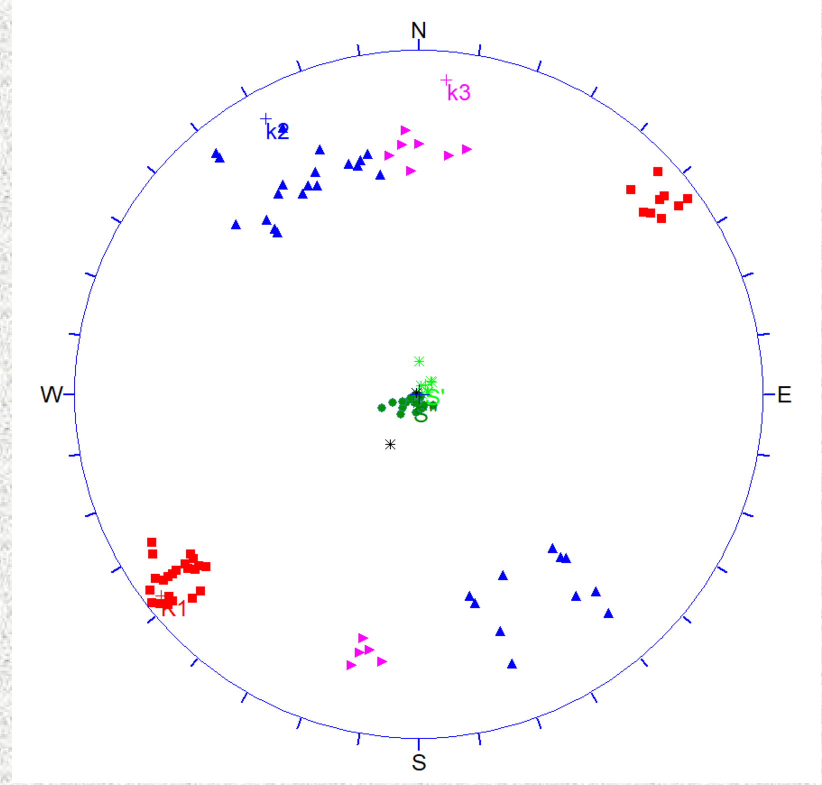


Figure 5. Map of Grave, showing the identified discontinuity plans by geological-structural analysis on the point cloud



family	dip direction	dip
K1	52	87
K2	151	85
K3	185	85
S'	212	4
S''	35	3

Figure 6. Pole stereographic projection of data identified by geological-structural analysis on the point cloud

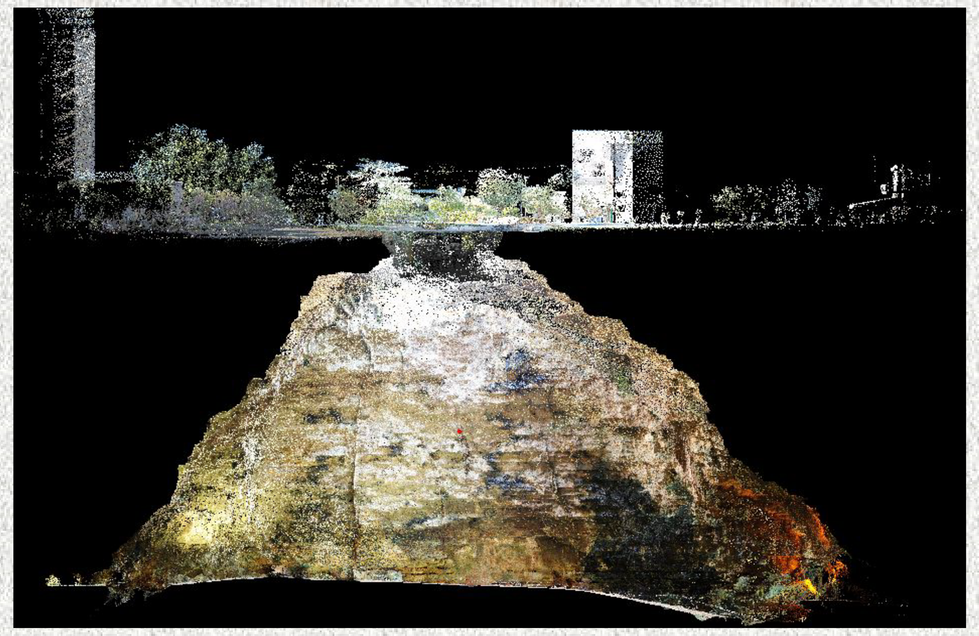


Figure 3. Point cloud – Real numerical model

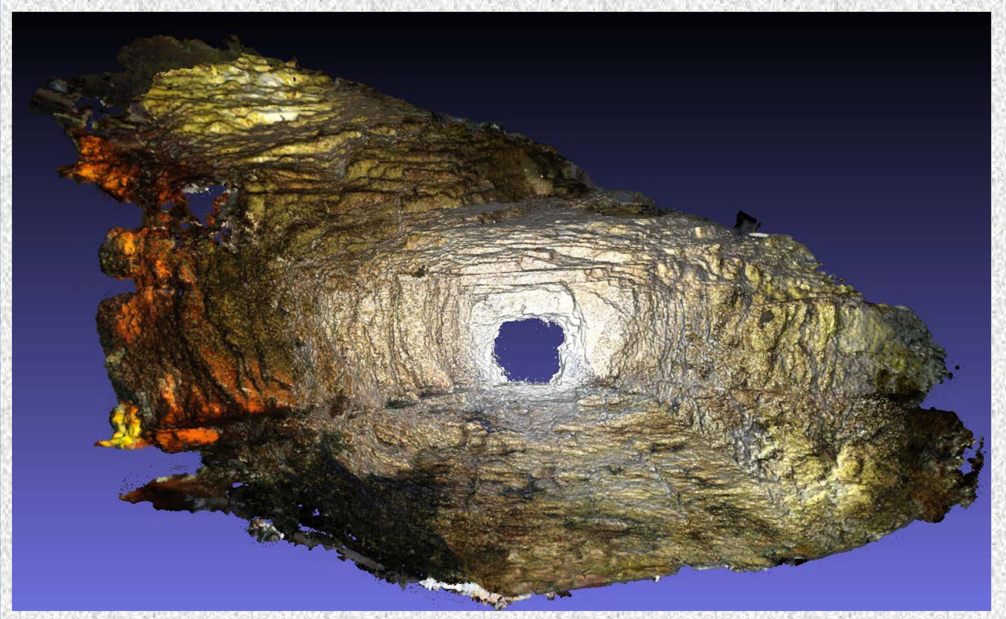
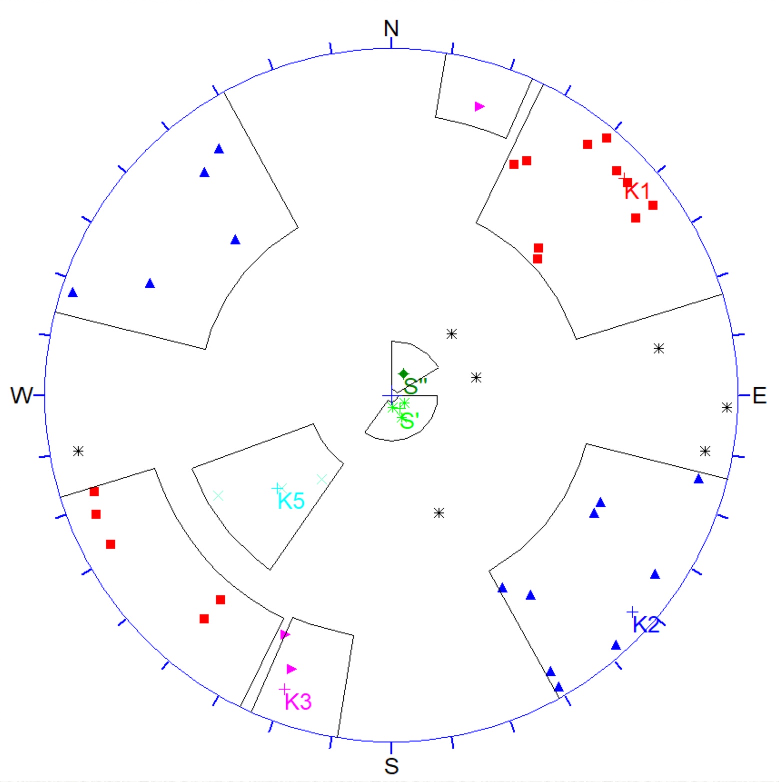


Figure 4. 3D Mesh

4 GEO-MECHANICAL SURVEYS

Two scanlines have been performed by geologist-climbers along the walls of the Grave through traditional survey, following the recommendations suggested by the International Society for Rock Mechanics [8]. The data so acquired (no. 46) have been collected and represented in polar equiareal projection, and have been analysed through cluster analysis. The field data allowed to identify, besides the bedding, three main families of discontinuity (Fig. 7); in addition to these, some random discontinuities were also measured.



measure station	family	dip direction	dip
ST1	K1	237	84
	K2	298	83
	K3	24	87
	S'	322	6
	S''	208	8
ST2	K1	225	88
	K2	319	88
	K3	197	82
	K5	51	46
	S'	354	4

Figure 7. Pole stereographic projection of data acquired from the geo-mechanical surveys.

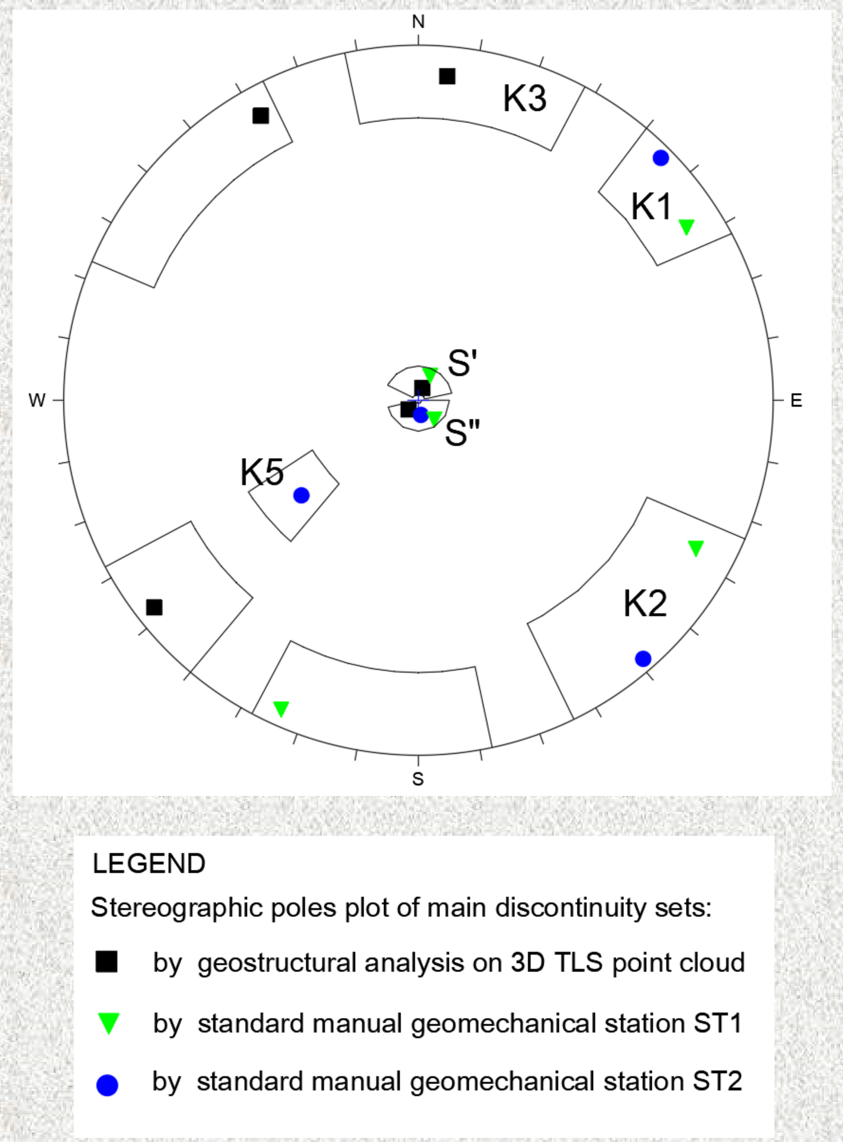


Figure 8. Quantitative comparison among the different techniques used for surveying the rock masses

5. QUANTITATIVE COMPARISON AMONG DIFFERENT TECHNIQUES

The quantitative comparison among the different techniques used for surveying the rock masses ("classical" geo-mechanical survey, and digital survey from cloud point acquired by TLS) resulted in a good agreement between the data obtained by the different techniques (Fig. 8). The slight differences observed should be attributed to the logistic difficulties in performing survey along vertical or overhanging rock walls.

6. CONCLUSIONS

Analysis of carbonate rock masses is complicated by the presence of karst features, which are typically not considered in the classical geo-mechanical approaches. Complexity of karst make this environment particularly difficult to be examined, and in many cases engineering works have to be carried out very carefully, only after a thorough knowledge of the karst features has been reached in order to reduce the likely negative consequences of wrong decisions and works. At this goal, we have presented in this paper the use of TLS survey, which allowed to obtain highly precise data in logistically difficult conditions, thus providing practitioners with the necessary amount of data to design and realize the specific projects.

REFERENCES

[1] F. Anelli, "*First researches of the Italian Institute of Speleology in the Murge of Bari*", Le Grotte d'Italia, 2 (3), 11-34, 1938.
[2] M. Parise, "Some considerations on show cave management issues in Southern Italy", In: P.E.Van Beynen (ed.), "Karst management", Springer, ISBN 978-94-007-1206-5, 159-167, 2011.
[3] U. Sauro, "*A polygonal karst in Alte Murge (Puglia, Southern Italy)",* Zeit. Geom., 35 (2), 207-223, 1991.
[4] M. Parise, and A. Reina, "*Geology of the Castellana Caves*", Grotte e dintorni, 4, 221-230, 2002.
[5] S. Slon, R. Hack, and K. Turner, "*An approach to automated discontinuity measurement of rock faces using laser scanning techniques*", Proc. ISRM EUROCK 2002, 87-94, 2002.
[6] S. Slon, R. Hack, B. van Knapen, and J. Kemeny, "*Automated identification and characterisation of discontinuity sets in outcropping rock masses using 3D terrestrial laser scan survey techniques*", Eurock 2004 Meeting, 2004.
[7] S. Slon, R. Hack, B. van Knapen, K. Turner, and J. Kemeny, "*A method for automated discontinuity analysis of rock slopes with 3D laser scanning*", TRB 2005 Ann. Meeting, 2005.
[8] International Society for Rock Mechanics, "*Suggested methods for the quantitative description of discontinuities in rock masses*", Int. J. Rock Mech. Min. Sci. & Geomech. Abstr., 15, 319-368, 1978.