Escuela Superior Politécnica del Litoral

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Un break científico

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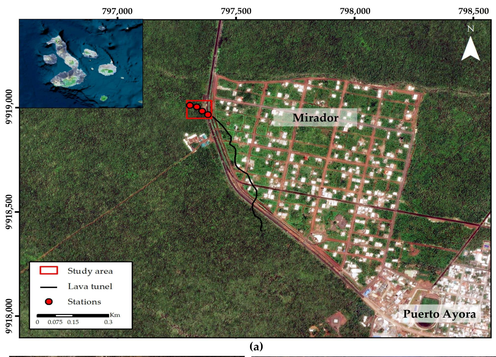
STABILITY ANALYSIS OF THE VOLCANIC CAVE EL MIRADOR (GALÁPAGOS ISLANDS, ECUADOR) COMBINING NUMERICAL, EMPIRICAL AND REMOTE TECHNIQUES

PROBLEM

The “Mirador de los Túneles” is a tube-shaped volcanic cave with a sinuous structure in the Galápagos Islands formed due to cooled near-surface lava flows. Since this natural formation is considered a tourist site, a large number of people frequent it daily. However, its safety conditions have not yet been defined by a comprehensive geotechnical study.

MAIN GOAL

To improve the geomechanics data on cave in the Galápagos Islands, considering that only a few publications have addressed this topic. Principally, the ultimate objective of the research is to validate in a particular case a simple and effective methodology to geomechanically characterize caves through field data.



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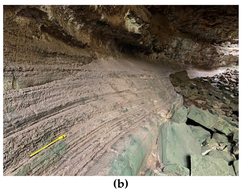
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METHODOLOGY

This research applied the Q Index and Rock Mass Rating (RMR), the most widely used geomechanical classifications. In addition, the study was complemented with the recently developed Cave Geomechanical Index (CGI), which allows comparison and validation of the rock quality results.

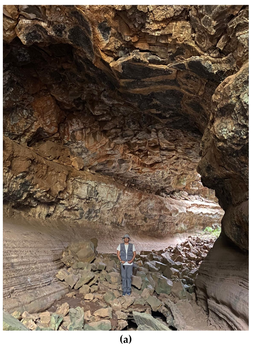
In the numerical analysis of the cave, the most unfavorable sections were chosen and assigned rock mass strength values based on the Hoek-Brown criterion for basaltic materials by means geotechnics software.

For the generation of the 3D model of the lava tunnel interior, a total of 2079 photographs were taken from different angles and points using an iPhone 13. To orient and scale the 3D point cloud, obtained by SfM, it is necessary to have the precise coordinates of some control points, at least three, on the ground surface of the mapped area. With the help of Agisoft Metashape software the 3D point cloud was obtained. All point cloud files were exported to “xyz” format for processing using CloudCompare. Finally, the different parameters collected from the geomechanical stations were compared with the data that could be obtained from the model to check their accuracy.

Susceptibility to Structural Instability	CGI	Color
Very Low	81–100	
Low	61–80	
Moderate	41–60	
High	21–40	
Very High	0–20	

Parameter	Value
σc	25 MPa
GSI	55
mi	25
D	0
γ	0.028 MN/m3
Erm	6668 MPa
σtmass	−0.034 MPa

Note: σc, simple compressive strength; GSI, geological strength index; mi, intact rock constant; D, disturbance; γ, specific gravity; Erm, modulus of mass deformation; σtmass, tensile strength of the mass.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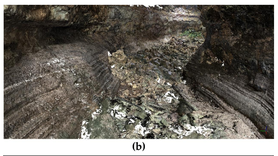
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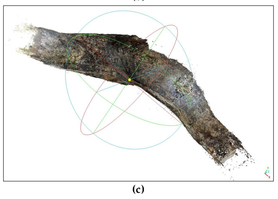
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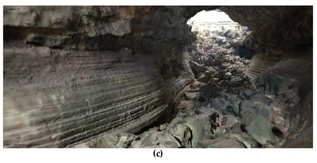
RESULTS

The finite element calculation has been carried out on the section where the geomechanical station 3 has been erected. Station 3 was chosen because it is inside the lava tunnel and does not show 3D entrance effects. The geometric model was also more reliable.. Here the total displacements are negligible, and the cavity is in elastic regime-stable. However, huge unstable blocks are visible at the entrance, which are kept in situ only by the roughness and interlocking of the discontinuities. From the generation of the strength factor graph, it is possible to deduce that except for very specific areas where stresses accumulate, no tensile effects are expected in the tunnel.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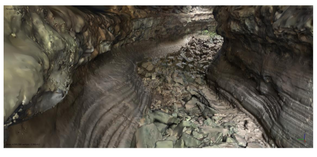

CONCLUSIONS

The SfM photogrammetric technique permit to generate a geometric model that allowed the acquisition of data that were difficult to take in situ and that helped to complete the parameters established in the geomechanical classifications. It is important to mention that remote techniques do not replace the field survey and manual data acquisition but are complementary to them. The present research show that there are no relevant displacements and the stresses around the cave are greater than the previous scenarios with emphasis on certain areas around the gables and the roof. However, it can be said that the cave remains stable.
Some openings in the roof and old rock falls were observed, therefore, constant monitoring should be carried out and visitors should be restricted.