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Un break científico

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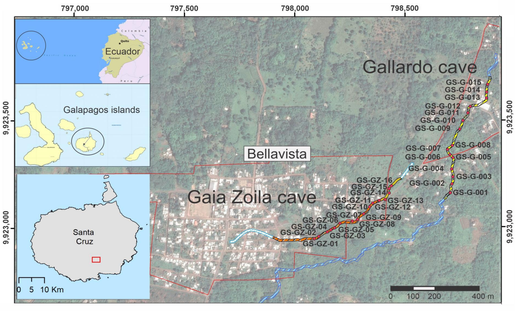
STABILITY ANALYSIS OF LAVA TUNNELS ON SANTA CRUZ ISLAND (GALAPAGOS ISLANDS, ECUADOR) USING ROCK MASS CLASSIFICATIONS: EMPIRICAL APPROACH AND NUMERICAL MODELING

PROBLEM

These 13 islands of Galapagos were generated by a hotspot. Several shield-shaped volcanoes on the islands are currently inactive. The main products of the eruptive activity were pahoehoe-type or AA-type lava flows. The differential cooling of the basaltic magma flow has locally originated cavities of the length of kilometers and metric height, known as lava tubes. Currently, the development of the urbanization of the Galapagos Islands is at its peak. Therefore, new stability studies of the existing cavities are needed because the caves are visited by tourists and by researchers.

MAIN GOAL

In this research, we compared different methodologies that consider geometric parameters as the width of the caves, where a function was determined to establish whether a cave is stable or unstable. The stability of lava caves in the Mirador and Bellavista sectors of Santa Cruz Island (Galapagos) was analyzed using three geomechanical classification methods (RMR, Q index, and CGI) to evaluate the tunnels' capacity for supporting vertical loads.



METHODOLOGY

The geomechanical classification of the rock mass was determined according to 3 classifications: rock mass rating (RMR), Q index, and Cave Geomechanical Index (CGI).
To obtain the input parameters we followed the methodology of "geomechanical stations".
A geomechanical station is a set of observations and measures of the orientation of discontinuities, rock strength (using the hammer of a sclerometer), and condition of joints (persistence, roughness, and infilling) using field "notebooks" and templates. Once each relevant parameter was obtained, then the rating of them was calculated using the tables and criteria of each system RMR, Q, or CGI.

Table 1. Rock mass rating (RMR) according to [15] was used in the CGI.

Sum	100–81	80–61	60–41	40–21	<20
Class number	I	II	III	IV	V
Description	Very good	Good	Regular	Poor	Very Poor

Table 2. Hydraulic radius from CGI according to [22].

Class Range	1.83–3 m	0.92–1.82 m	0.00–0.91 m
Class	Large	Regular	Small

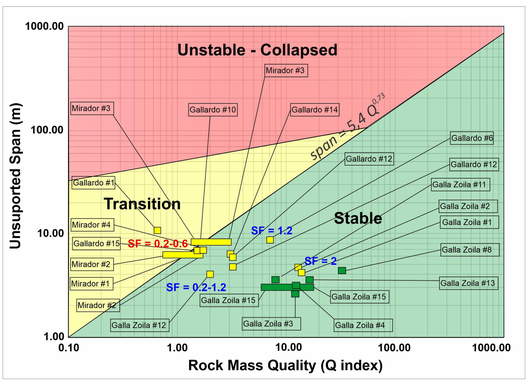
Table 3. Ceiling thickness from CGI according to [22].

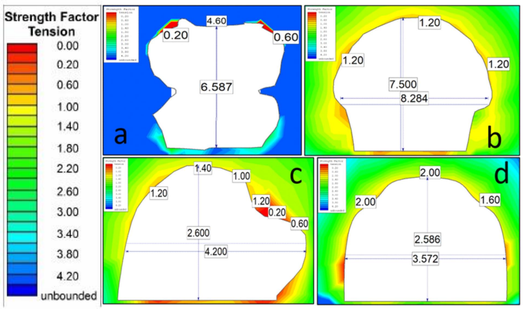
Class range	7.65–10 m	3.32–7.64 m	0.00–3.31 m
Class	Large	Regular	Small

RESULTS

Four caves were considered for the analysis: Mirador GS-M-02, Gallardo GS-G-06, Galla-Zoila GS-GZ-12, and Galla-Zoila GS-GZ-13. The results indicated that the Galla- Zoila cave GS-GZ-13, located in the stable zone according to Figure 7, has a safety factor of 2. However, as the caves approach the transition zone, the safety factor decreases, as is the case of Gallardo GS-G-06 (safety factor between 1.2), Galla-Zoila GS-GZ-12 (safety factor between 0.2 and 1.2), and Mirador GS-M-02 (safety factor between 0.2 and 0.6).
A numerical analysis was performed using boundary elements with the Examine2D program. This study was applied to some sectors of each cave, and the results shown the state of the caves.

Cave	Width (m)	Height (m)	Ceiling Thickness (m)	Overburden Unit Weight (MN/m3)	Em (MPa)	Poisson Ratio	Intact Comp. Strength (MPa)	GSI	mi	D	F. S
Mirador GS-M-02	6.3	6.6	3.6	0.026	12000	0.32	45	79	25	0	0.2–0.6
Gallardo GS-G-06	8.9	7.5	10	0.028	6668	0.32	37.3	60	25	0	1.2
Galla-Zoila GS-GZ-12	4.2	2.6	10.6	0.028	6668	0.32	27.5	70	25	0	0.2–1.2
Galla-Zoila GS-GZ-13	3.6	2.6	11.4	0.028	6668	0.32	27.5	80	25	0	2





CONCLUSIONS

The methodologies used exhibited different points of view for the stability analysis of lava tubes. The comparison graphs of the methods showed similarities concerning the visual description. However, the stability method based on the Q index was the closest to the description made in the field. The values obtained from the CGI were less conservative than those obtained through the Q index, visual inspection, and those made via numerical methods. In addition, in some of the caves the input parameters required for analysis via this method were not obtained.