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# Probabilistic Assessment of Slope Stability Based on Microseismic Monitoring at the Morro da Mina Pit, Cajati (SP)

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## Introduction

Slope stability in open-pit mining is a critical factor for operational safety and the sustainability of mineral extraction. Seismic events induced by mining activities can compromise the structural integrity of slopes, making it essential to adopt analysis methods that consider the variability of geotechnical parameters and the effects of seismicity.

This study presents a probabilistic approach applied to the assessment of slope stability at the Morro da Mina Pit, located in Cajati (São Paulo, Brazil), based on data obtained through continuous microseismic monitoring. Recorded induced seismic events supported analyses using the Point Estimate Method (PEM) and the Reliability Index Method (RIM).

## Methods

To assess slope stability, the Point Estimate Method and the Reliability Index Method were employed. The Point Estimate Method proposes a simplified numerical procedure for estimating the initial statistical moments of a random function, using the mean, standard deviation, and optionally, the skewness coefficient. For n variables, the method assigns two representative values to each—maximum and minimum point estimates—thus incorporating the uncertainty of geotechnical parameters into performance analyses.

The Reliability Index Method quantifies, in statistical terms, the safety margin of a slope, expressing the distance between the mean safety factor and the failure threshold (FS = 1) in standard deviation units. This approach enables the replacement of a single deterministic safety factor with a more robust measure of reliability.

Critical variables considered included slope geometry, seismic coefficient ($K_h$), lithologies, geomechanical classes, and structural discontinuities. Combinations of these variables were subjected to pseudo-static analyses for planar failure mechanisms to obtain safety factors.

## Results and Conclusions

The results showed that the probability of failure increases with higher seismic coefficients used in the analyses. Among the evaluated geomechanical classes, the most weathered class exhibited significantly greater sensitivity to variations in the seismic coefficient, indicating higher susceptibility to seismically induced instability.

For the reliability index (β), a decreasing trend was observed with increasing $K_h$, reflecting a scenario of lower structural safety. Low β values indicate less reliable conditions, whereas higher values represent a greater safety margin. The most weathered class also demonstrated a stronger influence of seismicity on this parameter.

The application of probabilistic methods proved to be an effective approach for estimating risk scenarios in slopes subjected to seismic activity, providing valuable information for geotechnical management in mining environments. This work presents high practical application potential, as it enables the simulation of hypothetical, realistic, and dynamic slope stability scenarios under induced seismic activity. This approach represents a significant advancement in the understanding and management of operational geotechnical risk.