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Below the surface - high resolution tailings imaging with HVSR and ambient noise tomography

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Introduction

The mining of ore generates tailings, a waste byproduct, stored long-term in engineered dams to minimize environmental impacts. Despite extensive instrumentation including piezometers, water-quality sondes, radar, cameras, and inclinometers, current dam monitoring systems fail to capture critical internal conditions such as material property changes and fluid saturation that control structural stability, limiting the accuracy of safety assessments and underscoring the urgent need for advanced monitoring technologies.

This paper presents a 28-day passive seismic survey at a Tailing Storage Facility (TSF) in western Tasmania using 213 Smartsolo nodes to map pre-construction topography, support remining and closure planning, and identify fluid pathways by characterizing subsurface structures and material properties via ambient noise surface wave tomography (ANSWT), horizontal-to-vertical spectral ratio (HVSR), and cone penetration tests (CPT).

Methodology

ANSWT utilizes the dispersive nature of Rayleigh waves, surface waves that propagate along the Earth's surface, to construct a 3D shear-wave velocity model. Continuous seismograms were segmented, spectrally whitened, and cross-correlated (normalized cross-correlation) to estimate Green's functions. Stacked cross-correlations revealed Rayleigh wave arrivals, and dispersion curves were generated using frequency-time analysis (Levshin, Pisarenko, and Pogrebinsky, 1972). Automatic dispersion curve picking, employing Bessel function fitting (Boschi and Weemstra, 2015), isolated the fundamental mode. Phase velocity maps were generated at frequencies within the range of 2 – 15 Hz, regionalized into a 15x15m grid (chosen due to the depth of the survey), using the approach by Mordret (2014). Finally, a 3D velocity model was obtained by inverting the phase velocity maps for depth, providing 1D S-wave velocity profiles for each grid cell. This model was then corrected for surface topography, yielding a model expressed in height above sea level.

HVSR, based on Nakamura (1989), estimates subsurface layering by analyzing the spectral ratio between horizontal and vertical ground motion components. Distinct peaks in the HVSR can be used to estimate the fundamental resonance frequency (f0) of the structure. F0 is related to layer thickness (H) and shear wave velocity (Vs) by $f0 = Vs/4H$. Therefore, estimates of f0 and the shear wave velocity calculated by ANSWT can be used to infer the thickness of tailings.

Results and Conclusions

Understanding and managing tailings storage facilities is of critical importance, particularly in light of recent failures and the associated geotechnical risks they pose. While both ANSWT and HVSR independently provided valuable subsurface constraints, their combined application significantly reinforced key structural interpretations. The combination of ANSWT, HVSR, and CPT data produced a comprehensive geophysical assessment of the TSF, providing critical information for enhancing our understanding of the subsurface conditions. This detailed characterization can directly inform future tailings remining efforts, engineering stability assessments, and long-term site closure planning.