Fibre optic Distributed Acoustic Sesning (DAS) for geotechnical monitoring in mining

S. Dande1, E. Forbes2, T. Butler2, A. Senso2

1ESG Solutions, USA

2ESG Solutions, Canada

Abstract

Fibre optic sensing technologies, particularly Distributed Acoustic Sensing (DAS), show promise for monitoring seismicity, stress in underground mining, and assessing tailings dam integrity. While its application in mining is still evolving, this poster presents two case studies:

Case Study 1: At Glencore's Onaping Depth Project in Ontario, DAS was used to monitor seismicity and Strain by installing fibre optic cables in a 200-meter-deep borehole. The analysis of both high and low-frequency signals indicated that DAS could effectively co-locate seismic events with conventional methods and may help monitor stress changes related to mining activities.

Case Study 2: A lab-scale tailings dam model was used to test DAS for monitoring stress before collapse and for perimeter security. DAS successfully detected various activities, including foot, vehicle traffic, environmental events, and strain signals during the dam's collapse.

These studies suggest DAS could enhance existing monitoring systems in mining applications.

Introduction

DAS is a fibre optic sensing technology that uses fibre optic cables to detect vibrations and strain along the entire length of the cable. Unlike traditional sensors that collect data at fixed points, DAS provides a continuous stream of information across kilometers of infrastructure.

By sending pulses of light through the fibre and analyzing the light that is reflected back, DAS systems can detect subtle changes caused by movement or acoustic activity near the fibre (Figure 1). This means the cable itself becomes the sensor delivering data at high spatial resolution (1.6 m) without the need for complex electronics in the field.

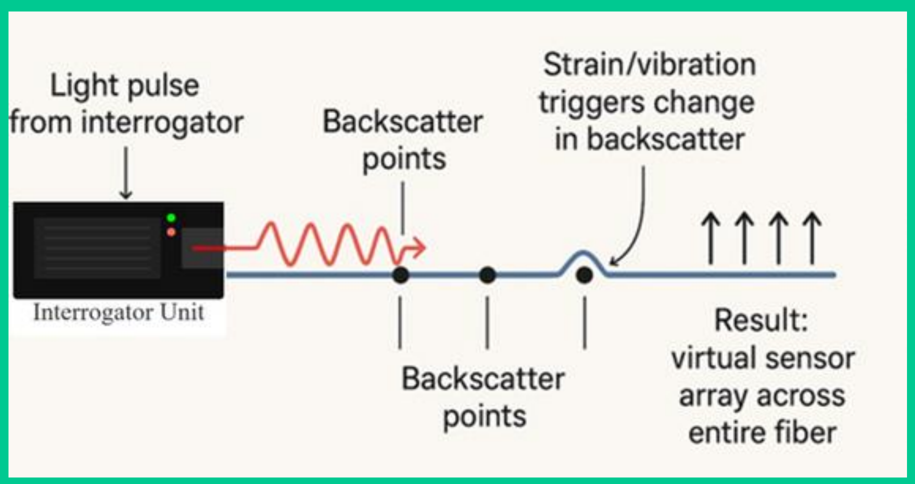

Figure 1. DAS working principle

Applications of fibre Optics in Mining

- **Slope Stability:** Monitoring movement patterns before failure zones evolve.
- **Tailings Storage Facilities (TSFs):** Detecting internal seepage, deformation, and flow-related noise.
- **Underground Tunnels:** Monitoring for rockbursts, fractures, and human activity.
- **Conveyor and Rail Infrastructure:** Tracking vibration, machinery alignment, or dynamic loads.

Case Study 1: Underground Mine

A pilot study was conducted in 2023 utilizing DAS technology to monitor rock mass stress conditions in an underground mining environment. An engineered fibre optic cable was installed and grouted in a 200-meter-deep borehole at Glencore's Onaping Depth Project (ODP) in Sudbury, Ontario, Canada as shown in Figure 2. A detailed view of the fibre cable, nearby seismic stations, and Red Clay Fault are presented in Figure 3. The goal of the project was to assess the applicability of fibre optics in monitoring the rock mass response to mining in this area.

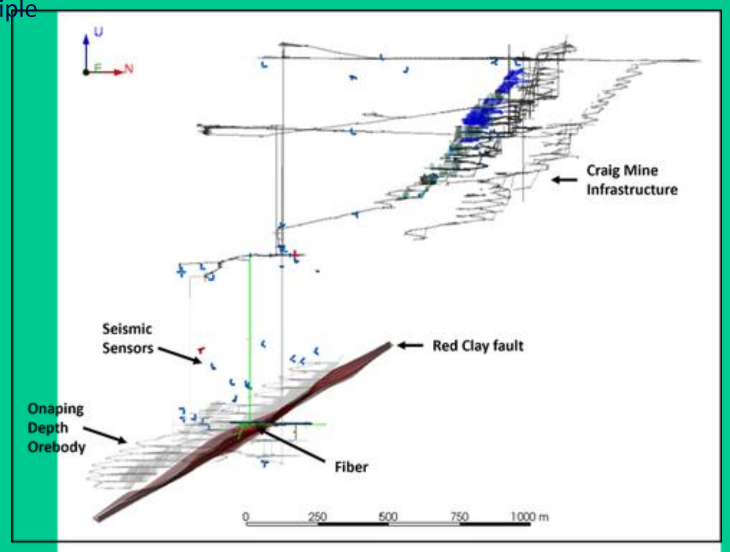

Figure 2. Onaping Depth Project: Location of the fibre and seismic stations

The DAS data were analyzed across two frequency bands: the high-frequency band (above 10 Hz), focused on the microseismic event detection, and the lower 1-10 Hz frequency band that was analysed for strain derived energy data. By integrating DAS data with existing geophones and accelerometers, we achieved slightly enhanced accuracy and precision in seismic event localization. Additionally, the energy attribute within the 1-10 Hz band correlated with raisebore operations, demonstrating DAS's potential for real-time monitoring of rock mass stress during such activities. For a comprehensive overview of this study, please refer to Dande et al., (2024).

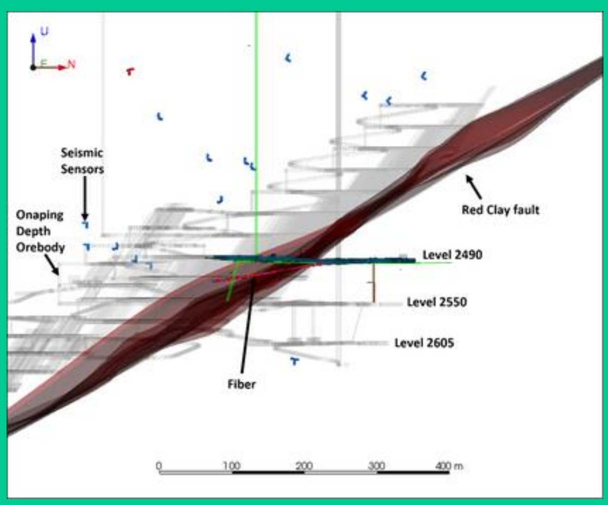

Figure 3. Close-up view of the location of the fibre, Red Clay Fault and surrounding seismic sensors

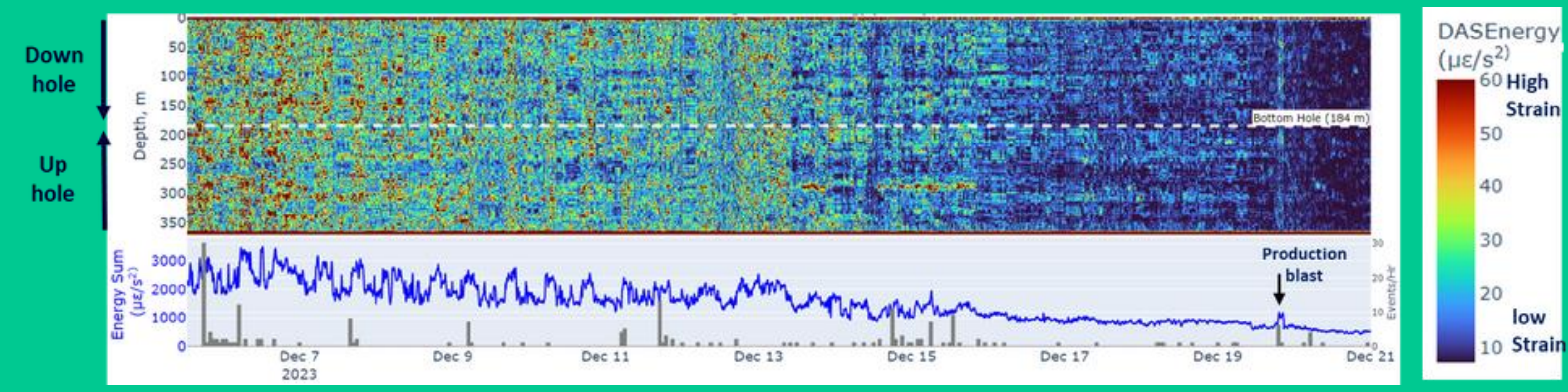

Figure 4. Heatmap of the distributed acoustic sensing energy attribute (5–20 December) using 1–10 Hz strain data (top), the DAS energy sum attribute (average of downhole and uphole fibre) and event rate/hour (bottom).

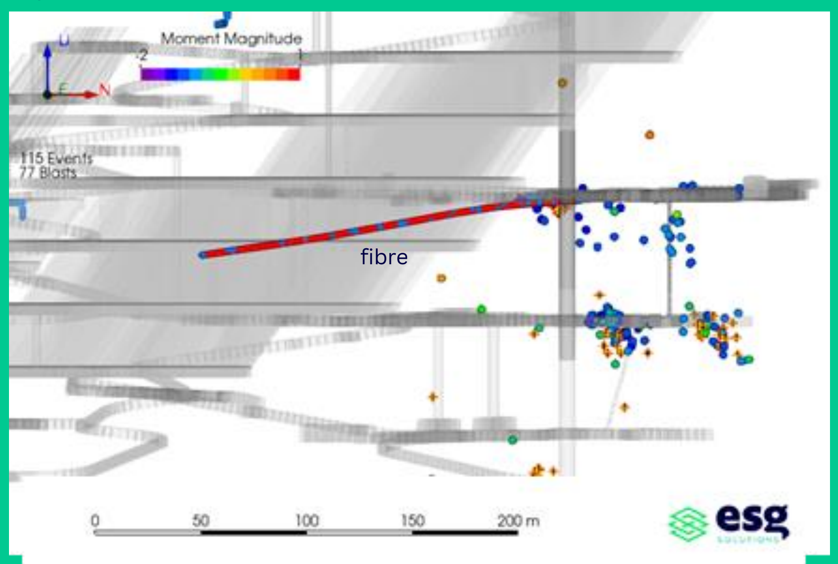

Figure 5. Real-time detection and location of seismicity with fibre

Case Study 2: Simulation of Tailings Dam Collapse and Perimeter Monitoring

Tailings dams are vital for storing mining by-products, but their failure can have severe environmental, economic, and human impacts. Traditional monitoring methods, like piezometers and inclinometers, provide limited data for early failure detection. In contrast, Distributed fibre Optic Sensing (DFOS) technologies such as DAS, DTS and DSS offers continuous, real-time monitoring along the entire dam. This enables early detection of geotechnical issues like seepage and deformation, thereby significantly improving risk management.

To evaluate the sensitivity of DAS in detecting early signs of dam failure, we conducted a controlled lab-scale simulation replicating a dam collapse scenario. The experimental setup involved approximately 250 ft (76 m) of fibre trenched and 100 ft (30.4 m) of fibre optic cable trenched beneath a soil-constructed dam (inside the stock tank). Left over fibre was attached to the tank walls and exposed to ambient disturbances such as wind. A DAS interrogator was connected to the fibre to continuously monitor strain and acoustic activity along its length.

As shown in Figure 6, the experiment involved incrementally replenishing the tank with water. At 13:37, additional water was introduced, leading to a measurable increase in fibre strain due to rising hydrostatic pressure. This was captured as a shift in the acoustic signal profile, indicating heightened tension on the fibre buried in the dam soil. At 14:29, the dam experienced a controlled collapse due to overflow, which was clearly detected by the DAS system as a sharp transition from compression to tension in the fibre signal. The color scale in the graph illustrates this dynamic, with positive values indicating fibre tension and negative values corresponding to compression.
This simulation demonstrates that DAS can effectively capture both gradual pressure build-up and sudden structural failure, making it a powerful tool for real-time monitoring and early warning in tailings dam applications.

Figure 7 and Figure 8 illustrate the validation of DAS for monitoring both human and vehicle activity utilizing the trenched fibre.

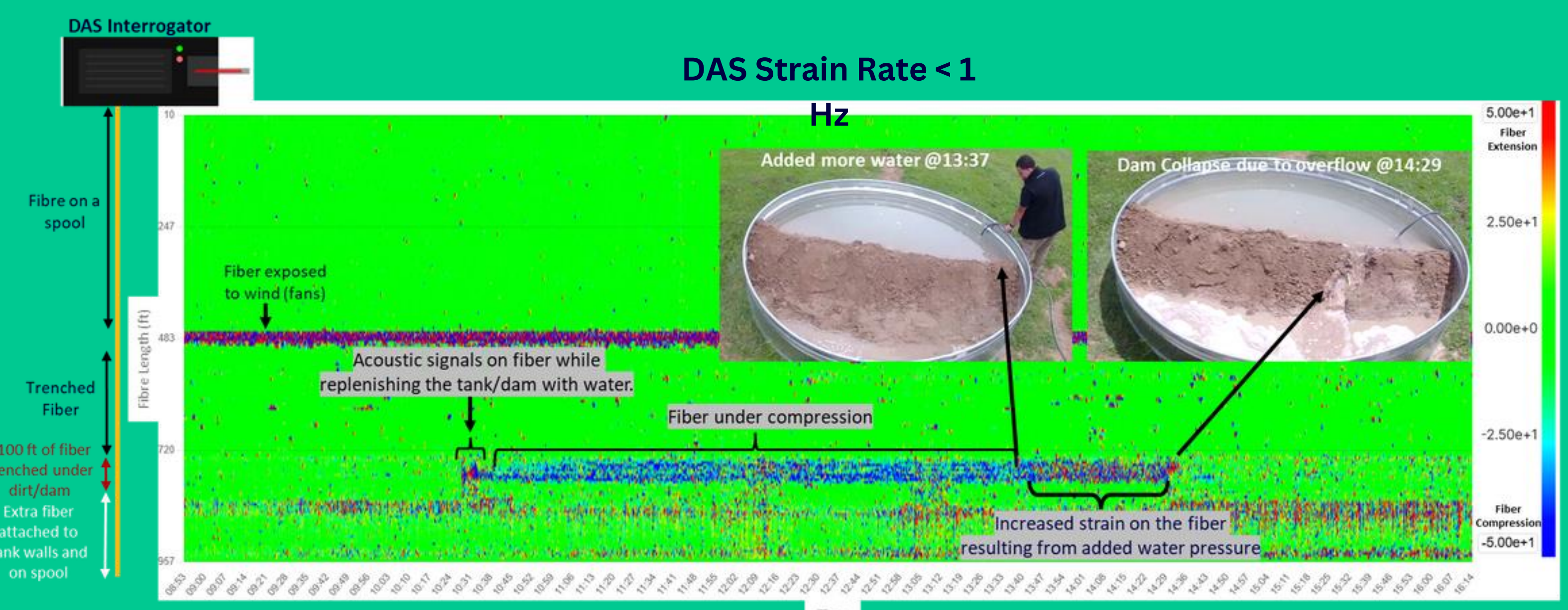

Figure 6. Lab-scale simulation of tailings dam collapse showing DAS response. Increased fibre strain was observed after water addition (13:37), followed by extension during dam failure (14:29), demonstrating DAS sensitivity to structural changes.

Figure 7. Validation of DAS response to human activity along trenched fibre. Signal patterns correspond to walking toward and away from the interrogator, with distinct acoustic features from jumping events.

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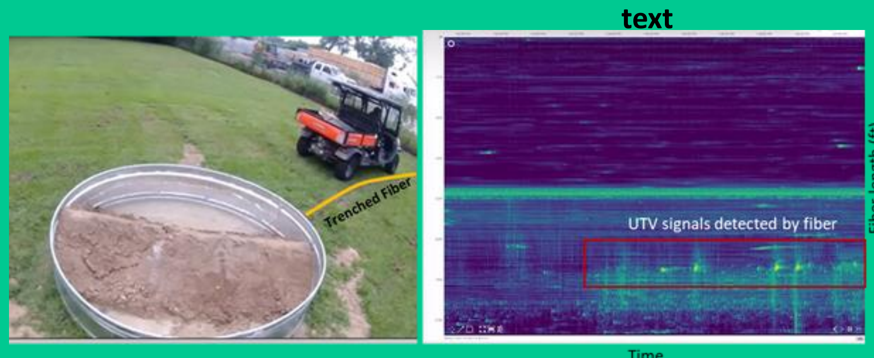

Figure 8. Detection of utility vehicle (UTV) activity using trenched fibre. Left: experimental setup with UTV near buried fibre. Right: DAS response showing UTV-induced signals highlighted in red.

Conclusions

This study highlights the effectiveness DAS for geotechnical monitoring in mining. Field tests in an underground mine and a lab-scale tailings dam simulation showed DAS's ability to detect microseismic activity and structural changes with high resolution. It proved sensitive to early-stage deformation and potential failures, supporting its use for real-time risk mitigation. Additionally, DAS can monitor perimeter activities like footsteps and vehicle movements, enhancing safety and security in mining operations.

For further information

Please contact suresh.dande@esgsolutions.com for more information on this and related projects and ODP referennced paper can be found here https://doi.org/10.36487/ACG_repo/2465_19

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