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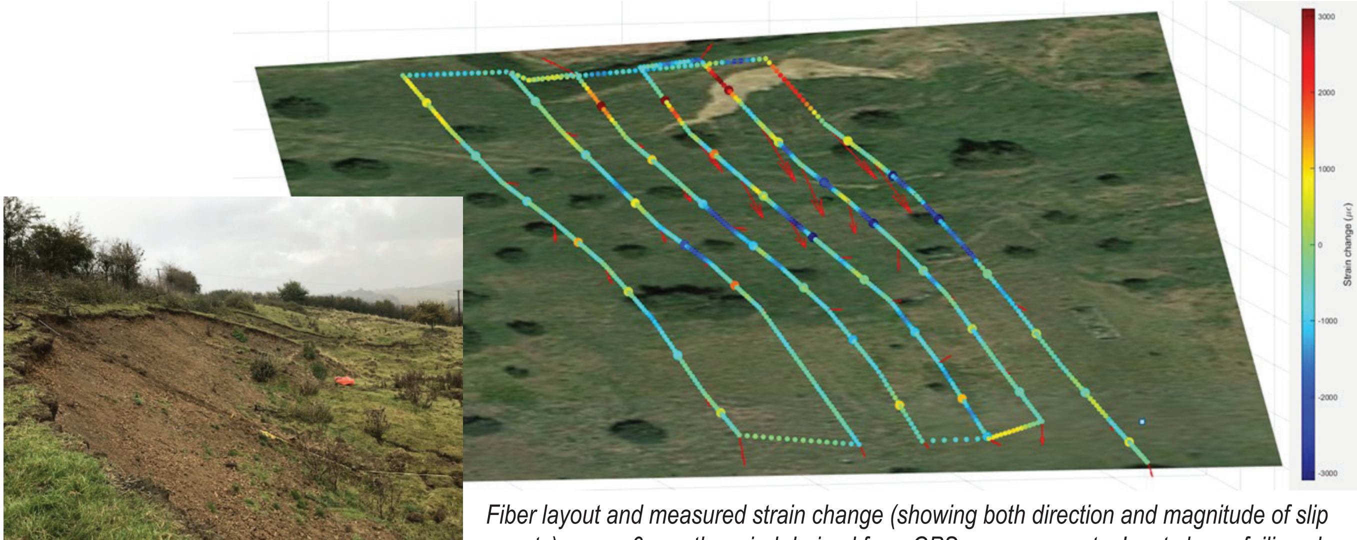
Innovative Measurement Techniques for Railway Earthwork Monitoring With Fiber

Recent advances by OptaSense in the application of Distributed Fiber-Optic Sensing (DFOS) technology have enabled powerful new and innovative methods for monitoring the stability of earthworks alongside railway lines to be developed. Specifically, OptaSense is using trackside fiber-optic cable combined with static strain, static temperature and passive seismic profiling techniques to monitor both ambient seismic noise and the signals generated by passing rolling stock to detect small movements and structural changes in trackside slopes to deliver systems capable of providing early warning of potential service affecting earthwork instability events.

Specialist tight buffered cable (which closely couples the glass fiber cores and the cable exterior together) is installed in the area of interest to ensure the monitored glass core within the fiber cable is well coupled to the slope. This tight buffered fiber cable can be connected to any existing fiber network to enable the possibility of monitoring multiple slopes and earthworks with a single sensing system.

Continuous monitoring of the stabilized DC component of the received signal from the monitored core enables both static strain and static temperature change to be accurately captured at high resolution and in real-time along the fiber cable from a given start point. Additionally, these measurands can be combined with emerging passive seismic profiling techniques using DFOS. These techniques use ambient seismic noise within the environment (such as from passing trains) to create “virtual noise sources” and through the application of advanced signal processing methods produce a snapshot of the sub-surface.

Early development of techniques for static strain and static temperature measurement were undertaken at the UK National Landslip Laboratory in northern England. This laboratory is located on an unstable slope that is prone to frequent earth slip events during wet weather. The test site is highly instrumented and provided an ideal environment to verify system capabilities by comparing the response of DFOS solutions with a range of alternative sensor technologies during slip events. At the conclusion of this long-term deployment, it was confirmed that the OptaSense fiber optic sensing solutions delivered high short-term accuracy, spatial resolution and long-term stability measurements to provide a comprehensive ground condition monitoring capability, offering a range of functionality that would traditionally require multiple measurement systems.



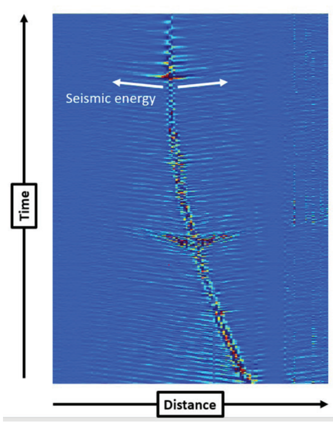
Fiber layout and measured strain change (showing both direction and magnitude of slip events) over a 6-month period derived from GPS measurements. Inset shows failing slope at UK National Landslip Laboratory test site.

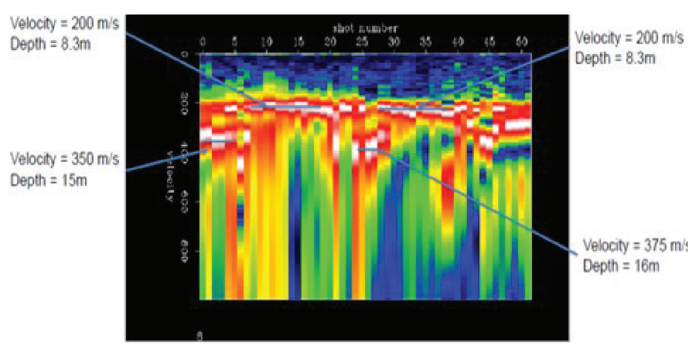
Commencing in 2021, static strain and static temperature measurement methods plus passive seismic profiling techniques will be trialled alongside an operational railway in Europe where the issue of slope stability is an operational concern. This railway operator has long managed slope stability risks through a combination of physical measures (masonry, wire nets) and visual inspections but are keen to implement more efficient and cost-effective monitoring solutions. A successful trial will lead to the implementation of DFOS based solutions in a number of risk areas across their network.

These complimentary measurement methods delivered from a single fiber-optic cable installed in the area of interest offer the potential for an intriguing toolkit of methods for monitoring slopes and earthworks alongside an operational railway line and predicting any service-impacting slope failure events before they occur. In addition to the techniques developed at the UK National Landslip Laboratory passive seismic profiling will enable OptaSense to generate a snap-shot of the seismic wave velocity in the sub-surface of the monitored area. Each time a passing train generates seismic energy this will travel at different speeds through the different types of material types in the sub-surface.

Over time the static strain, static temp and seismic profiling can be monitored to build a complete 3-D picture of the area of interest. Any changes which might indicate potentially serious issues in the slope and earthwork structure can be alerted enabling proactive works to take place to prevent service affecting events before they occur. For example, possible track washout events or cold weather events may be predicted by charting the changing position of the water table or the permafrost layer. The early formation of sinkholes or cavities within the slope can also be revealed.

For further technical information on the application of DFOS for strain and temperature measurement please refer to the OptaSense white paper **Strain And Temperature Monitoring Using Rayleigh Backscatter Sensing**.





Sonic wave velocity can be determined from dispersion of the radiated seismic energy from passing trains (above) enabling inverted Vs models to be generated (right).

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