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Characterisation of the soil properties along railway tracks using Distributed Acoustic Sensing

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A precise understanding of the soil profile is important for railway operations, impacting not only vibration and noise propagation but also broader aspects such as train speed adjustments and infrastructure resilience. Soil properties influence track stability, and changes due to climate variations—such as extreme rainfall or drought—can affect safety and performance. Monitoring these variations enables proactive maintenance and operational decisions, including speed regulation to prevent track deformation or instability. Traditional geophysical campaigns using methods like geophones, while useful, are not suited for large-scale, long-distance monitoring. These methods provide valuable data but are limited by their spatial and time coverage, as they are temporary.

In this context, Distributed Acoustic Sensing (DAS) technology provides a complementary solution, enabling high-resolution, continuous monitoring over long distances. DAS uses optical fibers, installed for communication purposes along railway tracks, and we use the dark fiber to measure vibration. This study explores the potential of DAS for passive seismic monitoring of soil properties along railway tracks.

DAS operates by sending a laser pulse through optical fibers, where backscattered light is analyzed to detect strain-rate. SNCF has developed an in-house DAS for use in railway applications, allowing real-time monitoring of the tracks. DAS offers spatial resolution on the order of a meter, making it a valuable tool for large-scale monitoring and a complement to traditional geophysical site studies.

In this study, DAS is used for passive seismic monitoring of soil properties. The wavefields generated by passing trains are analyzed using cross-correlation and using a Multi-channel Analysis of Surface Waves (MASW) technique to analyze their propagation. These wavefield can also be used to characterize the dominant frequency of the site. This methodology could also enable the monitoring of soil conditions in earthworks, such as embankments, by detecting potential changes in soil properties. This provides valuable insights for early warning systems and improved maintenance strategies.

This work demonstrates how DAS technology can complement traditional geophysical methods for large-scale soil characterization along railway tracks. DAS is a promising, cost-effective tool for monitoring the tracks and the mechanical properties of the soil beneath, with no need for specialized teams to be deployed in the field.

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