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MASW (Multichannel Analysis of Surface Waves) for High-Speed Rail: A Non-Invasive and Efficient Approach to Prevent Critical Velocity Effects

Higgs, H.G.
Guideline Geo
harry.higgs@guidelinegeo.com

Introduction

High-speed rail faces unique challenges in managing seismic energy transfer, particularly when trains approach critical velocities of Rayleigh waves, Krylov, V. V. (1994). When these velocities are approached, excessive rail displacement can occur, posing risks to infrastructure. Holm, et al. (2002). This case study demonstrates how MASW (Multichannel Analysis of Surface Waves) can be used to accurately assess these risks and provide data to inform rail design and maintenance strategies.

Geological setting of test site and considerations

The test site consists of soft clays overlying weak fractured mudstones, such geology poses a risk of low Rayleigh velocities and makes this a key area of concern for critical velocity effects in high-speed rail.

Project deliverables:

- In-situ measurements of Rayleigh wave measurements, and shear wave models down to 20 meters below track design level where design level is 2-3mbgl.

Fieldwork

Seismic data were collected using a 48-channel ABEM Terraloc Pro 2 system, with 4.5Hz vertically polarized geophones spaced at 1m intervals. This array allows for both deep testing (>20m) and shallow testing (<2m) to capture near-surface velocity variations, essential for identifying critical velocity zones in the rail's vicinity.

Figure 1: Image of data collection showing a seismic shot being undertaken using a hammer source.

Basic MASW theory

Seismic surface waves are dispersive meaning longer wavelengths penetrate deeper into the subsurface, allowing the method to detect variations in material properties at different depths. The waves travel at the velocity of the material in which they travel. By looking at the fundamental mode of these waves in the frequency domain we can extract the phase velocity of the Rayleigh waves with depth. using a hammer source.

Data processing

Time domain data acquired by the seismograph are converted to frequency domain using a 2D Fourier transform. The transformation of time-domain signals to the frequency domain allows for better analysis of the dispersive properties of Rayleigh waves. The dispersion of Rayleigh waves are then extracted and provided for inversion and subsequent presentation.

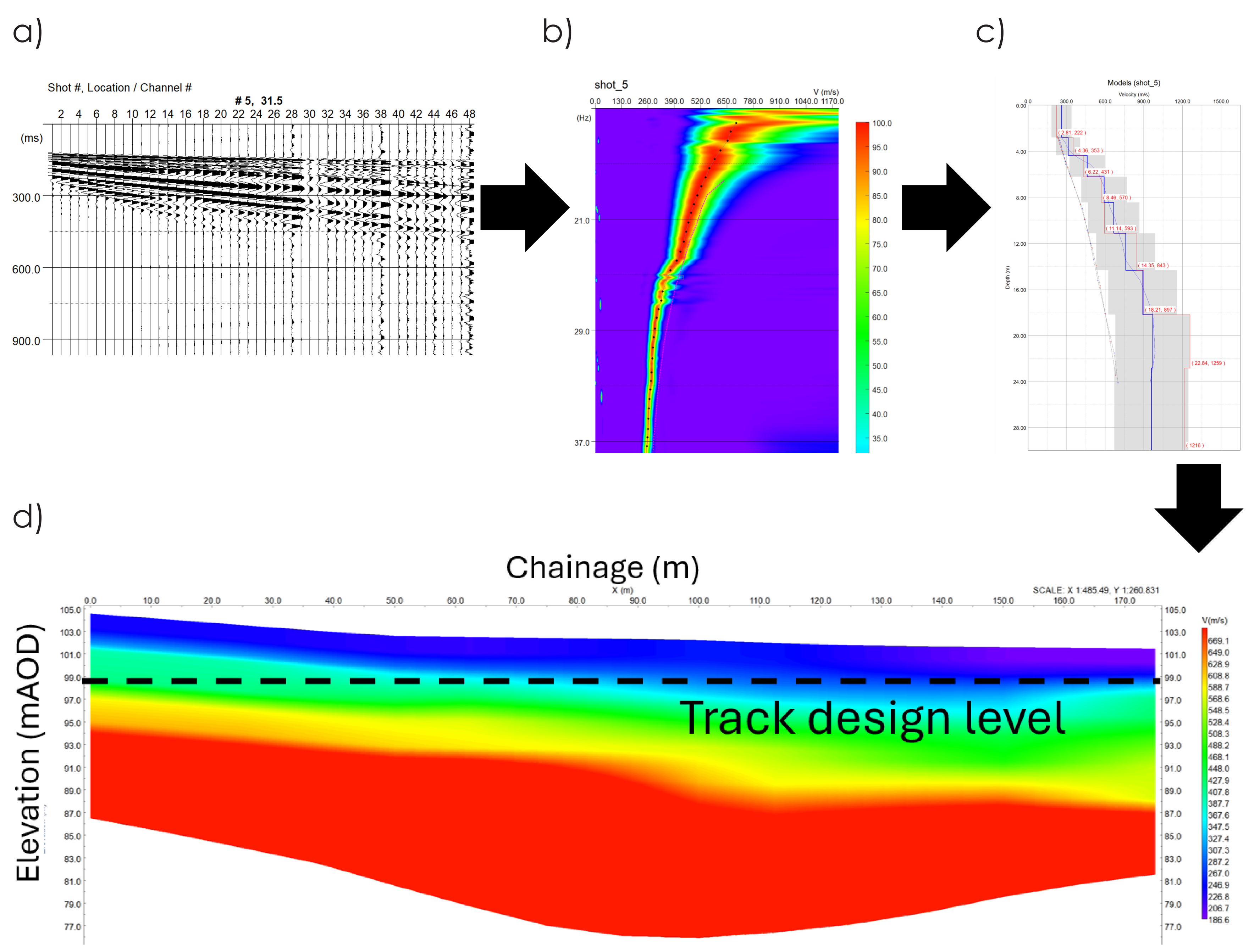

Figure 2

a) Raw seismogram showing initial data acquisition
b) 2D Fourier transform illustrating frequency content
c) 1D inversion model of subsurface material properties
d) 2D interpolated Vs velocity section.

Results

- The trial proved the suitability of MASW for efficiently collecting the data needed to make assessments of critical velocity effects.
- MASW is more time efficient than laboratory testing or other geophysical methods such as downhole and crosshole testing.
- Using 1m-separated geophones provided a minimum testing depth between 0.8-1.2m with a design depth of 2.2-4mbgl this ensures comprehensive data coverage.
- Data collection rate can be greatly increased by using a seismic land streamer, allowing long sections of route to be assessed rapidly and with minimal disruption.
- MASW is a robust, nonintrusive and efficient method for this application.

References

Krylov, V. V. (1994). "Generation of ground vibrations by superfast trains." Applied Acoustics, 44(2), 149-164.
Holm, G., Andréasson, B., Bengtsson, P.-E., Bodare, A., & Eriksson, H. (2002). Mitigation of track and ground vibrations by high-speed trains at Ledsgård, Sweden.