

**Document Version**

Final published version

**Licence**

Dutch Copyright Act (Article 25fa)

**Citation (APA)**

Chieppa, D., Comina, C., Vergnano, A., & Socco, L. V. (2025). Traffic induced noise analysis for river embankment monitoring. In *4th Conference on Geophysics for Infrastructure Planning, Monitoring and BIM 2025, Held at Near Surface Geoscience Conference and Exhibition, NSG 2025 EAGE*. <https://doi.org/10.3997/2214-4609.202520222>

**Important note**

To cite this publication, please use the final published version (if applicable).  
Please check the document version above.

**Copyright**

In case the licence states "Dutch Copyright Act (Article 25fa)", this publication was made available Green Open Access via the TU Delft Institutional Repository pursuant to Dutch Copyright Act (Article 25fa, the Taverne amendment). This provision does not affect copyright ownership.  
Unless copyright is transferred by contract or statute, it remains with the copyright holder.

**Sharing and reuse**

Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

**Takedown policy**

Please contact us and provide details if you believe this document breaches copyrights.  
We will remove access to the work immediately and investigate your claim.

## Traffic induced noise analysis for river embankment monitoring

D. Chieppa<sup>1</sup>, C. Comina<sup>3</sup>, A. Vergnano<sup>3</sup>, L.V. Socco<sup>1,2</sup>

<sup>1</sup> Politecnico di Torino 2Department of Environment, Land and Infrastructure Engineering; <sup>2</sup> Delft University of Technology, Department of Civil Engineering and Geosciences; <sup>3</sup> University of Turin, Department of Earth Sciences

---

### Summary

We use traffic induced noise generated by vehicles over a river embankment to retrieve seismic surface wave dispersion curves along the embankment structure. The vehicle transit is tracked in the noise records in space and time and the trace closer to the source at each time interval is used as a virtual source. Interferometry is applied and a dense dataset is obtained and processed to retrieve dispersion curves. The results are compared with active data dispersion curves and show that a small number of vehicle transits allow for the seismic characterization of the embankment and the foundation soil.

## Traffic induced noise analysis for river embankment monitoring.

### Introduction

River embankments are subjected to increasing extreme weather events induced by climate change and the monitoring of their integrity is a fundamental asset for the resilience of areas prone to flooding. Among geophysical methods that can be used for embankment characterization and monitoring, seismic investigations are attractive because they provide a detailed mapping of the mechanical properties within the infrastructure. On the other hand, the acquisition of seismic data is time consuming and expensive, making seismic methods not convenient as monitoring tools.

To reduce the acquisition time and cost, ambient noise measurements can be applied and several researchers (Quiros et al. , 2016; Cheng et al. ,2016; Brenguier et al., 2019) have shown the possibility of using traffic induced noise and retrieve seismic surface wave data through seismic interferometry (Dou et al., 2017; Fang et al., 2020; Spica et al., 2020). If the data are acquired along a road, the vehicles are likely to be source in the stationary phase region, making the identification of the direction of propagation of the noise wavefield unnecessary. Most of the approaches use the passive records without identifying the position of the vehicles, Zagar et al (2023) have shown that using the information of the position of the source improves the signal-to-noise ratio of the dispersion curves.

In this work, we compare surface wave dispersion curves obtained over a river embankment through the analysis of traffic induced noise, with dispersion curves obtained through an active survey on the same site and we show that, thanks to the identification of the source position, it is possible to retrieve high quality dispersion curves with the transit of a very limited number of vehicles.

### Methods

The seismic data acquired with continuous recording by a line of receivers is analysed following the method proposed by Zagar et al. (2023) according to the following steps:

1. The data are subdivided into windows of different lengths according to the speed of the vehicle travelling along the embankment. Each window is processed with a detrend, demeaning and a low-cut filter at 100 Hz.
2. The records where a vehicle transit is present are automatically recognised.
3. The vehicle is tracked in time and space identifying the maximum of energy along each trace
4. The trace closer to the vehicle at each time is used as virtual source and cross-correlated with all the other traces using a window of 1.5s around the maximum of the vehicle signal to generate a virtual shot gather for every position of the source
5. The virtual shot gathers are used as densely sampled seismic survey and processed with a classical dispersion curve picking algorithm over a moving spatial window along the line
6. For each spatial window position, multiple sources coming from different position of the vehicle and from different vehicles passing along the line are used to stack the velocity spectra and improve the signal-to-noise ratio

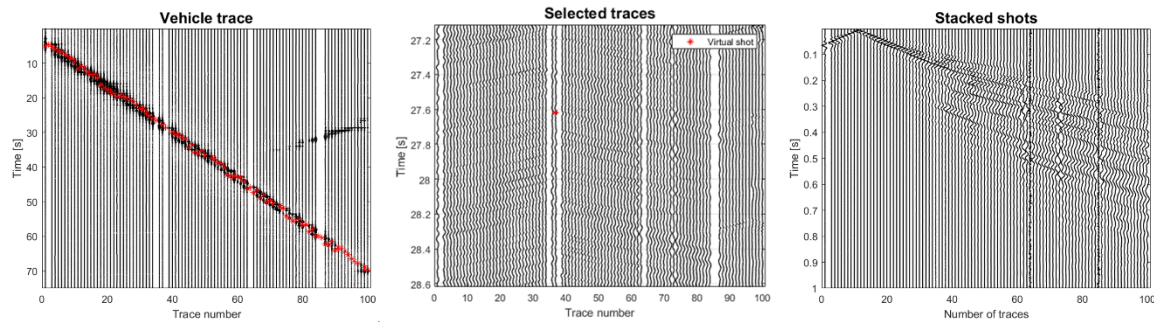
### Data and results

In July 2024, seismic measurements were carried out along a 300 m portion of the Verolengo embankment of the Po River, near Torino. This embankment was recently raised to guarantee improved protection levels with respect to recently occurred flood events (October 2000). The raising was performed in different periods in two different working lots that are covered by the survey.

The seismic data were acquired using 100 one-component wireless geophones (4.5 Hz) with a spacing of 1 m and a 5-kg hammer source with 10 meters shot spacing along the line. Three separate acquisitions were carried out in three consecutive days with 10 receivers overlap between different acquisition. The data were acquired with continuous recording and for every line a vehicle was driven at low speed several times along the line of receivers. The number of transits is equal to 7 for the first day, 9 for the second day, and 4 for the third day.

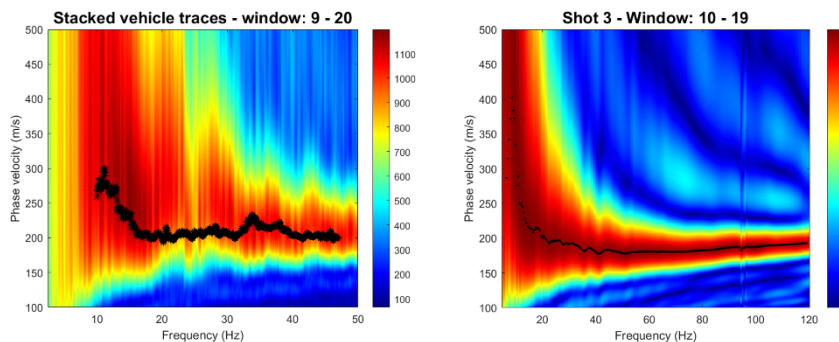
In Figure 1 we show a 75 s passive record with a vehicle transit tracked as energy maxima (red dots), a virtual shot records obtained through cross correlation with the traces close to the vehicle, and an example of active seismic record in the same portion of the seismic line. The vehicle is clearly identified,

and the time-space position is accurately identified. For the processing of the data and the extraction of the dispersion curves we used the portion of virtual shot gathers opposite to the direction of the vehicle to avoid the disturbance of the vehicle itself.



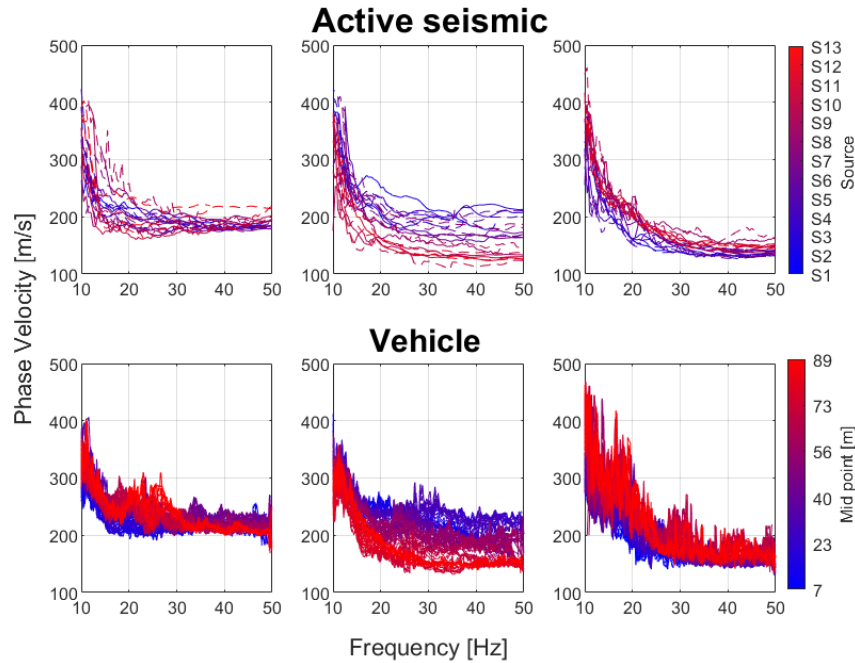
**Figure 1** From left to right: seismogram containing a vehicle travelling along the deployed geophones, cross-correlation plot for trace 20 with all traces and an example of an active recording for shot location S3 located at 10 meters from the first geophone. Red stars in the left plot shows the energy maxima along each trace. Traces in all plots are normalized to the maximum of each trace to highlight the seismic recording.

In Figure 2 we show examples of velocity spectra of active and passive data. The passive data are obtained by stacking more than 100 velocity spectra computed for different position of the vehicle and for different vehicles travelling in both directions along the embankment during the same day. For the passive data, the number of shots used for the stacking varied between 7 and 22 for the same vehicle; for the active we stacked the 10 repetitions at each shot location but not the data from different shots. The spectra were computed using a window of 10 and 12 receivers for the active and passive data, respectively, with a step of 1m.



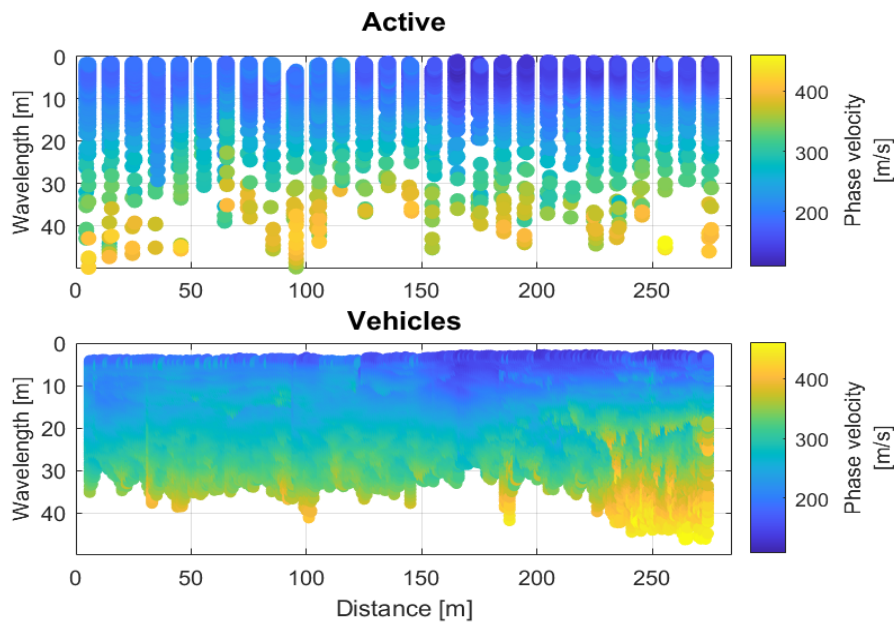
**Figure 2** Examples of velocity spectra of passive (left) and active (right) data for the first day of acquisition. Black dots show the picked Rayleigh-wave dispersion curve.

Figure 3 reports the picked dispersion curves from active and passive datasets for the three days. The colour of the curves identifies their spatial location along the line. The retrieved phase velocities are in good agreement and the frequency band are comparable for all three days. The passive DC are noisier, particularly at low frequency. By using each receiver as a virtual source, we obtained a much denser dataset from the passive data than from the active, resulting in a larger and denser set of DCs.



**Figure 3** comparison between the dispersion curves extracted from the active (top row) and traffic induced passive data (bottom row) for the three acquisition days. The blue to red colorbars reflect the position along the deployment line from the first to the last geophone, respectively. For the top row the colors are linked to the shot location, while for the bottom row the colors refer to the mid-point of the window of 12 traces used for the computation of dispersion curves.

In Figure 4 we report the dispersion curves of the three days in the form of pseudosections where the DC are depicted on their midpoint as a function of wavelength; the colour scales represent the phase velocity. The investigation depth and coverage at shallow depth are comparable, with active data (top row) having a slightly greater investigation depth due to the different range of picking. Bottom row of Figure 4 shows a zoom into the shallowest 15 meters for the pseudosection generated using vehicles traces. Resolution for this plot starts at about 5 m, not enough to identify variations in the embankment (height of 3m).



**Figure 4** comparison between the active (top row) and passive (bottom rows) dispersion curves in form of pseudosections.

## Conclusions

We applied time-space source tracking and interferometry to generate a dense set of seismic data from traffic induced noise records. The results show that with a very limited number of vehicle recordings, a dense set of dispersion curves can be obtained over a river embankment. The obtained curves agree with those obtained with active data and cover the required investigation depth between 5 and 35 meters. To investigate the 3m embankment, the picked dispersion curves for the passive data should be extended to higher frequencies increasing the resolution in the shallowest 5m. This experiment opens to the use of traffic noise for seismic monitoring of river embankment also for those sites where there is a very limited traffic expected. In the future we plan to repeat a similar experiment with longer acquisition and using fiber optics for the recording.

## Acknowledgements

This study was carried out within the GEOCHARME project – funded by the European Union – Next Generation EU within the PRIN 2022 program (D.D. 104 - 02/02/2022 Ministero dell'Università e della Ricerca). This manuscript reflects only the authors' views and opinions and the Ministry cannot be considered responsible for them. Authors are indebted with AIPO – Moncalieri section for support for the identification of relevant case histories for the project and for the sharing of independent geotechnical data.



## References

- Brenguier, F., P. Boué, Y. Ben-Zion, F. Vernon, C. W. Johnson, A. Mordret, O. Coutant, P.-E. Share, E. Beaucé, D. Hollis, and T. Lecocq, 2019, Train traffic as a powerful noise source for monitoring active faults with seismic interferometry: *Geophysical Research Letters*, 46, 9529–9536, <https://doi.org/10.1029/2019GL083438>
- Cheng, F., J. Xia, Y. Luo, Z. Xu, L. Wang, C. Shen, R. Liu, Y. Pan, B. Mi, and Y. Hu, 2016, Multichannel analysis of passive surface waves based on crosscorrelations: *Geophysics*, 81, no. 5, EN57–EN66, <https://doi.org/10.1190/geo2015-0505.1>
- Dou, S., N. Lindsey, A. M. Wagner, T. M. Daley, B. Freifeld, M. Robertson, J. Peterson, C. Ulrich, E. R. Martin, and J. B. Ajo-Franklin, 2017, Dis tributed acoustic sensing for seismic monitoring of the near surface: A traffic-noise interferometry case study: *Scientific Reports*, 7, 11620, <https://doi.org/10.1038/s41598-017-11986-4>.
- Fang, G., Y. E. Li, Y. Zhao, and E. R. Martin, 2020, Urban near-surface seismic monitoring using distributed acoustic sensing: *Geophysical Research Letters*, 47, e2019GL086115, <https://doi.org/10.1029/2019GL086115>.
- Quiros, D. A., L. D. Brown, and D. Kim, 2016, Seismic interferometry of railroad induced ground motions: Body and surface wave imaging: *Geophysical Journal International*, 205, 301–313, <https://doi.org/10.1093/gji/ggw033>
- Spica, Z. J., M. Perton, E. R. Martin, G. C. Beroza, and B. Biondi, 2020, Urban seismic site characterization by fiber-optic seismology: *Journal of Geophysical Research, Solid Earth*, 125, e2019JB018656, <https://doi.org/10.1029/2019JB018656>
- Zargar, A., Karimpour, M., and L.V. Socco, 2023, Data Driven Auto-Picking of Surface Wave Dispersion Curve, NSG2023 29th European Meeting of Environmental and Engineering Geophysics, p.1-5, <https://doi.org/10.3997/2214-4609.202320076>