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Surface Waves & Beyond

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case study#7 (*winMASW* Academy)
Joint Analysis of Rayleigh- & Love waves via *Full-Velocity Spectra* analysis

Site location: Valestra, Reggio Emilia (Italy)

Goal: to show an example of *Full-Velocity Spectra* (FVS) modeling in the joint analysis of Rayleigh- and Love waves (acquired using just horizontal geophones) and demonstrate the importance of a joint analysis performed while considering Love waves.

In fact, Rayleigh-wave propagation can occur without any evidence of the fundamental mode (see further case studies from our *newsletters*) thus leading non-skilled interpreters to erroneous velocity spectra interpretation (when the fundamental mode is completely missing, higher mode(s) can be misinterpreted as the fundamental one thus leading to higher V_S values).

The presented *dataset* was acquired in the Italian Apennines using horizontal geophones only in their radial (RVF) and transversal (THF) configuration useful to acquire Rayleigh-wave radial component and Love waves, respectively.

Figure 1. Site location.

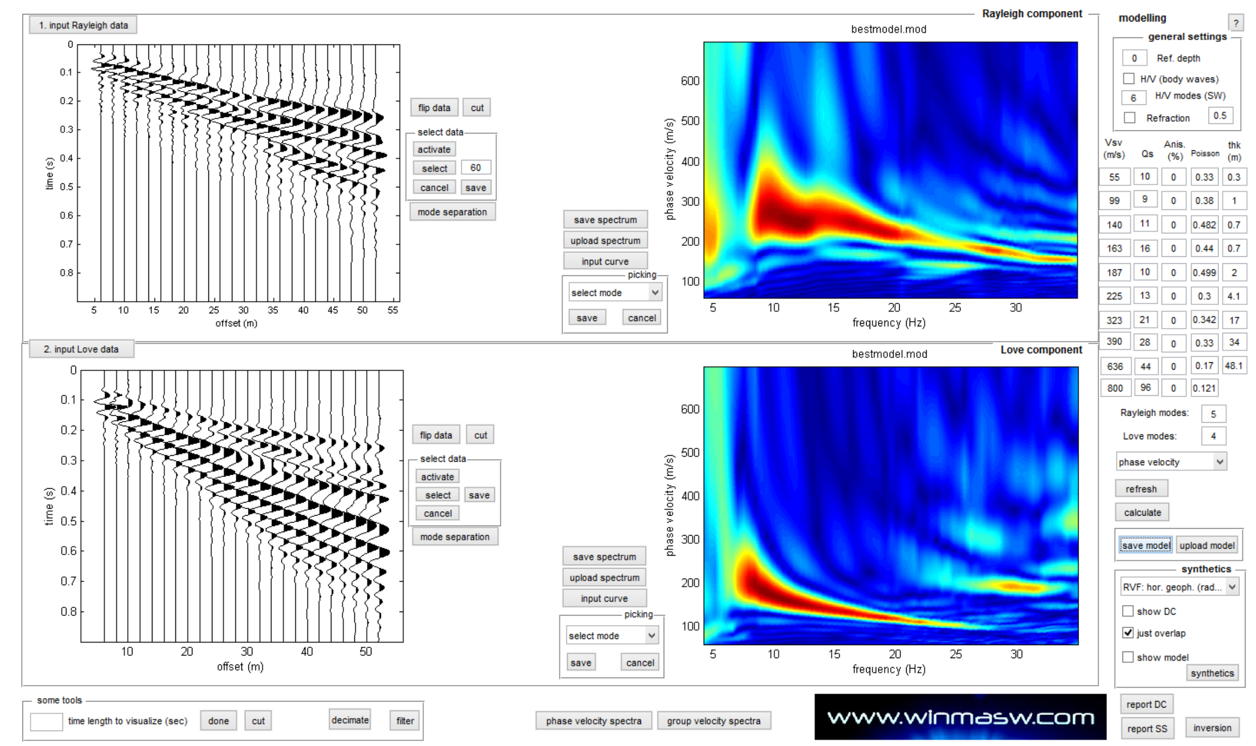


Figure 2. Filed data. *Upper panel*: Rayleigh waves (RVF component); *lower panel*: Love waves (THF component).

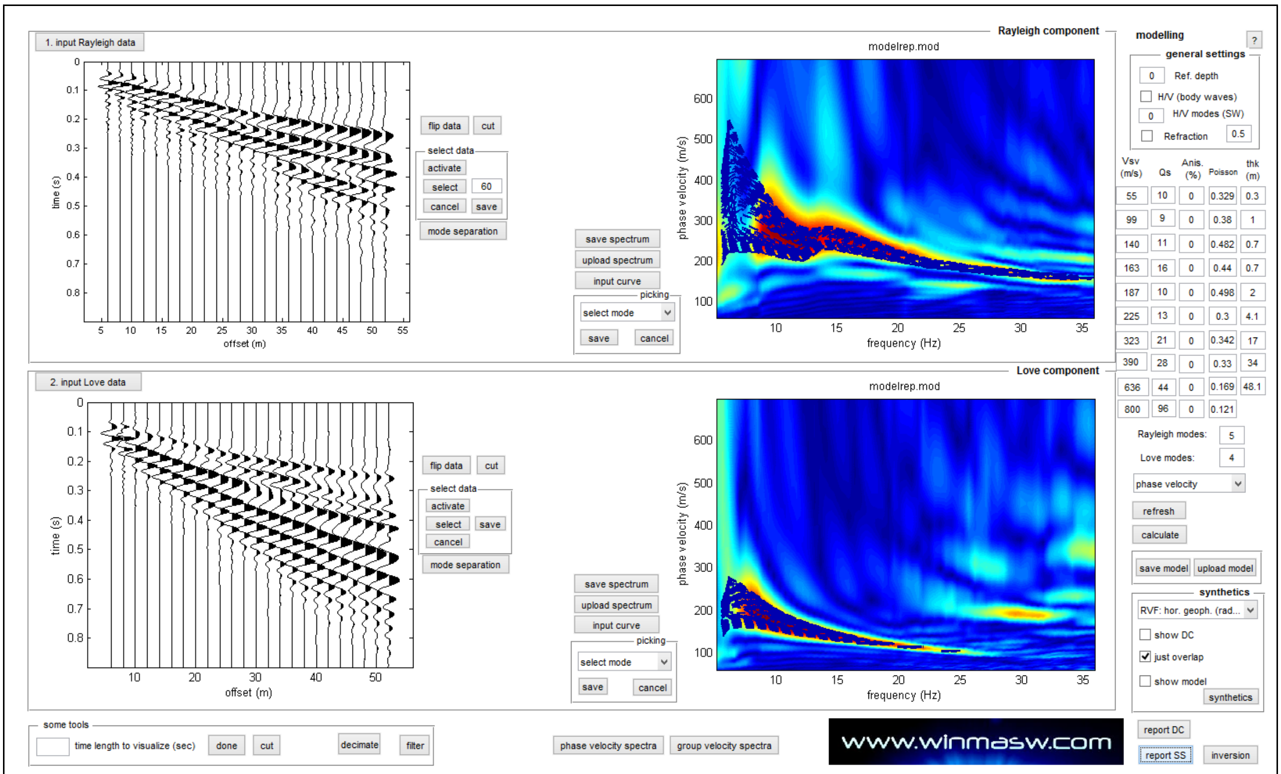


Figure 3. RVF and THF components (Rayleigh and Love waves): blue contour lines overlaying the field-data velocity spectra refer to the identified V_S model reported in Figure 7.

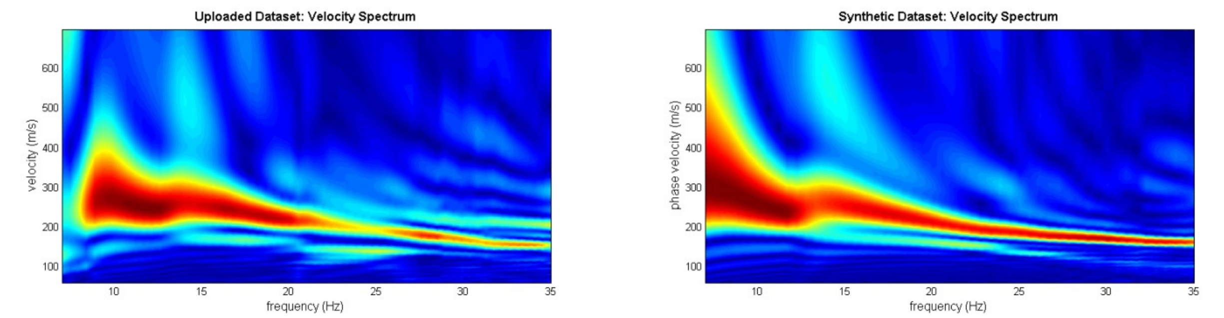


Figure 4. RVF component (Rayleigh waves): on the left the phase velocity spectrum of the field dataset; on the right the velocity spectrum of the model reported in Figure 7.

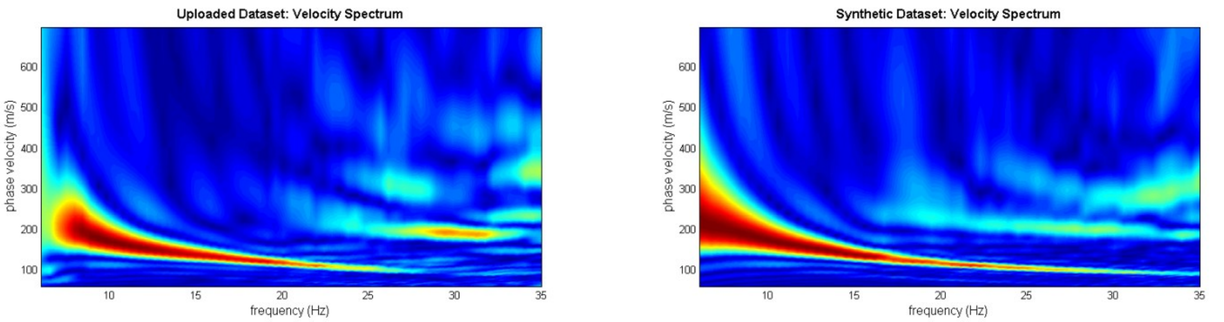


Figure 5. THF component (Love waves): on the left the phase velocity spectrum of the field dataset; on the right the velocity spectrum of the model reported in Figure 7.

The match between the observed and modeled/inverted phase velocity spectra result apparent (see Figure 3, 4 and 5) and the modal dispersion curves reported in Figure 6 (overlaying the observed velocity spectra) show that the energy dominating the Rayleigh-wave velocity spectrum actually pertain to the first higher mode.
Love-wave velocity spectrum is dominated by the fundamental mode (some energy around 30Hz relates to the first higher mode).

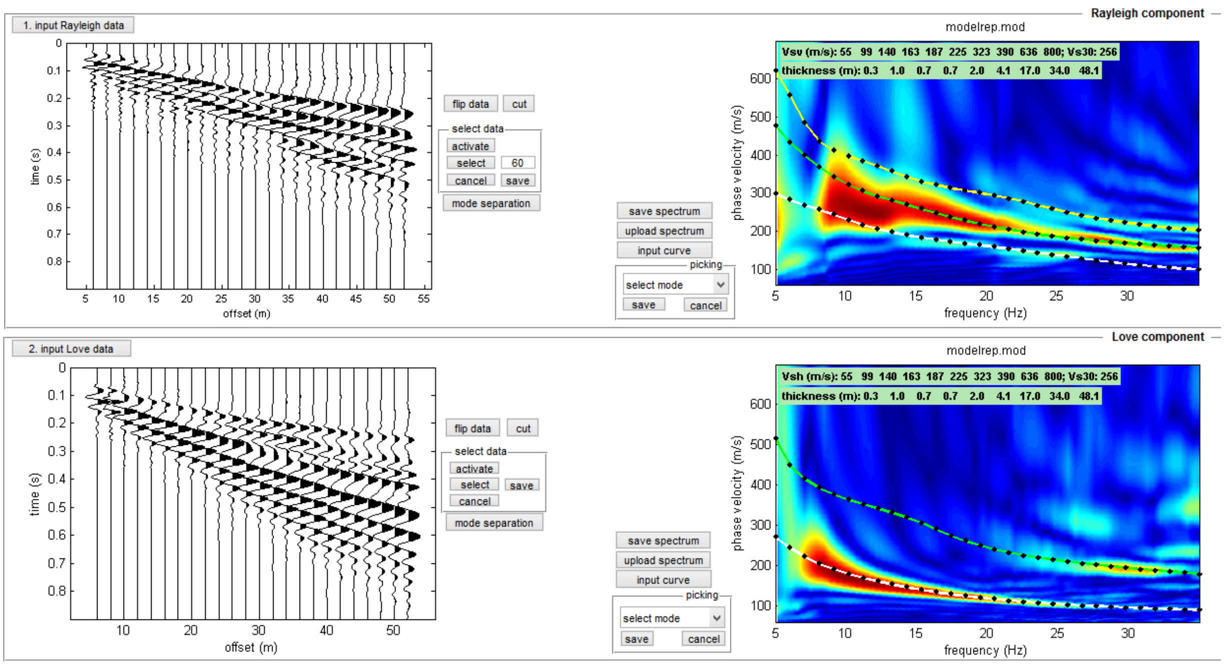


Figure 6. Filed data. *Upper panel*: Rayleigh waves (RVF component); *lower panel*: Love waves (THF component). Shown the modal dispersion curves of the proposed model (Figure 7).

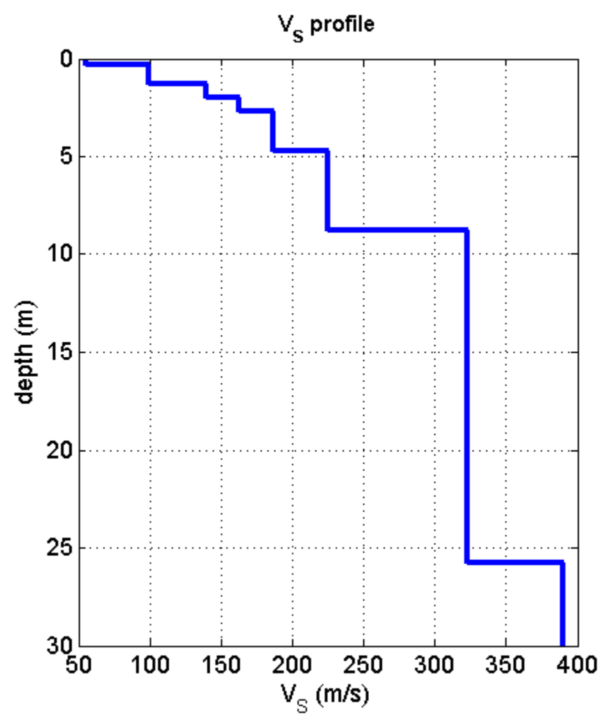


Figure 7. Second interpretative hypothesis: the energy dominating the Rayleigh-wave spectrum in the 20-55Hz frequency range is interpreted as belonging to the first higher mode.

Figure 8 reports the DPSH (Dynamic Penetration Super Heavy) which results quite consistent with the V_S trend reported in Figure 7.

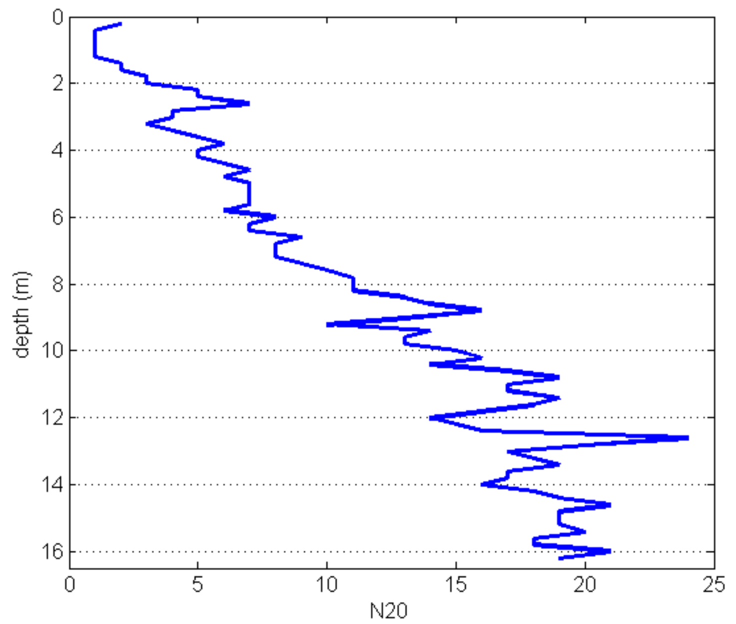
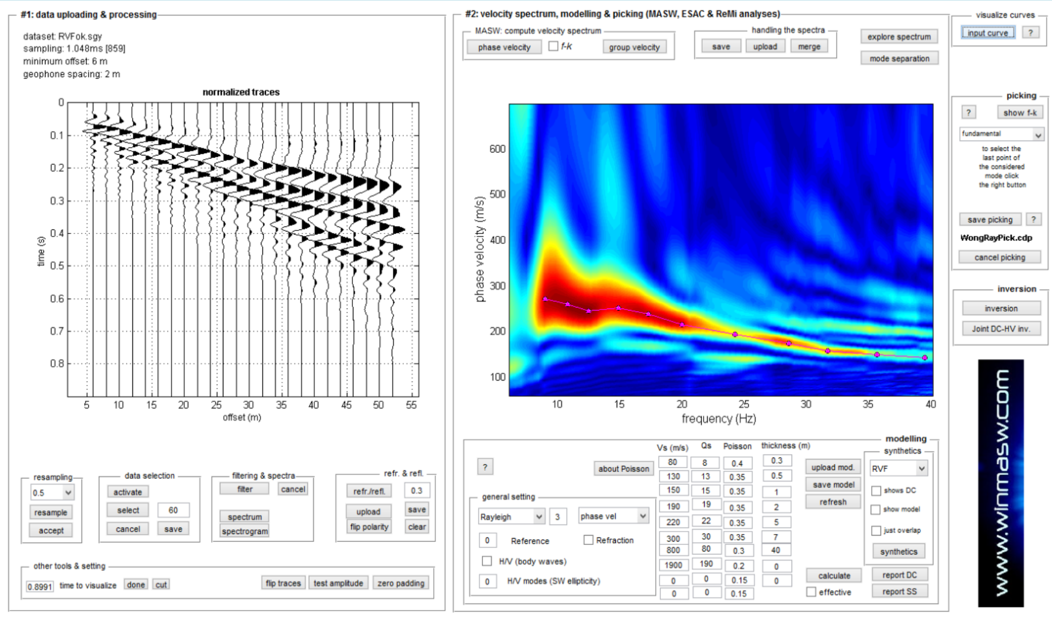


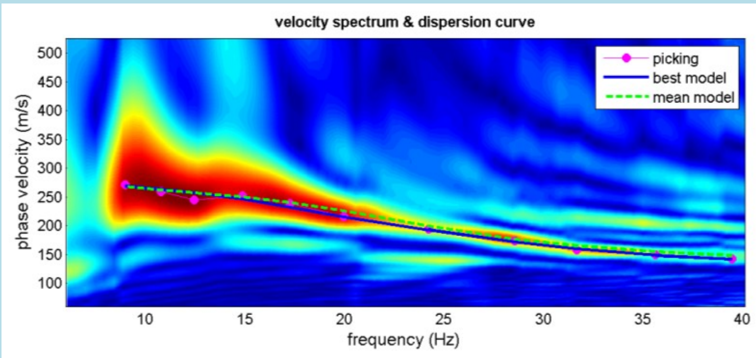
Figure 8. *DPSH*: number of blows to penetrate 20cm (N20).

Final remarks

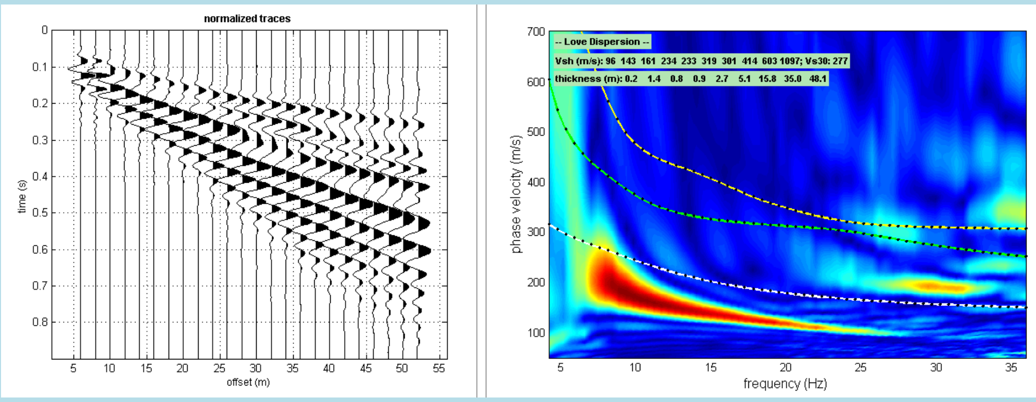
It should appear quite apparent that without the possibility of considering Love waves the user risks to interpret the Rayleigh-wave signal as pertaining to the fundamental mode. In the picture below we show a picked dispersion curve interpreted as (Rayleigh-wave) fundamental mode.



The picture below reports the final result of the inversion performed while considering the picked dispersion curve as belonging to the fundamental mode: formally speaking the misfit is quite good.



Once you plot the Love-wave dispersion curve of this V_S model (obtained while analyzing Rayleigh waves only) over the Love-wave field dataset (velocity spectrum) you will obtain the following <u>bad</u> agreement, actually demonstrating that the simplistic interpretative hypothesis adopted for Rayleigh wave velocity spectra is badly wrong:



In this case the mistake would not have been very large but in other cases much more serious problems can occur (see reported references and [case study#4](#)).

Finally please notice that, with respect to Rayleigh wave propagation, the excitation of the higher mode(s) and the complete absence of the fundamental one (quite apparent both in the present case study and in the #4) can occur also without the presence of low-velocity layers. Some authors sometimes state that higher modes are excited by the presence of shear-velocity inversions but both this case study (and the #4) and theory (Dal Moro and Moura, 2013) show that this is not necessarily true and also seemingly simple VS profiles (see Figure 7 and 8) can produce Rayleigh-wave propagation without any evidence of the fundamental mode.

References

Multi-component Acquisition and Joint Analysis of Surface Waves: Two Case Studies for Two Possible Inversion Strategies (Dal Moro G. and Marques Moura R.M., 2013), submitted to *J. Appl. Geophysics*

Joint Analysis of Rayleigh and Love Wave Dispersion for Near-Surface Studies: Issues, Criteria and Improvements (Dal Moro G. and Ferigo F., 2011), *J. Appl. Geophysics*, 75, 573-589

Some Aspects about Surface Wave and HVSR Analyses: a Short Overview and a Case Study (Dal Moro G., 2011), *invited paper*, BGTA - Bollettino Geofisica Teorica e Applicata, 52, 241-259

Unambiguous determination of the V_S profile via joint analysis of multi-component active and passive seismic data (Dal Moro G. and Keller L., 2013), EAGE Near Surface 2013, 19th European Meeting of Environmental and Engineering Geophysics, Bochum, Germany, 9-11 September 2013 (accepted)

Acknowledgements

Data courtesy *of Studio Geologico Guidetti - Segalini - Zucchi*, Castelnuovo Fogliani (PC) - Italy

Registered *winMASW* users can require the data and compare their solution with the one illustrated: winmasw@winmasw.com