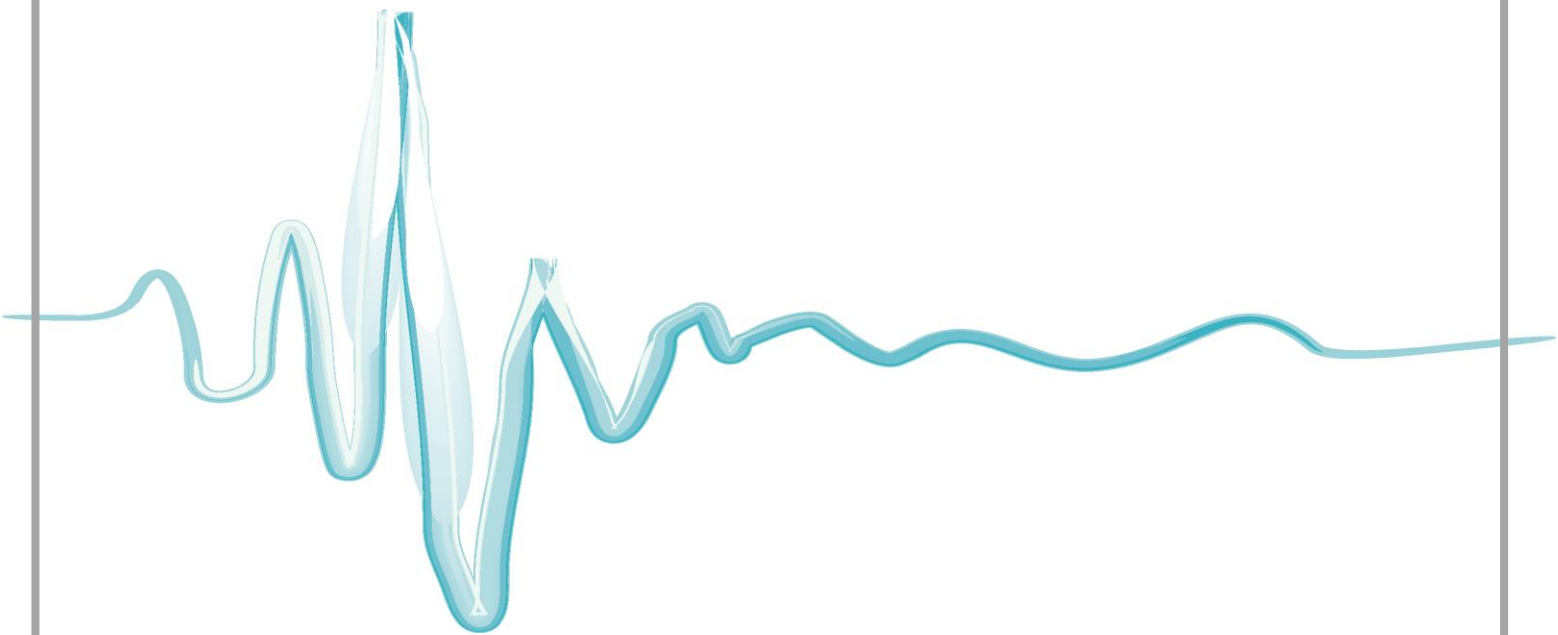
Applications of TROMINO® and SOILSPY ROSINA



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APPLICATIONS WITH ONE TROMINO®

ON THE GROUND

H/V (subsoil resonances/eigenfrequencies)

Determining whether a subsoil can amplify seismic motion and, if so, at what frequencies, is the first step of the seismic site response study, both for seismic microzoning and construction purposes. This also helps overcoming some limits of a subsoil classification based on the Vs30 parameter.

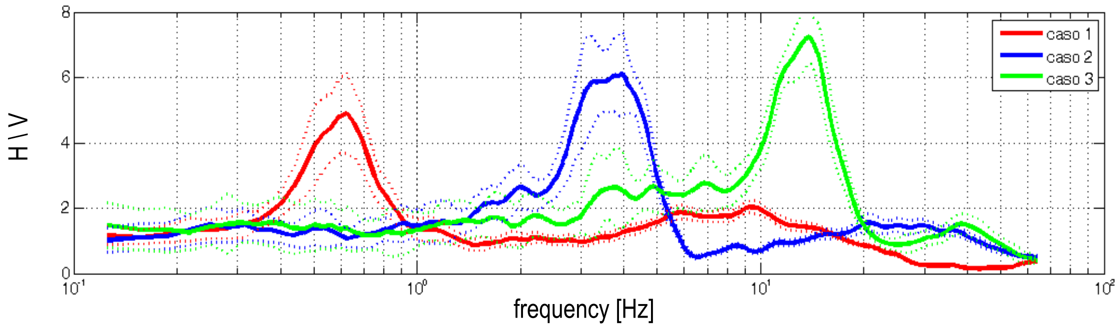


Figure 1: Example of seismic bedrock at different depths which generate H/V peaks at different frequencies. Case 1: bedrock at 300 m depth, case 2: bedrock at 20 m depth, case 3: bedrock at 4 m depth.

Vs (seismic shear wave velocity) profiles from the H/V fit constrained to independent data

Vs (seismic shear wave velocity) profiles can be estimated from the fit of the H/V curve constrained to independent data (typically drilling and penetration tests) (*Bull. Seism. Soc. Am.*, 99, 761-773).

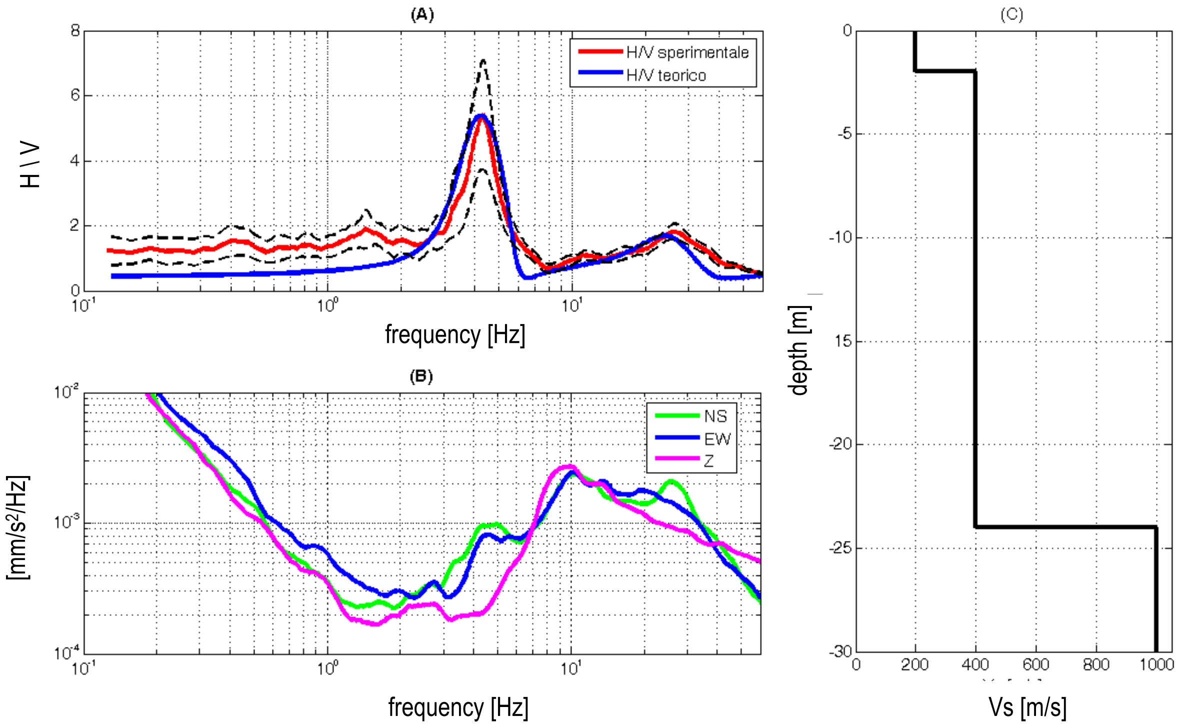


Figure 2: A) Experimental (average in red, standard deviation in black) and theoretical H/V curve (blue) obtained for the Vs model of panel C); B) single component amplitude spectra used to obtain the H/V curve of panel A).

Vs (seismic shear wave velocity) profiles

Estimate of Vs (seismic shear wave velocity) profiles from the joint fit of:

- H/V curve
- MASW survey, which can be performed:
  - with a single Tromino® ENGY + the radio trigger,
  - with a multichannel seismic array system (e.g. SoilSpy),

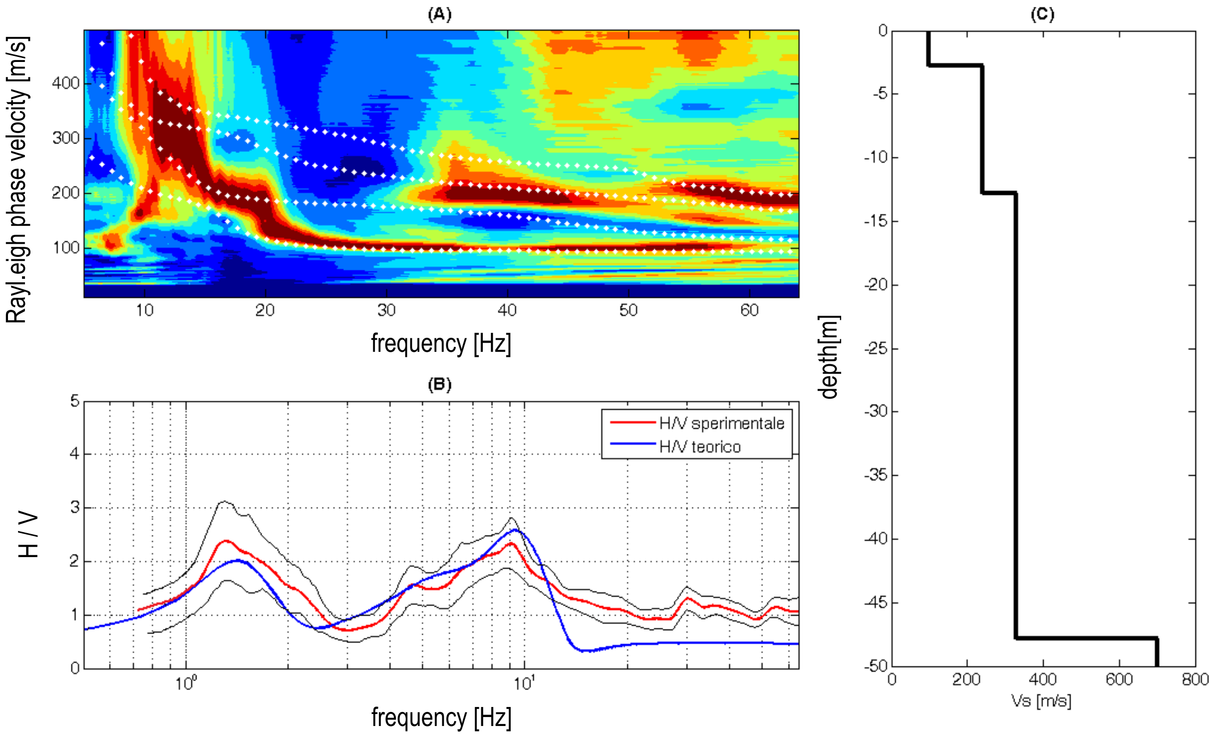


Figure 3: A) Phase velocity spectra of Rayleigh waves (contour plot) and first 4 modes of the theoretical dispersion curve for the subsoil model of panel C) (white dots); B) experimental (average in red, standard deviation in black) and theoretical (blue) H/V.

Synthetic view of the main seismic reflectors

In presence of a Vs profile, several H/V curves can be combined to get a synthetic view of the main seismic reflectors (e.g. bedrock, gravel layers, etc.) at local or regional scale.

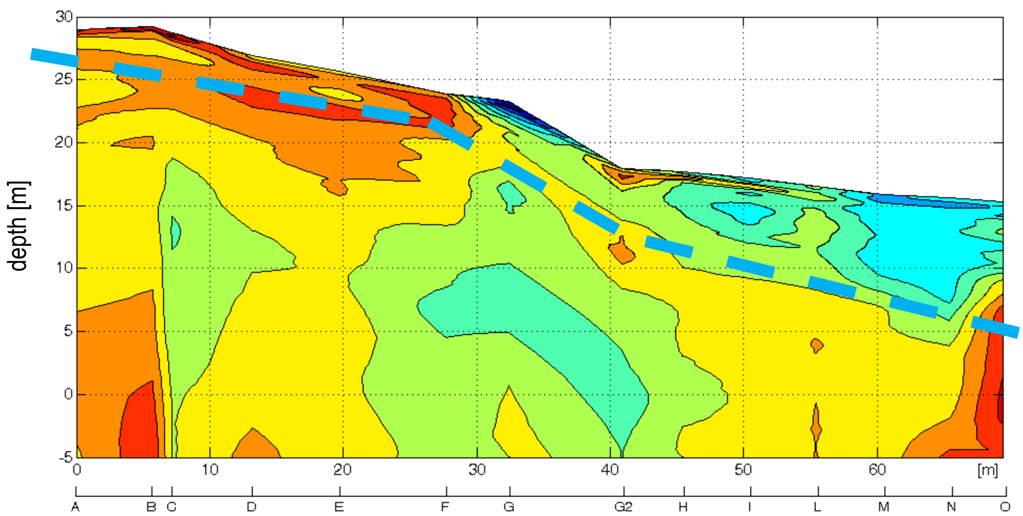


Figure 4: Synthetic view of several H/V curves acquired along a profile. According to the color scale adopted, this view shows the top of the bedrock (blue dashed line), which dips eastwards.

ON STRUCTURES (buildings, bridges, etc.)

Modal analysis of structures

Modal analysis of buildings, bridges, etc. in active or passive way. No need for external load/forces other than ambient microtremor:

a) **modal frequencies** (1 Tromino® is sufficient),
b) **modal shapes** (2 Tromino® are sufficient but under stationary noise 1 Tromino® is enough to determine the first flexion mode shape),
c) **modal damping** (1 Tromino® is sufficient).

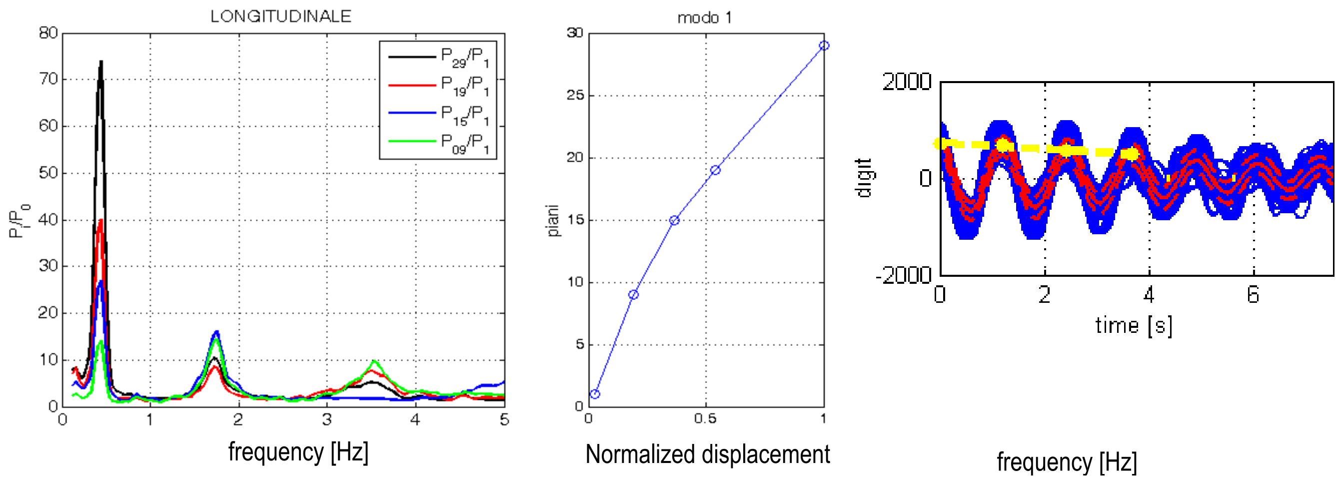


Figure 5: ***Left:*** **modal frequencies of a 30 storey building.** ***Centre:*** **modal shape of the first flexion mode.** ***Right:*** **damping.**

Detection of subsoil-structure double resonances

The coincidence of resonance between the soil and the structure is a particularly unfavorable condition in earthquake engineering because the structure will undergo amplified motion.

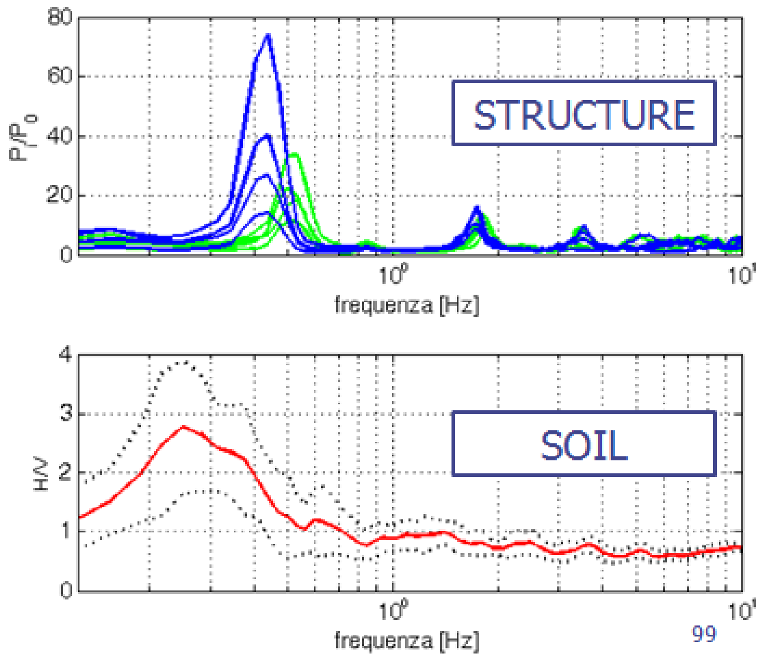


Figure 6: ***Top:*** **modal frequencies (transversal in blue, longitudinal in green) of a structure.** ***Bottom:*** **resonance frequency of the foundation soil of the same structure. Soil and structure frequencies are close to the so called condition of double-resonance.**

Off-line vibration analyses

Analysis of strong vibrations, potentially damaging for the structures, according to European norms (UNI9916, DIN4150) (e.g., potential damage induced by traffic on structures, etc.).

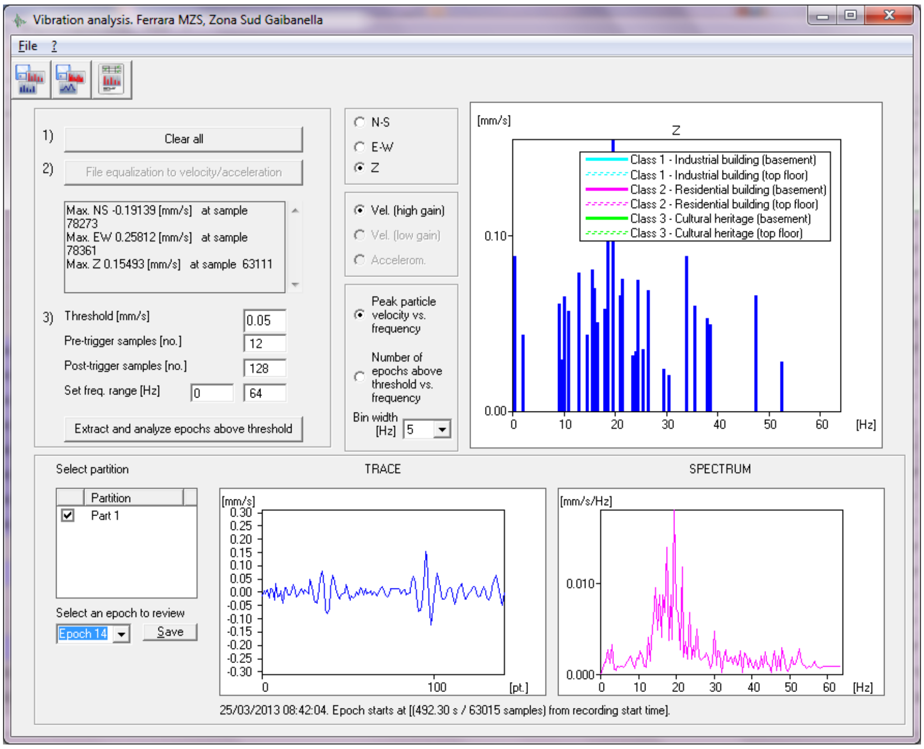


Figure 7: Interface of the *Grilla* software module for vibration analysis.

On-line vibration monitoring (Tromino® Manager),

Real time monitoring of vibrations with threshold-based event detection, recording at predefined time intervals, remote managing (via web) of up to 20 Tromino® units and several other features.

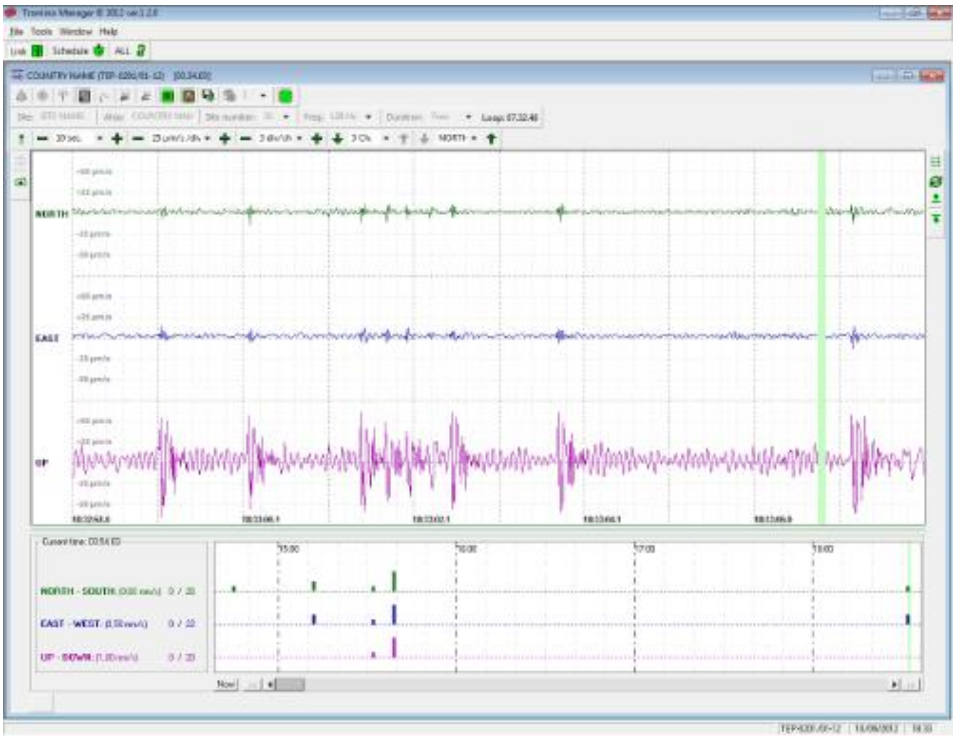


Figure 8: Interface of the Tromino® Manager software for on-line vibration monitoring.

APPLICATIONS WITH MORE THAN ONE TROMINO®

ON SUBSOILS

2D seismic arrays

Seismic arrays synchronized through the GPS time marker (Tromino® ENGY only) or radio (Tromino® ENGY only). These arrays (both active and passive) provide shear wave velocity profiles (Vs) from spatial autocorrelation techniques (or similar) and compression wave velocities (Vp) from refraction/reflection methods.

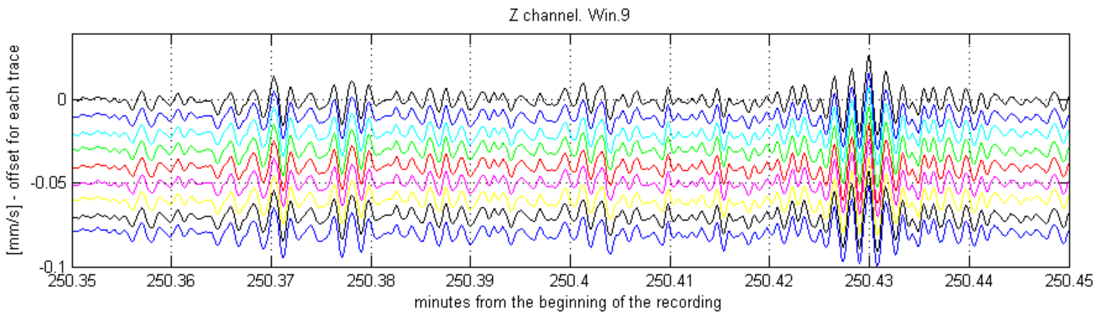


Figure 9: Seismic array with Tromino®.

ON STRUCTURES

Modal analyses

Active or passive modal analysis (e.g. NIMA, Natural Input Modal Analysis) through Tromino® ENGY networks, where the single units communicate via radio. A master Tromino® manages all the slave units.

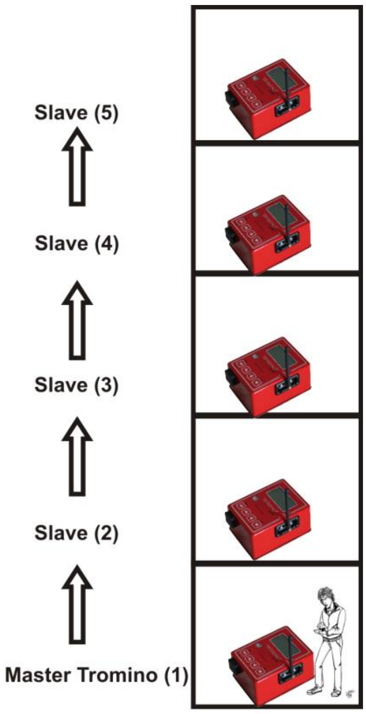


Figure 10: A master Tromino® manages all the slave units connected via radio.

Vibration monitoring

Real time monitoring of vibrations with threshold-based event detection, recording at predefined time intervals, remote managing (via web) of up to 20 Tromino® units and several other features.

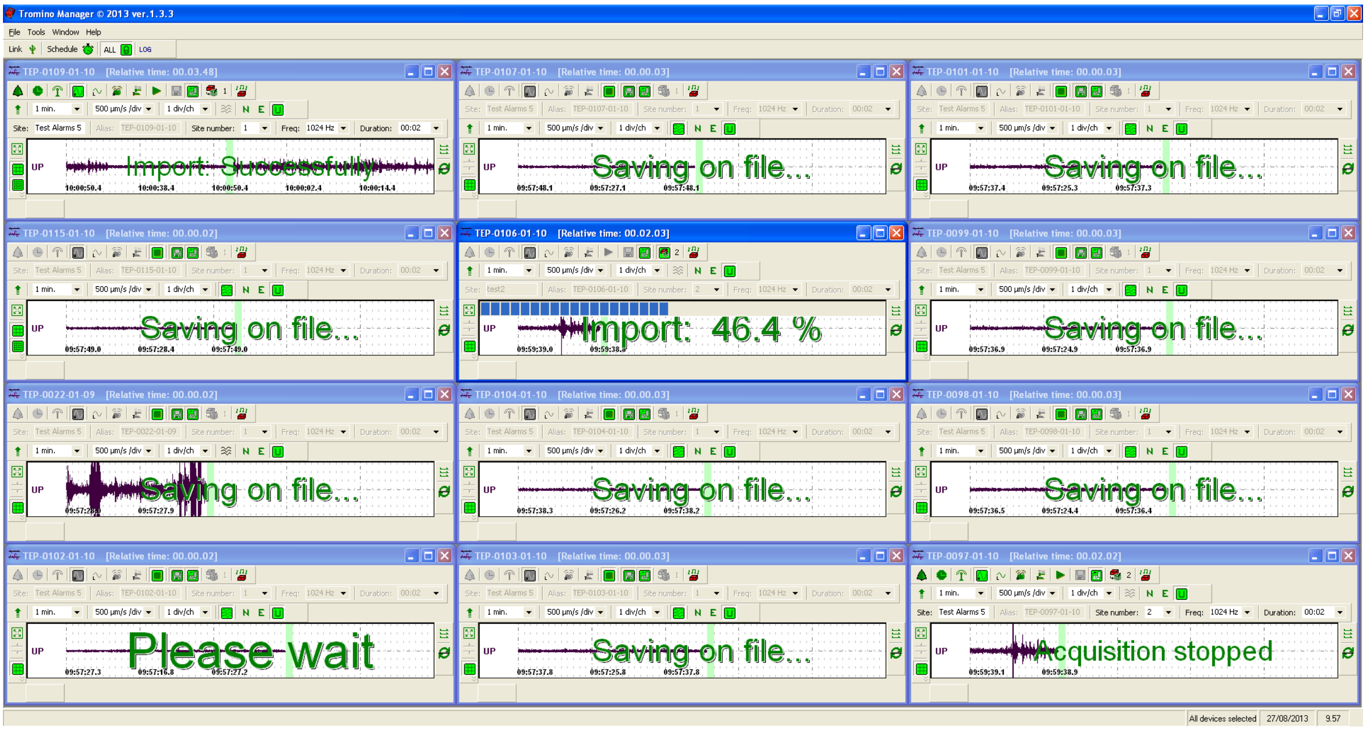
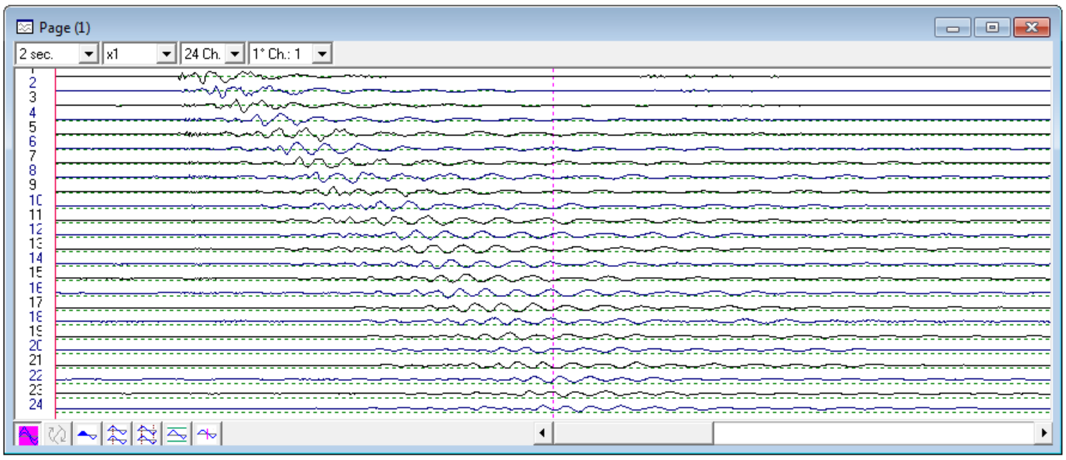
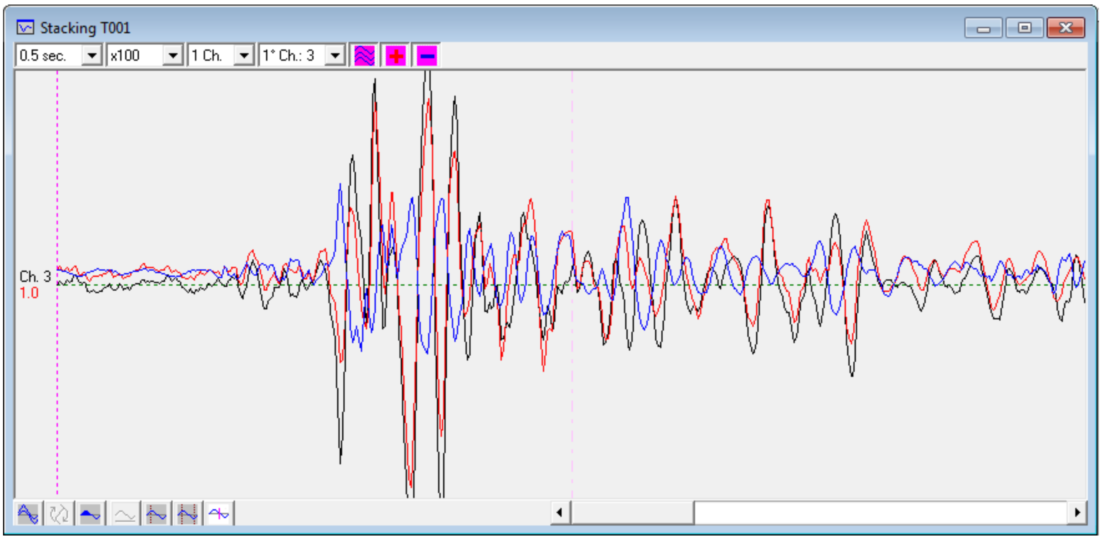


Figure 11: Interface of the Tromino® Manager software for on-line vibration monitoring.

APPLICATIONS OF SOILSPY ROSINA

SoilSpy Rosina is the multichannel digital system for active and passive seismic prospections, that allows to apply all the traditional (refraction, reflection, tomography) and modern (surface wave based) techniques, as summarized in the table below.

METHOD	RESULTS	SOILSPY SOFTWARE	GRILLA SOFTWARE	NOTES
P-WAVE REFRACTION	P-wave velocity profiles (Vp)	Acquisition and pre-processing software - On-line and off-line stacking - On-line and off-line phase reversal - phase-picking		Output in SEG2/ASCII format. Analysis software not included.
				

METHOD	RESULTS	SOILSPY SOFTWARE	GRILLA SOFTWARE	NOTES
S-WAVE REFRACTION	S-wave velocity profiles (Vs)	Acquisition and pre-processing software - On-line and off-line stacking - On-line and off-line phase reversal - phase-picking		Output in SEG2/ASCII format. Analysis software not included.
				

<table>
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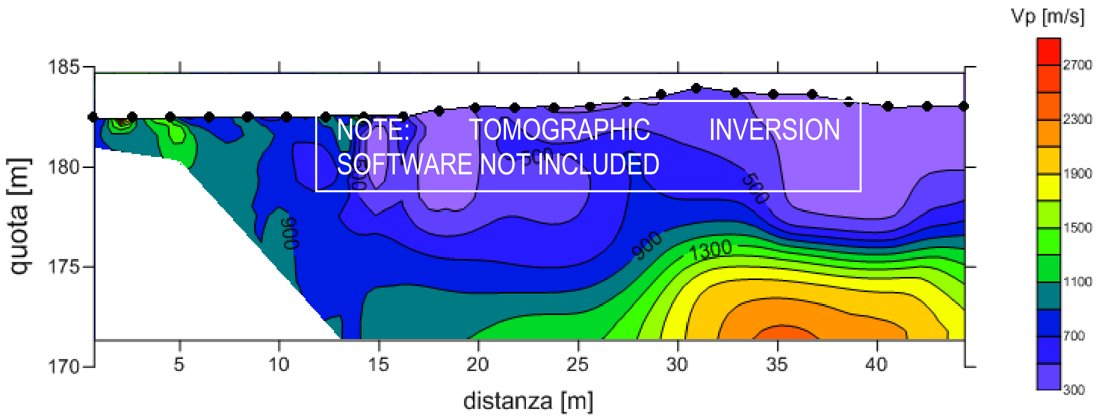
<tr><td rowspan="2">REFRACTION TOMOGRAPHY</td><td></td><td>Acquisition and pre-processing software
- On-line and off-line stacking
- On-line and off-line phase reversal
- phase-picking</td><td></td><td>Output in SEG2/ASCII format. Analysis software not included.</td></tr>
<tr><td colspan="4">
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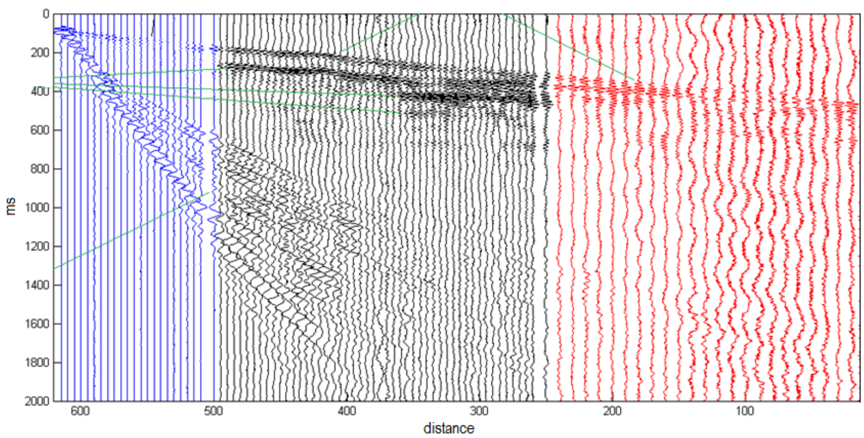
<tr><th>METHOD</th><th>RESULTS</th><th>SOILSPY SOFTWARE</th><th>GRILLA SOFTWARE</th><th>NOTES</th></tr>
<tr><td rowspan="2">REFLECTION</td><td></td><td>Acquisition and pre-processing software
- On-line and off-line stacking
- On-line and off-line phase reversal
- phase-picking</td><td></td><td>Output in SEG2/ASCII format. Analysis software not included.</td></tr>
<tr><td colspan="4">
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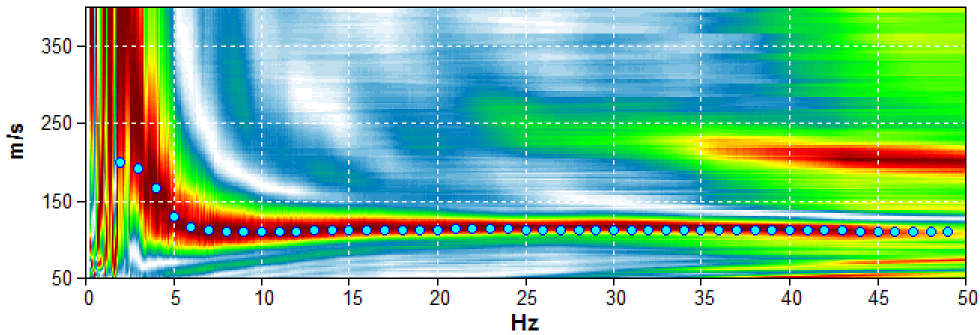
<tr><td rowspan="2">MASW / SASW
multichannel/spectral analysis of surface waves
1D active method</td><td>S-wave velocity profiles (Vs) from surface waves dispersion</td><td>Acquisition and pre-processing software
- On-line and off-line stacking</td><td>Analysis software includes
- Phase velocity spectra determination
- Surface wave dispersion determination
- Rayleigh/Love wave dispersion curve fitting also with higher modes
- Joint fit of H/V and dispersion curves</td><td>Output in SEG2/ASCII format.</td></tr>
<tr><td colspan="4">
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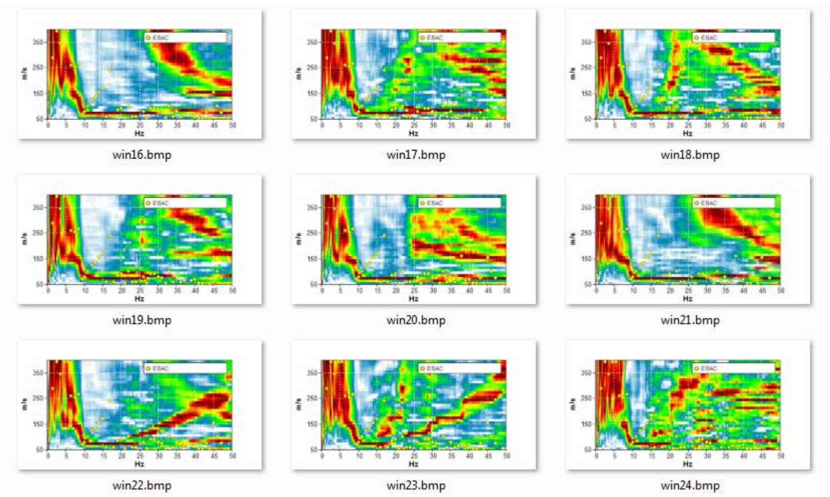
<tr><th>METHOD</th><th>RESULTS</th><th>SOILSPY SOFTWARE</th><th>GRILLA SOFTWARE</th><th>NOTES</th></tr>
<tr><td rowspan="2">ReMi™
Refraction Microtremors
1D passive method</td><td>S-wave velocity profiles (Vs) from 1D passive surface waves dispersion</td><td></td><td>Analysis software includes
- Phase velocity spectra determination
- Surface wave dispersion determination
- Rayleigh/Love wave dispersion curve fitting also with higher modes
- Joint fit of H/V and dispersion curves</td><td>Output in SEG2/ASCII format.</td></tr>
<tr><td colspan="4">
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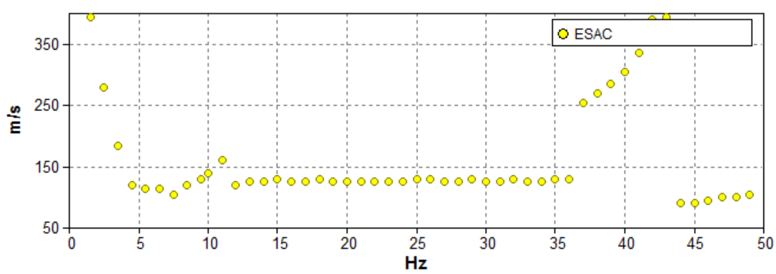
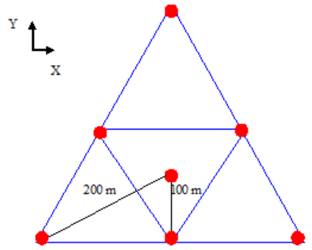
METHOD	RESULTS	SOILSPY SOFTWARE	GRILLA SOFTWARE	NOTES
ESAC / SPAC Extended spatial autocorrelation methods (2D passive surface-wave based methods)	S-wave velocity profiles (Vs) from 2D passive surface waves dispersion		Analysis software includes - Surface wave dispersion curve determination - Rayleigh/Love wave dispersion curve fitting also with higher modes - Joint fit of H/V and dispersion curves	Output in SEG2/ASCII format.
	 			

METHOD	RESULTS	SOILSPY SOFTWARE	GRILLA SOFTWARE	NOTES
DOWNHOLE CROSSHOLE	P and S wave velocity profiles			Output in SEG2/ASCII format. Borehole geophone not provided.