Site characterization of the INGV station IV.CMPO – Campotto Po (Municipality Argenta, Ferrara)

Working Group:	Date: July 2016
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Subject: **Final report illustrating measurements, analysis and results at IV.CMPO station**	

Convenzione DPC-INGV 2016, Allegato B2: Obiettivo 1 (Responsabile: C. Meletti) - TASK B: Caratterizzazione siti accelerometrici (Responsabili: P. Bordoni, F. Pacor)

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1. Introduction

In this report, we present the geophysical measurements and the results obtained in the framework of the 2016 agreement between INGV and DPC, named "*Allegato B2: Obiettivo 1 (Responsabile: C. Meletti) - TASK B: Caratterizzazione siti accelerometrici (Responsabili: P. Bordoni, F. Pacor)*" for the characterization of sites of the Italian National Seismic Network (RSN) with accelerometers.

Here the results for station IV-CMPO are presented.

Geophysical measurements are two 2D arrays of seismic stations in passive configuration. Using surface-wave analysis, we provide results in terms of dispersion curves that are inverted to obtain shear-wave velocity (V_s) profiles for the studied area. The inverted models are suitable for computing the average Vs velocity in the uppermost 30 m (Vs30) and assegning then the EC8 soil class category.

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2. Geophysical investigation

IV.CMPO station is situated in the Po Plain in the municipality of Argenta, about 30 km south-east of Ferrara city.

Figure 1 shows the location of the seismic stations used for the two 2D arrays deployed in the target area surrounding IV.CMPO.

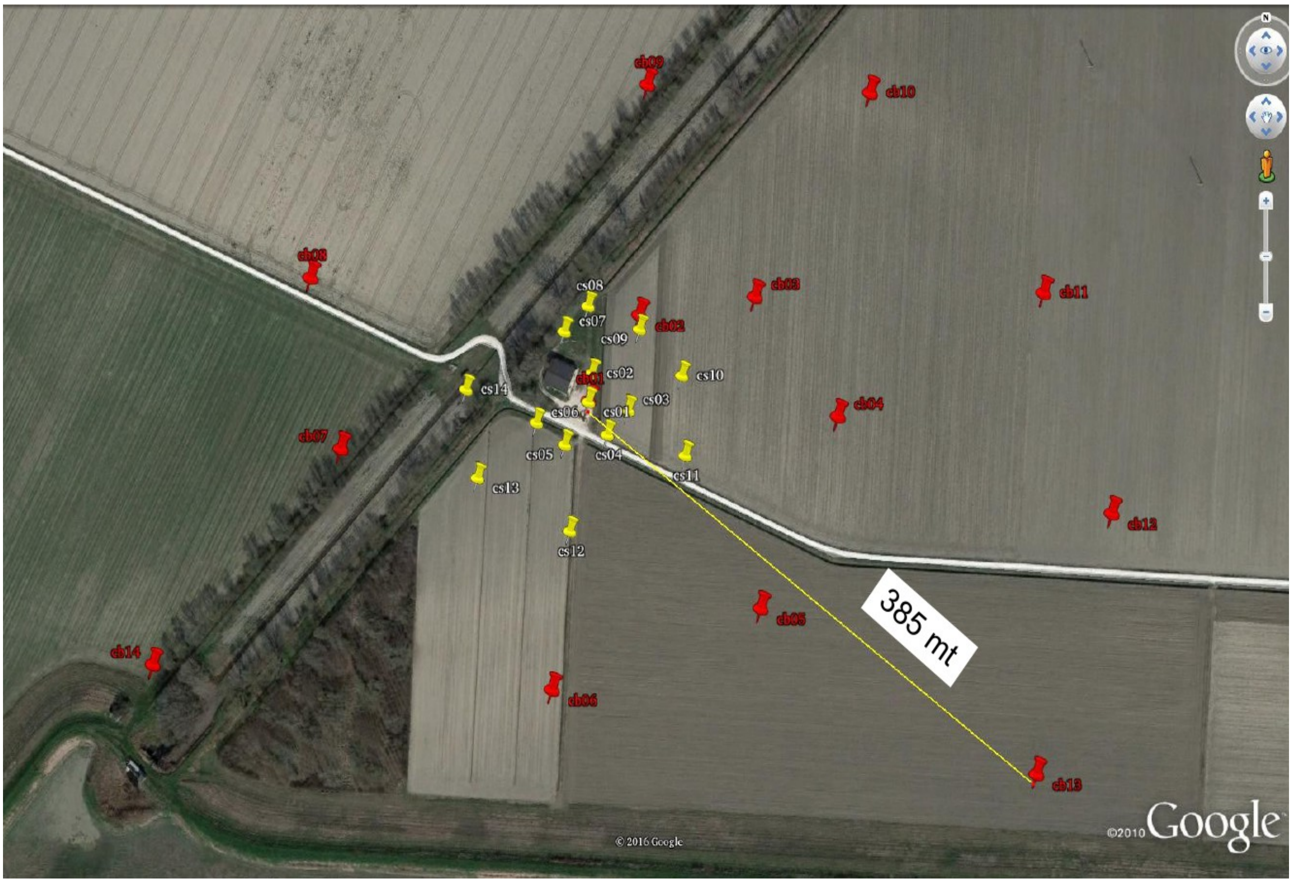

Figure 1: Plan view of the two 2D seismic arrays deployed around IV-CMPO site. The yellow and red points indicate the fourteen stations of the 2D array in passive configuration (named "*small*" and "*big*" array, respectively). All stations are equipped with Reftek R130 digitizer and Lennartz 3D-5sec velocimetric sensors. IV-CMPO station is situated in proximity of the center of the arrays (near the house recognizible in picture).

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2.1 ARRAY MEASUREMENTS RESULTS

Two 2D arrays were performed using 14 single seismic stations equipped with Reftek 130 digitizers and Lennartz 3d-5s velocimetric sensors. Figure 1 shows their position, and hereinafter we referred to these two arrays as "*big*" and "*small*" array (sharing the same geometrical centre). The common noise recording lasted approximately 2 hours for both arrays. The measurements were recorded the 5th of July 2016. The *small* and *big* array are characterized by a maximum aperture of 150 and 660 m, respectively. A view of field work is shown in Figure 2. The seismic sensors were positioned in a two-dimensional geometry with irregular spacing, as shown in Figure 2.

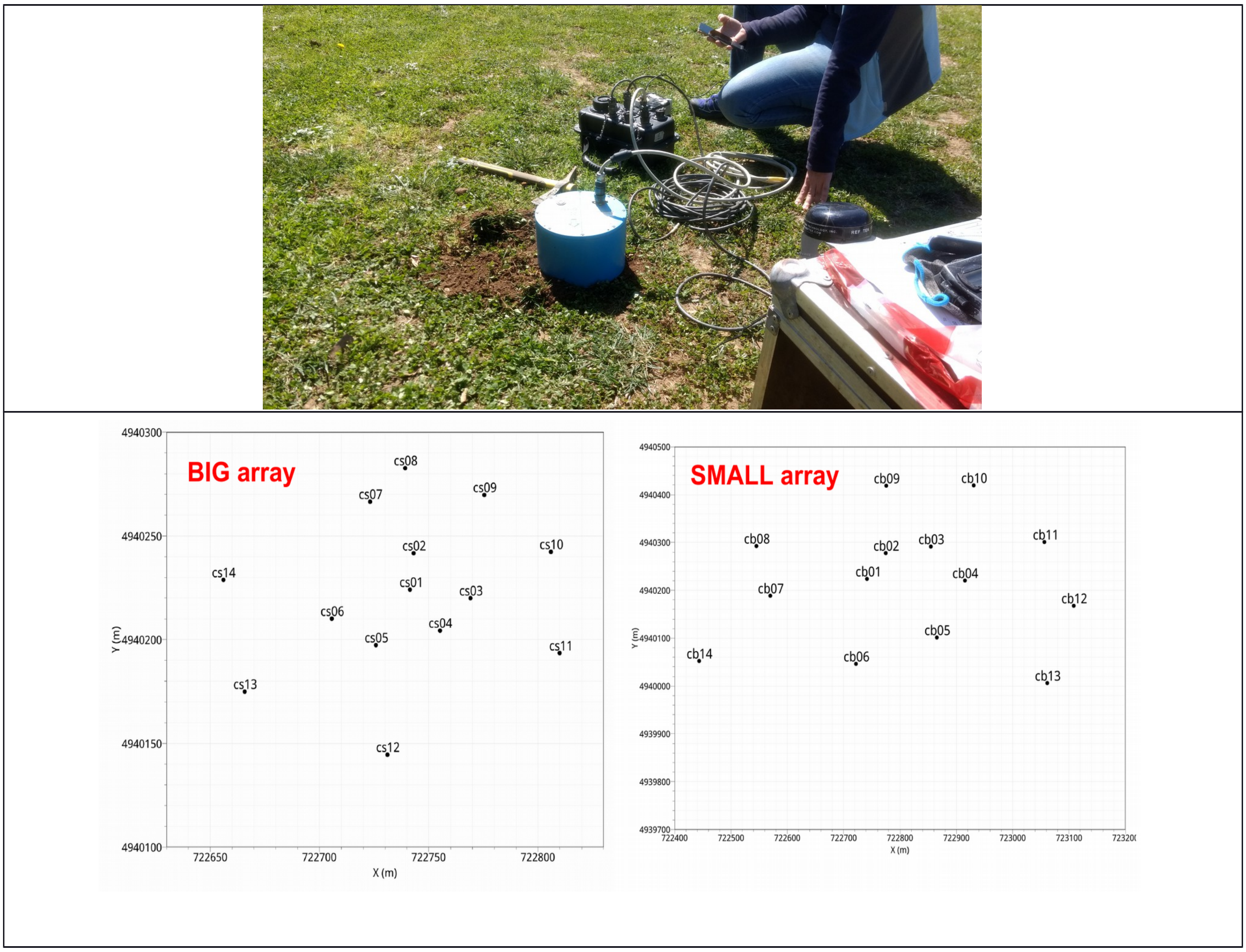

Figure 2: Top: Example of an installation of a seismic station. Bottom: 2D Array geometry of the *big* (left panel) and *small* (right panel) array.

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The geometries of the arrays allow the performance in terms of wavenumbers described in Figure 3, where the theoretical Array Transfer Function is reported for each array.

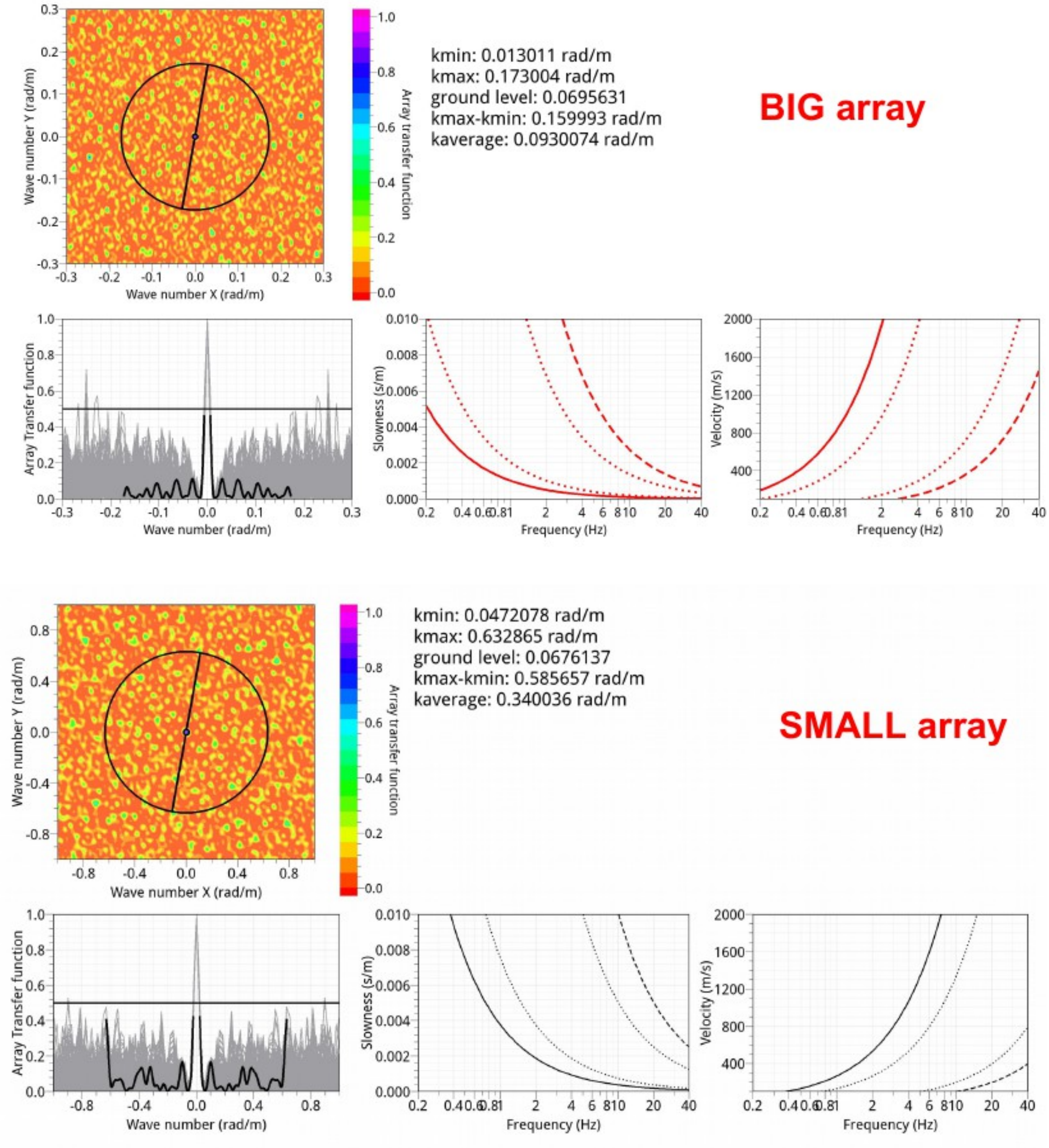

Figure 3: Theoretical Array Transfer function of the two 2D arrays installed in the target area of IV-CMPO. Alias and resolution curves are also reported in the slowness(or velocity)-frequency representation.

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The computed H/V curves of the 14 stations are overimposed at each array in Figure 4. There is a general agreement of the H/V shapes showing a good overlapping expecially below 2 Hz. The resonance frequency (Fo) is assigned at 0.5 Hz, even if a secondary H/V peak is present at 0.8 Hz. The rotated HV spectral ratios evidence consistently both the frequencies (0.5 and 0.8 Hz) showing no significant polarization effects (see Figure 5 where we show for semplicity only the results of the *big* array).

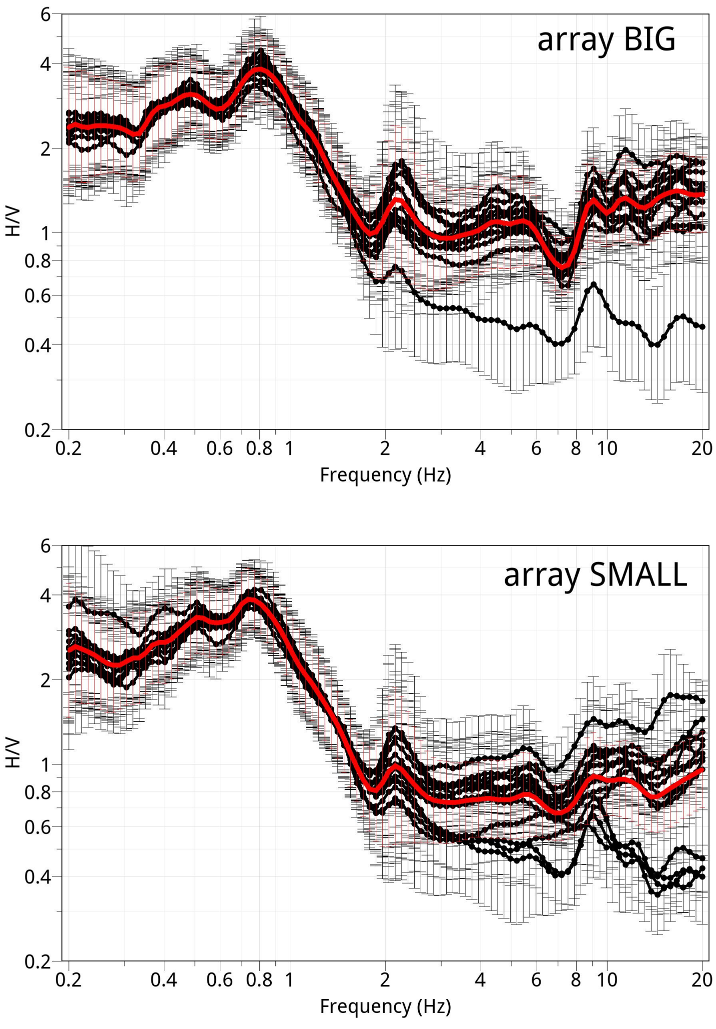

Figure 4: H/V curves of the 14 stations for the *big* (top panel) and *small* array (bottom panel). The red curves shows the average H/V curves. The vertical bars estimate the H/V uncertainties.

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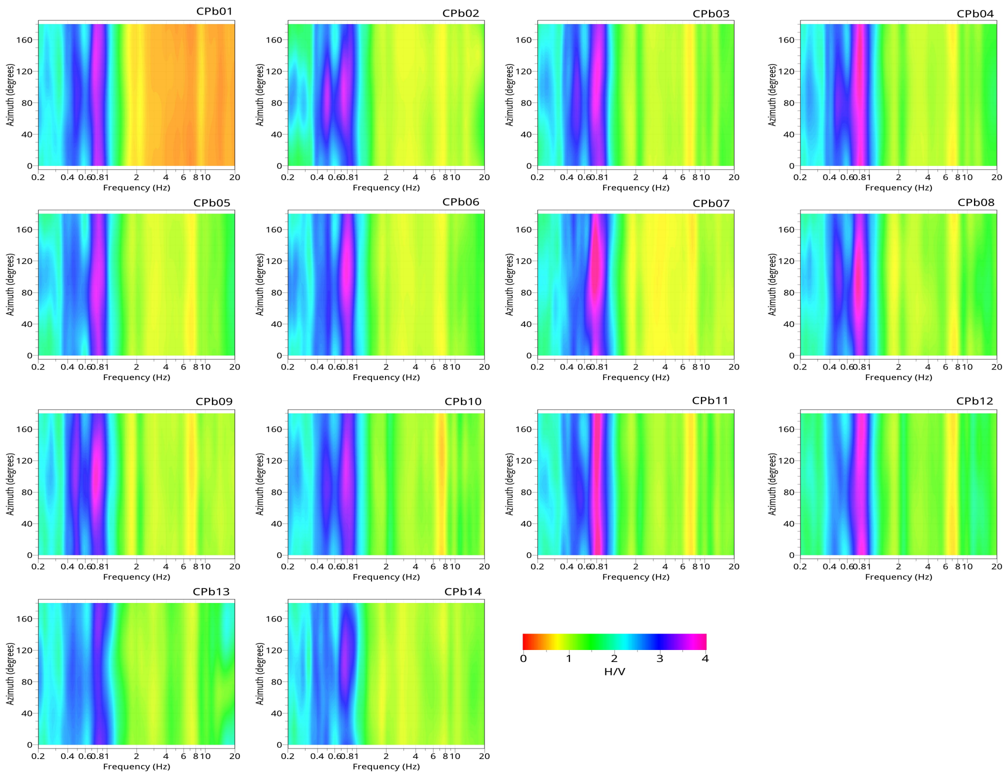

Figure 5: Rotating H/V curves at the 14 stations of the *big* array..

Data from the 2D arrays have been analysed in terms of conventional frequency-wavenumber (FK) analysis and high-resolution FK analysis. Because the two techniques lead to similar results, we present hereinafter only the results of the conventional FK method.

The FK analysis was performed on the three-components of motion; the results using the horizontal and vertical components were interpreted in terms of Rayleigh and Love surface waves, respectively. We used the GEOPSY code (http://www.geopsy.org) for the H/V computation and surface-wave analysis. Figure 6a shows the dispersion curves derived from the f-k analysis using the vertical signal recorded by the *big* and *small* array. The picked dispersion curves of the two arrays are in good agreement showing consistent values of apparent phase velocities in the overlapping frequency band (about 1-2 Hz), as shown by Figure 6b (left panel). The surface-wave analysis performed on the horizonal signal provides the dispersion curves shown in Figure 7.

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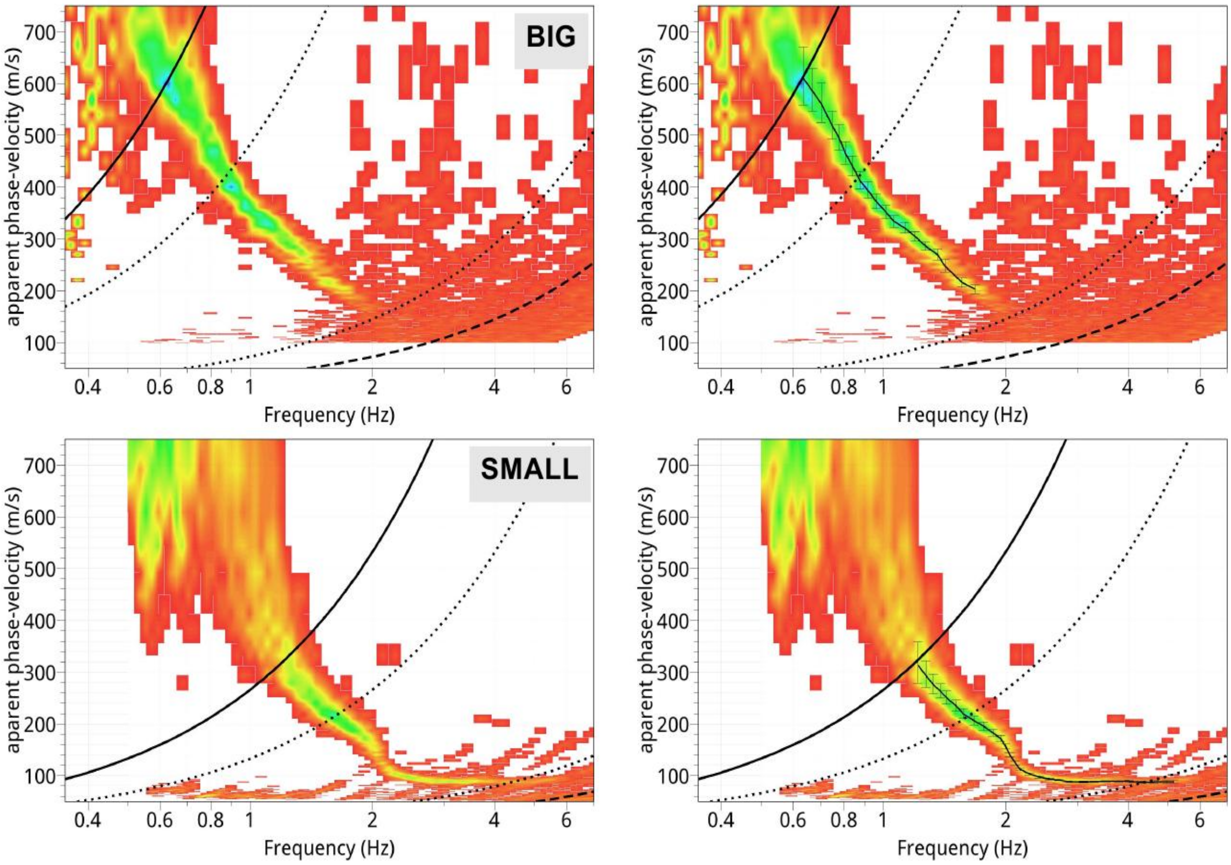

Figure 6a: Unpicked and picked dispersion curve in the velocity-frequency plan for the *big* (top) and *small* array (bottom panel) working with the vertical component.

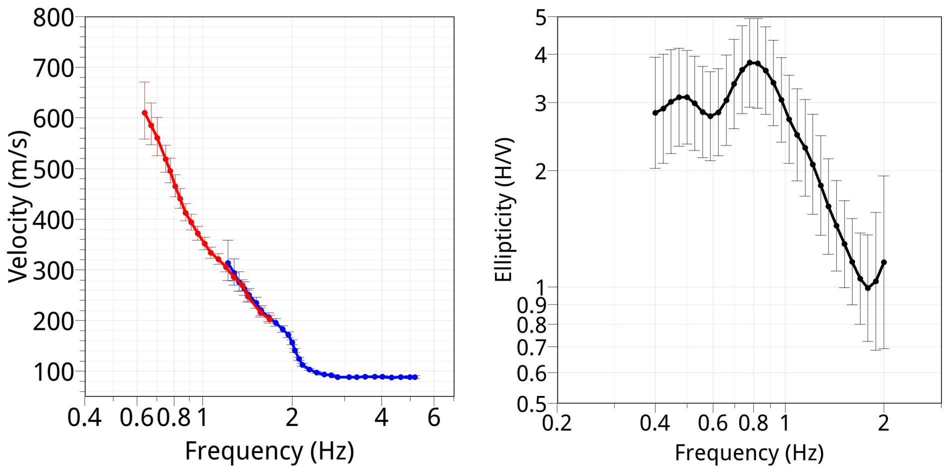

Figure 6b: Left) The picked dispersion curve from the *big* and *small* array are overimposed (red and blue curve, respectively). Right) Portion of average H/V curves considered in the inversion process.

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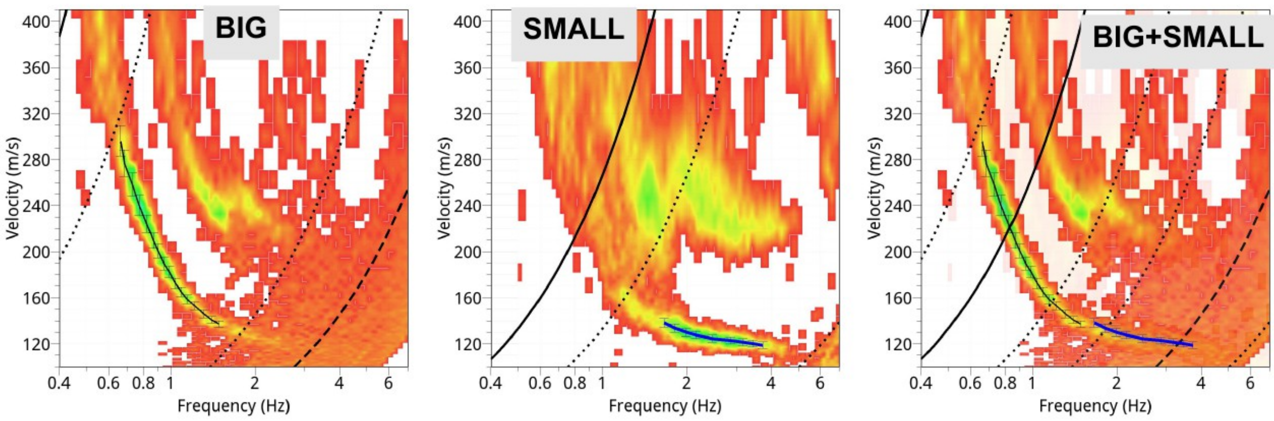

Figure 7: Picked dispersion curve in the velocity-frequency plan for the *big* (left) and *small* array (middle panel) working with the horizontal component. The two fk images were overlaid in the right panel. Although higher modes are visible in the fk images, for sake of semplicity we picked only fundamental curves.

The final dispersion curves selected for the inversion step are shown in Figure 8 assuming Rayleigh and Love fundamental mode (for vertical and horizontal components, respectively).

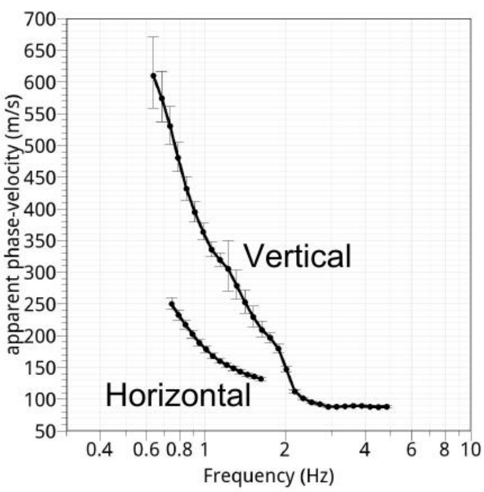

Figure 8: Dispersion curves considered during the inversion process. Rayleigh and Love waves are associated to the vertical and horizontal component, respectively.

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3. Vs Model

To proceed with the inversion step, we assume the dispersion curves derived from the vertical and horizontal component of motion associated to the fundamental mode of Rayleigh and Love surface-waves, respectively.

To summarize, the targets during the inversion process were:

1) Dispersion curves shown in Figure 8.
2) Ellipticity curve in terms of Rayleigh fundamental mode extracted from the most similar part of the H/V curves (from 0.4 to 2 Hz; see Figure 6b in the right panel)
3) Fundamental frequency (Fo=0.5 Hz)

The resulting models after the inversion step are shown in Figure 9. We obtained a fairly good fit between experimental and theoretical curves using a model parameterization composed of three main layers over halfspace, where a shear-wave velocity linearly increasing with depth was allowed in the second layer (see the zoomed view in Figure 9).

Focusing on the Vs models of Figure 9, the results indicate a very uppermost soft layer (thick < 20 m) with Vs around 90 m/s, a second layer (depth approximately from 15 to 90 m) show a Vs increasing with depth from 160 to 280 m/s. The third layer is characterized by Vs values in the range of 440-500 m/s. The halfspace is found by the inversion at about 250-330 m deep.

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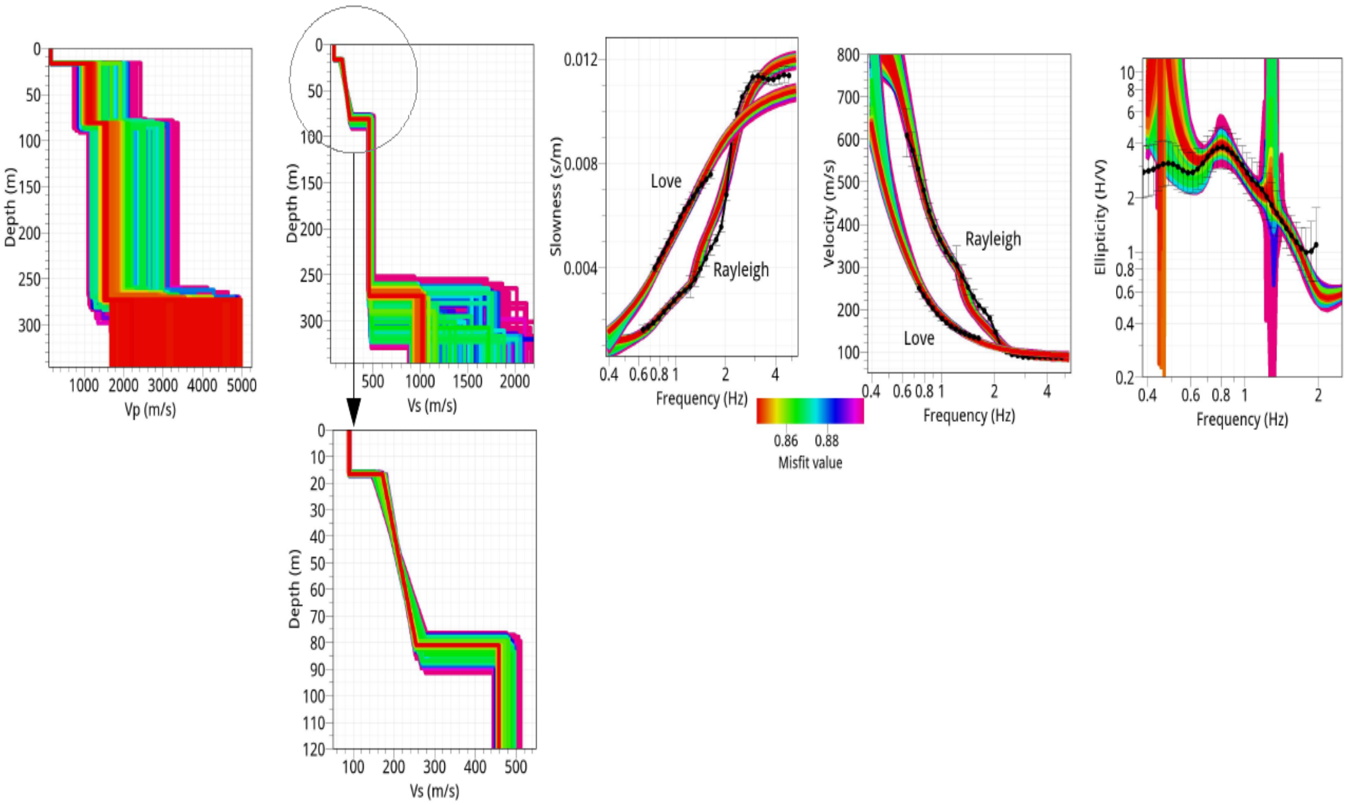

Figure 9: Resulting models obtained after inversion constraining the dispersion and H/V ellipticity curve (the field data are shown as black curves). A zoom of the Vs provile is shown in the bottom.

Cite as: Working group INGV of DPC-INGV 2016 agreement All. B2 Task B: Seismic characterization of accelerometric sites, doi: 10.5281/zenodo.807793

The best Vp and Vs model (i.e. lowest misfit) resulting from the inversion are proposed in Figure 10 and Table 1.

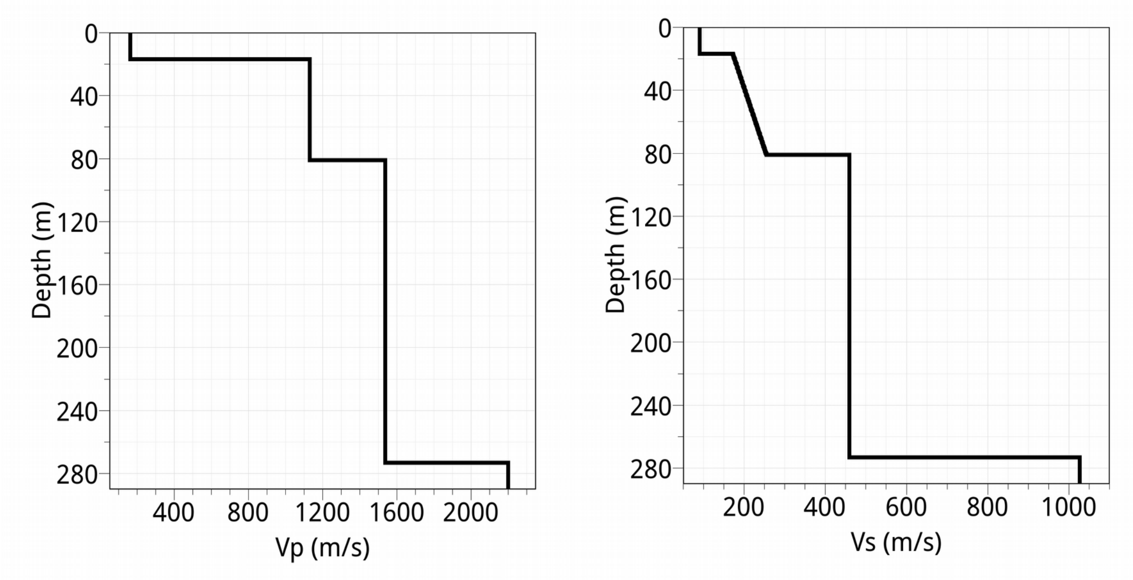

Figura 10: Best-fit model of Vp (left panel) and Vs (right panel) profiles [extracted from the ensemble of Fig. 9].

From (m)	*To(m)*	*Thickness (m)*	*Vs (m/s)*	*Vp (m/s)*
0	16,70	16,7	90	161
16,7	81,1	64,4	172-255	1130
81,1	273	191,9	458	1538
173		?	1027	2200

Table 1: Best-fit model

Cite as: Working group INGV of DPC-INGV 2016 agreement All. B2 Task B: Seismic characterization of accelerometric sites, doi: 10.5281/zenodo.807793

4. Conclusions

The surface-wave analysis at IV.CMPO station indicates a soft site. A first resonant peak is found around 0.5 Hz, suggesting a bedrock relatively deep (order of 200-300 meters). However the inversion results show two additional seismic contrasts at about 20 and 80 m deep (Figures 9 and 10). The very uppermost meters (< 20 m) show Vs very low with values of about 90 m/s; a second layer of about 60 m thickness shows Vs increasing with depth from 160 to 280 m/s; a third layer of about 200 m thickess shows average Vs around 500-550 m/s .

The V_{s30} retrieved from the best inverted model is 115 m/s (Table 2), therefore IV-CMPO is classified as class D soil type following the NTC08 seismic classification. A soil class S1 cannot be excluded.

V_{s30} (m/s)	***Soil class***
115	D (S1?)

Table 2: Soil Class

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