Velocity profile report at the seismic station IV.SEF1 - SEFRO

Working Group: **Claudia MASCANDOLA** **Sara LOVATI** **Marco MASSA** **Chiara LADINA**	Date: December 2018
Subject: **Final report illustrating measurements, analysis and results for station IV.SEF1**	

Convenzione DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B: "Caratterizzazione siti accelerometrici" (Coord. G. Cultrera, 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 2018 agreement between INGV and DPC, called *Allegato B2: Obiettivo 1 - TASK B: Caratterizzazione siti accelerometrici (Coord. G. Cultrera, F. Pacor).* In this report, the results for station IV.SEF1, belonging to the Italian National Seismic Network (RSN-INGV), are presented.

Geophysical measurements consist in a 2D array in passive configuration that provide results in terms of dispersion curves of surface waves. These curves are inverted to obtain a shear-wave velocity (Vs) profile that is suitable for assigning the soil class according to the current Italian seismic code (NTC 2018) and the current Eurocode (EC8).

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2. Geophysical investigations

Figure 1 shows the location of the stations used for the 2D array and Tab. 1 the corresponding geographic coordinates.

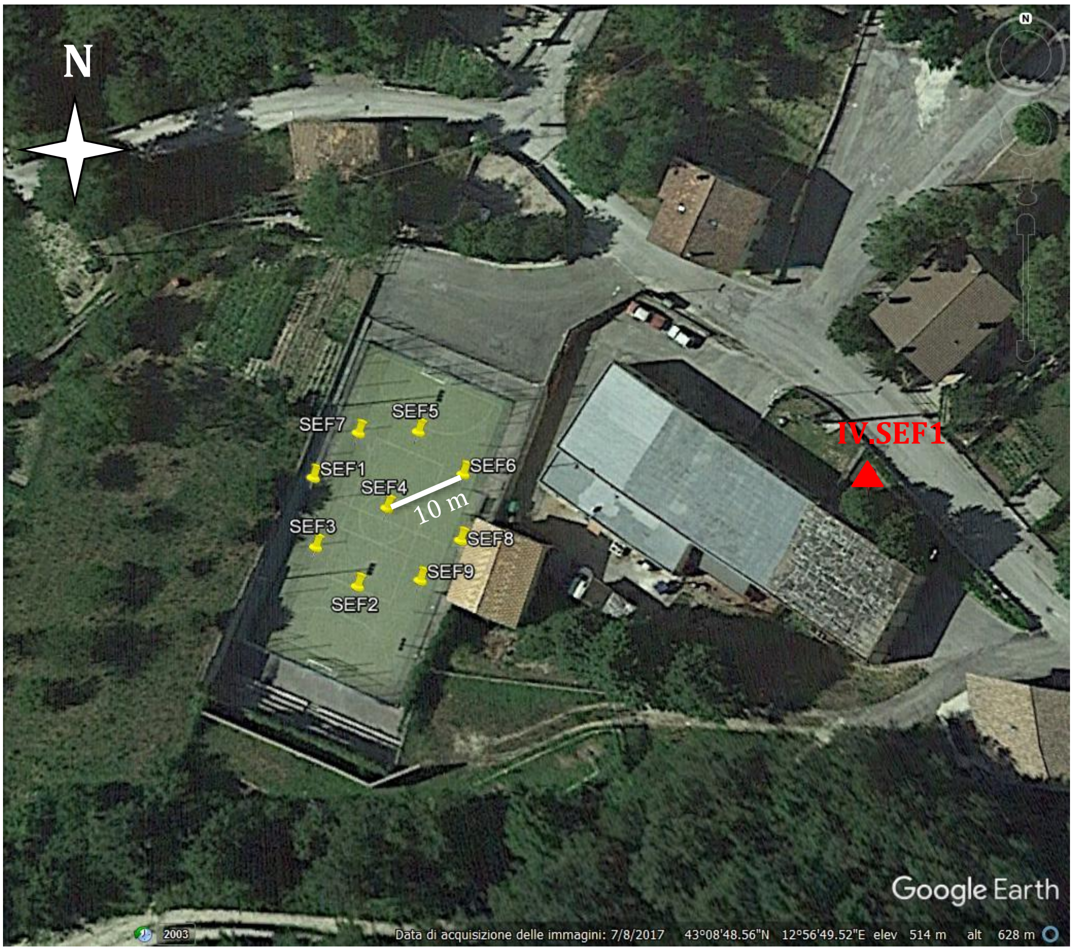

Figure 1: Map of the geophysical measurements performed at IV.SEF1 site. The yellow points are the nine stations of the 2D array in passive configuration (all stations are equipped with Reftek-130 digitizer and Lennartz 3D-5sec velocimetric sensors). The red triangle indicates station IV.SEF1.

staz	Lat (°)	lon (°)	El (m)
SEF1	43.14681	12.94674	513
SEF2	43.14669	12.94681	506
SEF3	43.14673	12.94675	506
SEF4	43.14677	12.94686	511
SEF5	43.14686	12.9469	512
SEF6	43.14681	12.94697	512
SEF7	43.14686	12.94681	508
SEF8	43.14674	12.94697	509
SEF9	43.1467	12.94691	514

Tab 1: array stations coordinates (WGS84)

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2.1 Array measurements results

A 2D array was performed using nine single seismic stations equipped with Reftek 130 digitizers and Lennartz 3D-5s velocimetric sensors. The noise recording lasted about 2 hours. A view of the 2D passive array survey is shown in Figure 2.

The seismic sensors were positioned in a circular geometry with a radius of 10 m, as shown in Figure 1 and 2.

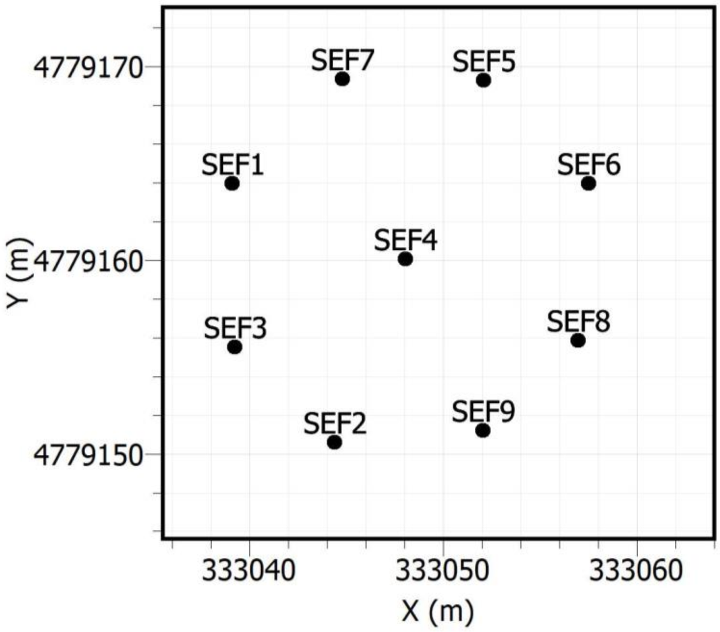

Figure 2: Top: example for the installation of an array station. Bottom: 2D Array geometry with UTM coordinates.

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The geometry of the array controls the response in terms of theoretical transfer function as described in Figure 3.

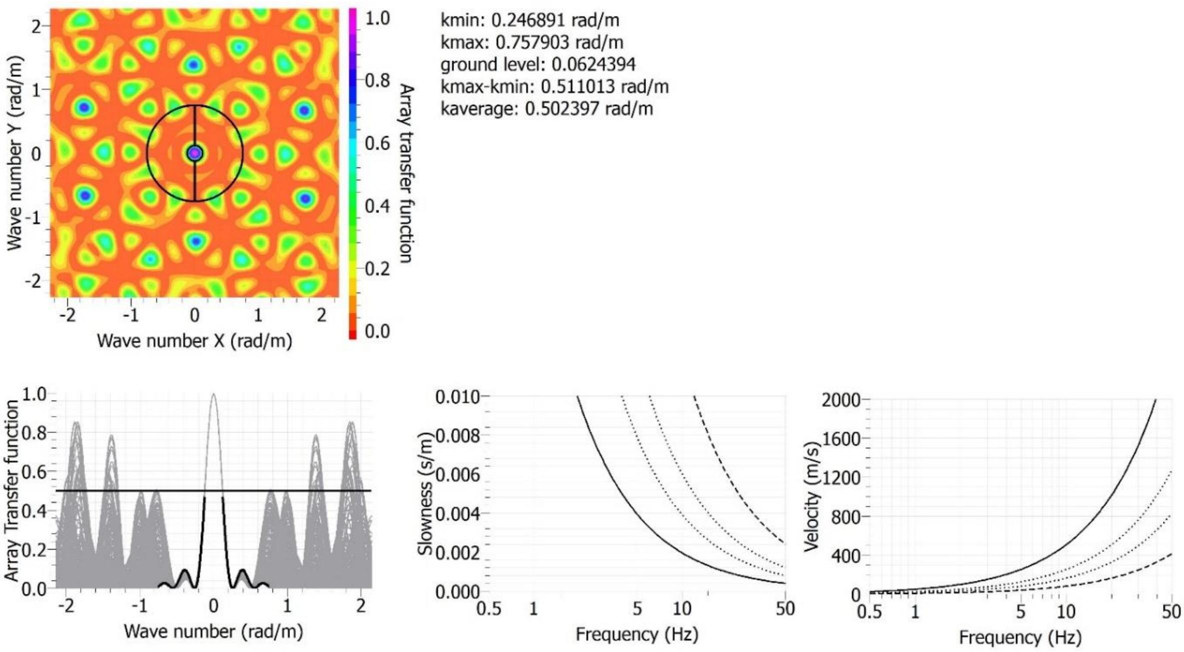

Figure 3: Theoretical Array Transfer function for the 2D array at IV-SEF1

In Figure 4, the H/V curves of the nine stations are superimposed on each other. The average H/V curve is reported in red. All the H/V curves present a good agreement, highlighting a clear H/V peak at 6 Hz.

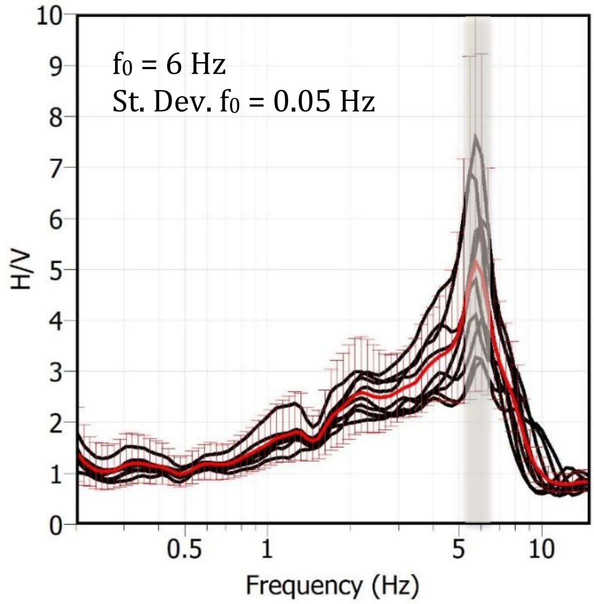

Figure 4: H/V curves of the 9 stations. The red curve is the average H/V and the red bars estimate the uncertainty of the average H/V.

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Data from the 2D array have been analysed in terms of FK analysis and high-resolution FK analysis. Because the two techniques lead to similar results, hereinafter we consider only the high-resolution FK method. For the analysis we use the code GEOPSY (http://www.geopsy.org). The dispersion curve is shown is Figure 5.

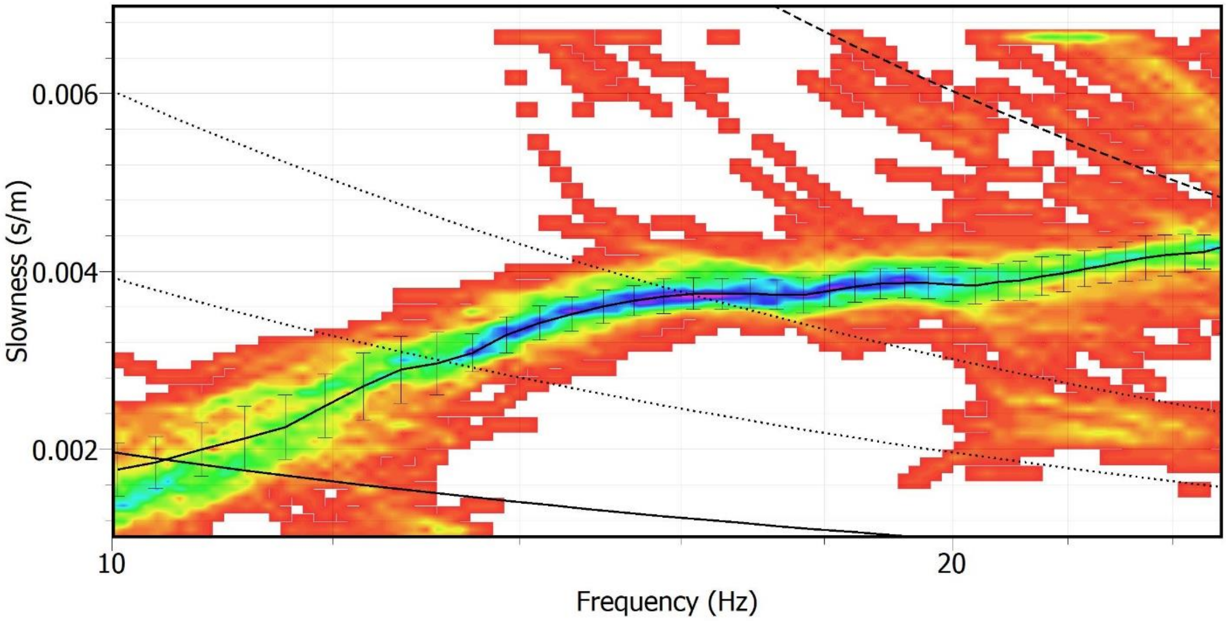

Figure 5: Picked dispersion curve in the slowness domain with the high-resolution FK analysis.

We interpret and assume that the dispersion curve obtained with the 2D array is relative to the fundamental mode of the Rayleigh dispersive waves.

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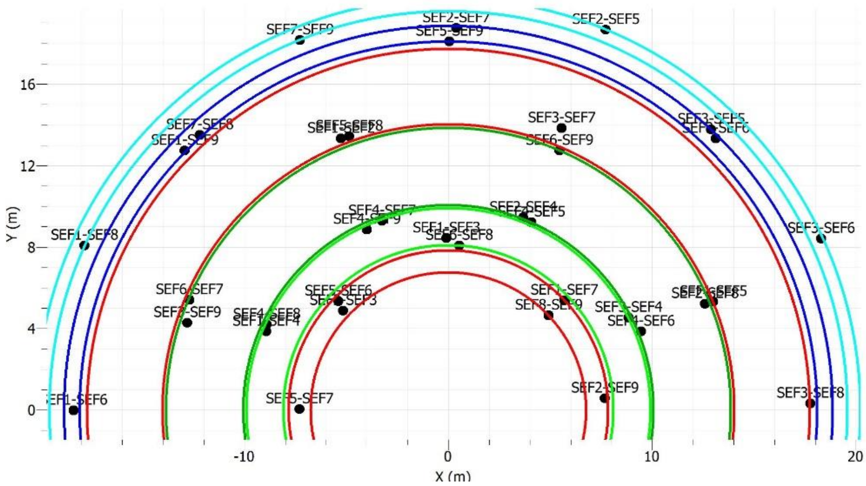
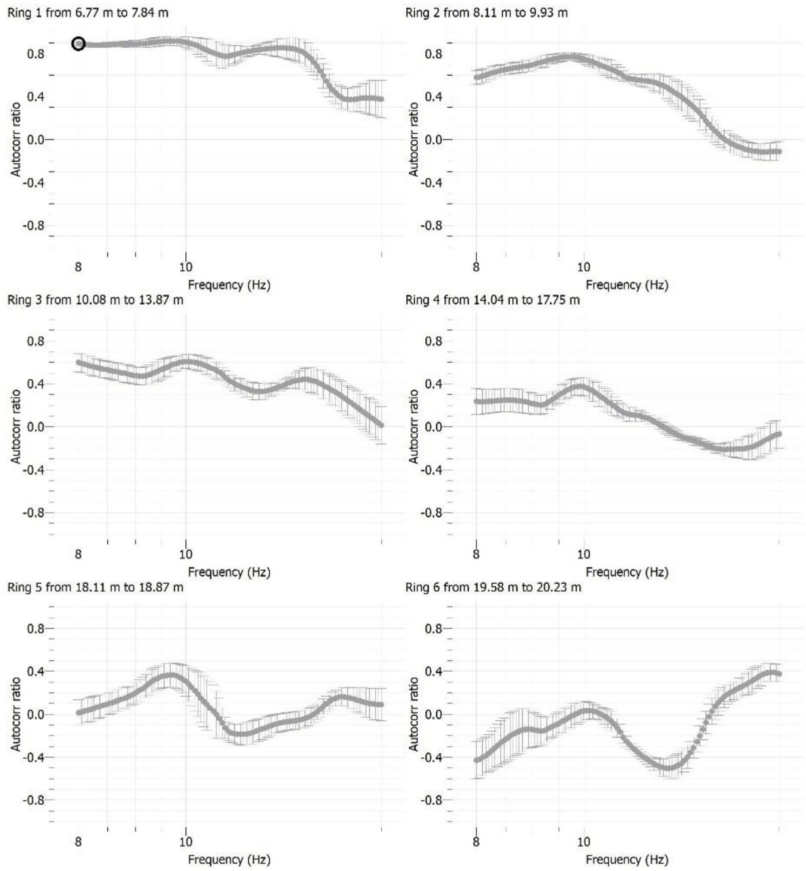
The spatial auto-correlation technique (MSPAC) has also been applied to the passive data to obtain the auto-correlation curves (Figure 6).



a)



b)

Figure 6: a) selected rings for the MSPAC analysis; b) autocorrelation curves for the six rings.

The auto-correlation curves in Figure 6b have been inverted to obtain the dispersion curve (Figure 7) that we assume as relative to the fundamental mode of the Rayleigh dispersive waves.

Unfortunately, in this case, the MSPAC method does not provide good results. Therefore, the dispersion curve obtained with the high-resolution FK method is adjusted just around 10-12 Hz.

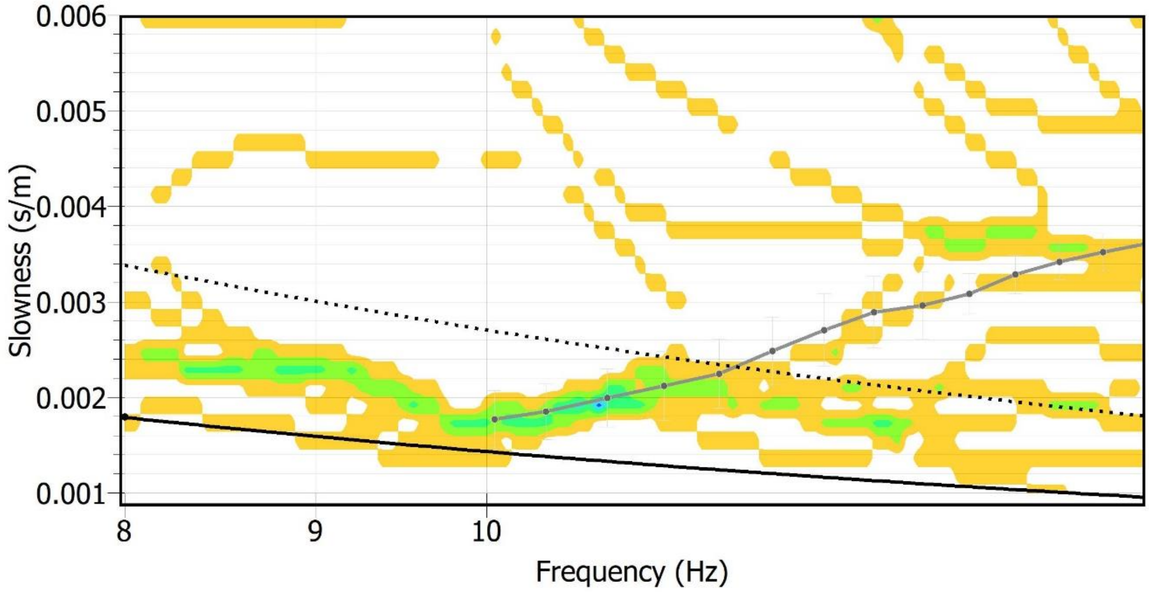


Figure 7: Picked dispersion curve in the slowness domain with the MSPAC analysis. The dispersion curve from the FK analysis is superimposed and prolonged in the range 10-12 Hz.

3. V_S Model

At IV.SEF1 site, just the FK analysis provides good results, allowing to define the Rayleigh wave dispersion curve (fundamental mode) from 12 Hz to 25 Hz. The MSPAC method allows to adjust and to extend the dispersion curve just in a narrow frequency range between 10 and 12 Hz. The final dispersion curve, adopted for the inversion process, is shown in Figure 8.

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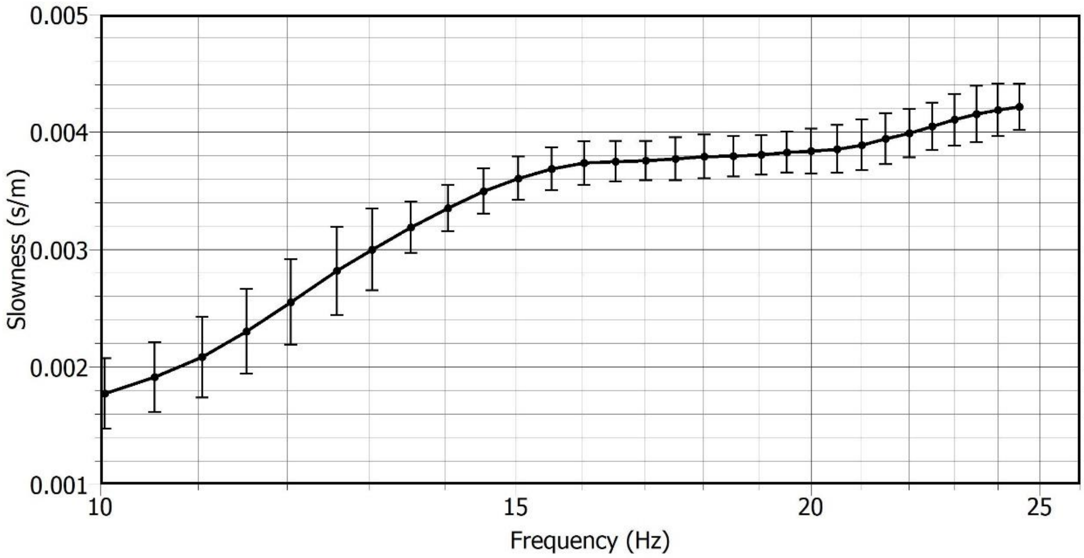

Figure 8: dispersion curve adopted for the inversion process.

To proceed with the inversion, we estimate the ellipticity curve from the H/V curve, considering in particular the right flank of the H/V peak, where the influence of the Rayleigh waves is higher. Moreover, to reduce the contribution of the other waves in the H/V flanks, a common practice consists in reducing the H/V amplitude for the square root of 2 (Figure 9).

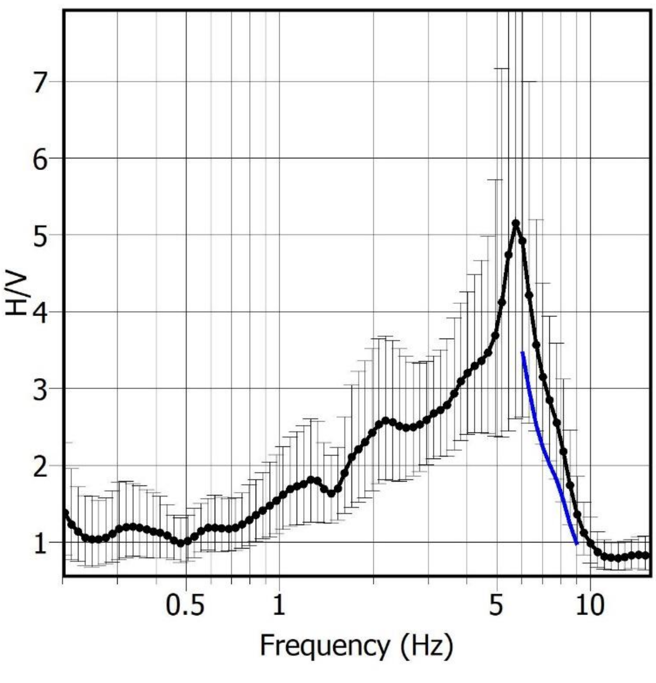

Figure 9: estimation of the ellipticity curve (blue) from the average H/V curve (black).

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Finally, we jointly invert the following targets:

1) Rayleigh wave dispersion curve (fundamental mode) in Figure 8

2) Ellipticity curve in Figure 9 (blue curve)

Figure 10 shows the comparison between the experimental targets and the ones expected for the best models coming from the inversion process.

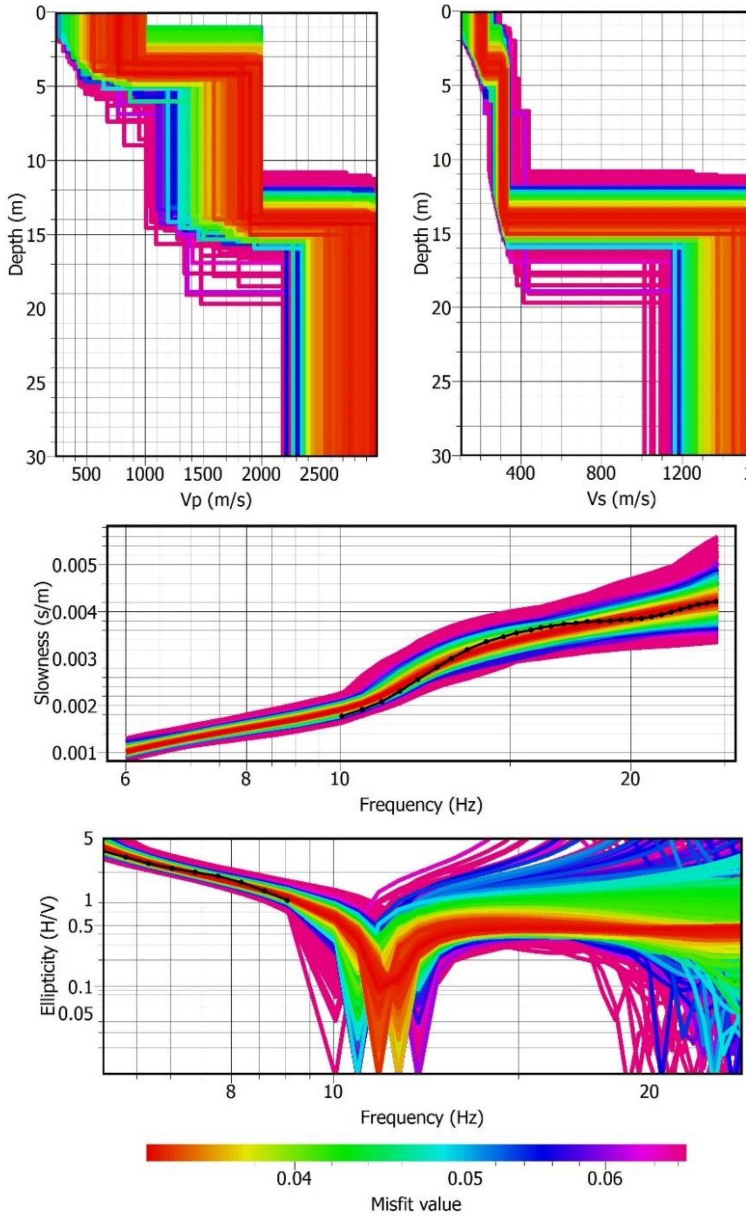

Figure 10: Inversion of the dispersion curve obtained with the 2D passive array, constrained with the H/V results.

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The best fit models of V_p and V_s are represented in Figure 11 and Tab 2.

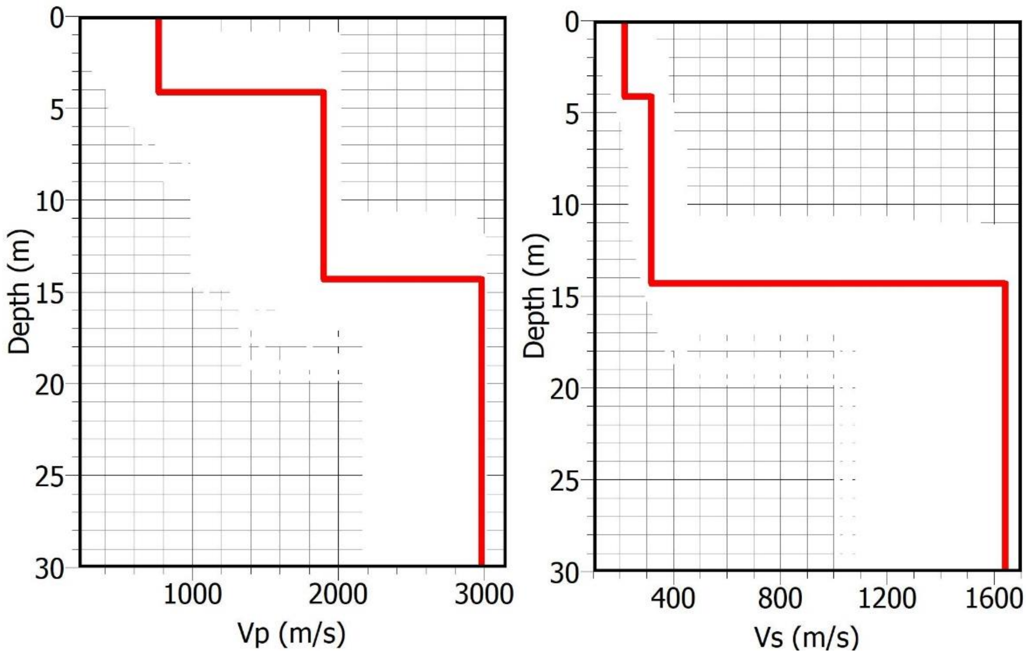

Figure 11: Best-fit models of Vp (left panel) and Vs (right panel) values

From	*To*	*Thickness (m)*	*V_s (m/s)*	*V_p (m/s)*
0	4	4	204	753
4	14	10	308	1879
14	?	?	1630	2955

Tab. 2: Best-fit model

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4. Conclusions

The H/V analysis for site IV.SEF1 shows a clear peak at 6 Hz that may be related to a high impedance contrast at about 14 m depth.

We can propose an interpretation of the velocity profile based on the nearest available downhole log, at a distance of 200 m from the study site (Agreement DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B, Geological report IV.SEF1). The very first 3-4 meters could be linked to the presence of superficial debris deposits. The second layer, about 14 m thick, could be related to fluvio-lacustrine deposits laying above the geologic bedrock, here represented by limestone and marly limestone. The high amplitude H/V peak at 6 Hz seems related to the high impedance contrast about 14 m depth, in correspondence to the soil-bedrock interface.

The Vs values are in good agreement with those expected from literature (i.e., nearest downhole survey in Agreement DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B, Geological report IV.SEF1). The $V_{S,eq}$ retrieved from the inversion of the dispersion curves is 269 m/s (Tab 3). The low Vs values of the soil above bedrock (lower than 20 m depth) allow the IV.SEF1 site to be classified in soil class E according to the NTC 2018 and EC8 seismic classifications.

$V_{s,eq}$ (m/s)	$V_{s,30}$ (m/s)	*Soil class (NTC 2018)*	*Soil class (EC8)*
269	485	E	E

Tab 3: Soil Class

It is worth noting that the array measurements were not performed in correspondence with the IV.SEF1 seismic station, but in the nearest available site (50 m away).

Due to the study site location in a small intermountain valley, the bedrock depth can change in the surroundings resulting in different $V_{s,eq}$ values.

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5. References

EC8: European Committee for Standardization (2004). Eurocode 8: design of structures for earthquake resistance. P1: General rules, seismic actions and rules for buildings. Draft 6, Doc CEN/TC250/SC8/N335.

NTC 2018: Ministero delle Infrastrutture e dei Trasporti (2018). Aggiornamento delle Norme Tecniche per le Costruzioni. Part 3.2.2: Categorie di sottosuolo e condizioni topografiche, Gazzetta Ufficiale n. 42 del 20 febbraio 2018 (in Italian).

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