Velocity profile report at the seismic station IV.MODE - MODENA

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Subject: **Final report illustrating measurements, analysis and results for station IV.MODE**	

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.MODE, 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.MODE site. The white triangles 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.MODE.

Staz	Lat (°)	Lon (°)	El (m)
MOD1	44.63028	10.949023	28
MOD2	44.63053	10.948979	25
MOD3	44.63045	10.948767	24
MOD4	44.63012	10.949302	23
MOD5	44.63048	10.94923	25
MOD6	44.63007	10.948811	20
MOD7	44.63028	10.948665	27
MOD8	44.6303	10.949383	20
MOD9	44.63002	10.949072	29

Tab 1: array stations coordinates (WGS84)

2.1 Array measurements results

A 2D array was performed using nine 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 28 m, as shown in Figure 1 and 2.

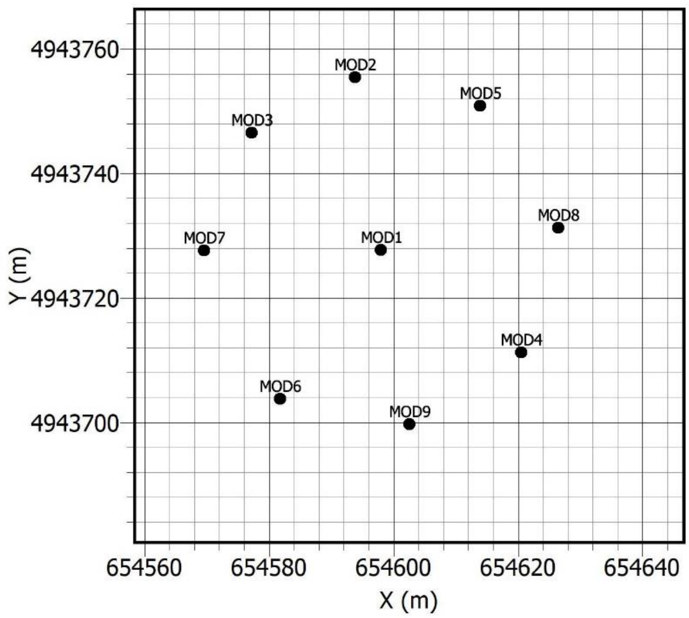


Figure 2. Top: example for the installation of an array station. Bottom: 2D Array geometry with UTM coordinates.

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

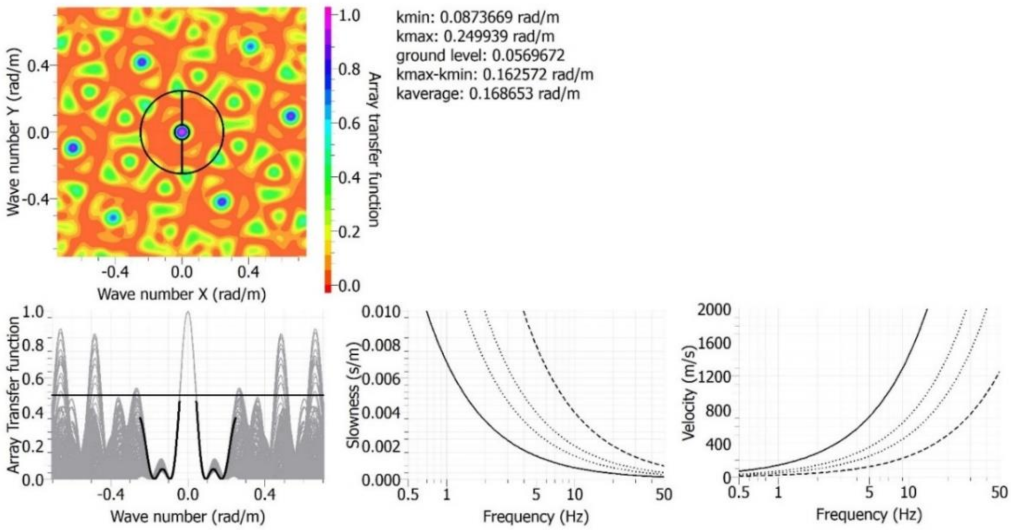
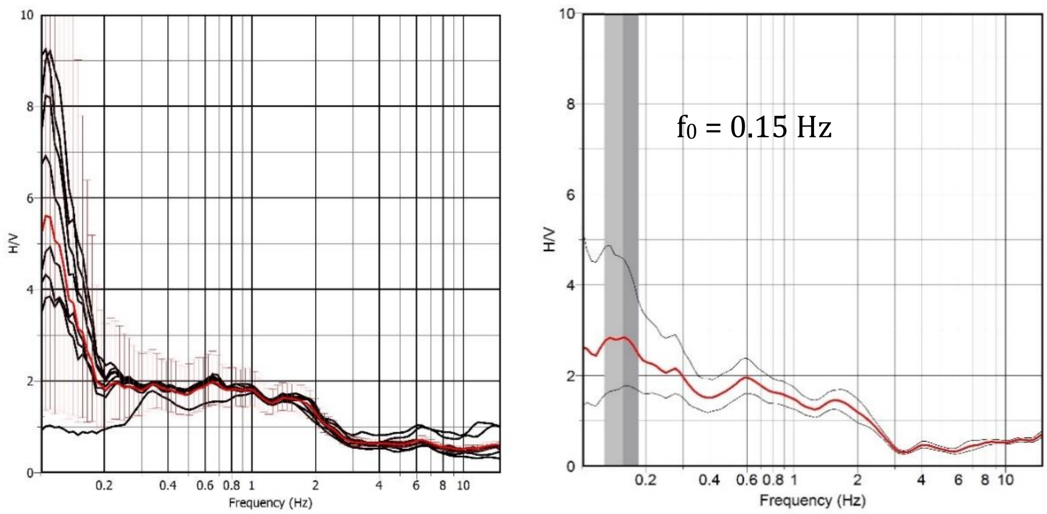


Figure 3: Theoretical Array Transfer function for the 2D array at IV.MODE

In Figure 4a, the H/V curves of the nine seismic stations are superimposed on each other. The average H/V curve is reported in red. All the H/V curves present a good agreement, except for station MOD9 that shows an amplitude decay at low frequency. These analyses are in good agreement with those obtained at the IV.MODE station, except for a low frequency instability (< 0.2 Hz). The f_0 value at the station is 0.15 Hz (Figure 4b).



a) b)

Figure 4: a) H/V curves of the nine stations of the array. The red curve is the average H/V curve and the red bars represent the corresponding standard deviation. b) H/V analysis at the station IV.MODE. The red curve is the average and the black curves represent the standard deviation.

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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 used the code GEOPSY (http://www.geopsy.org). The dispersion curve is shown in Figure 5.

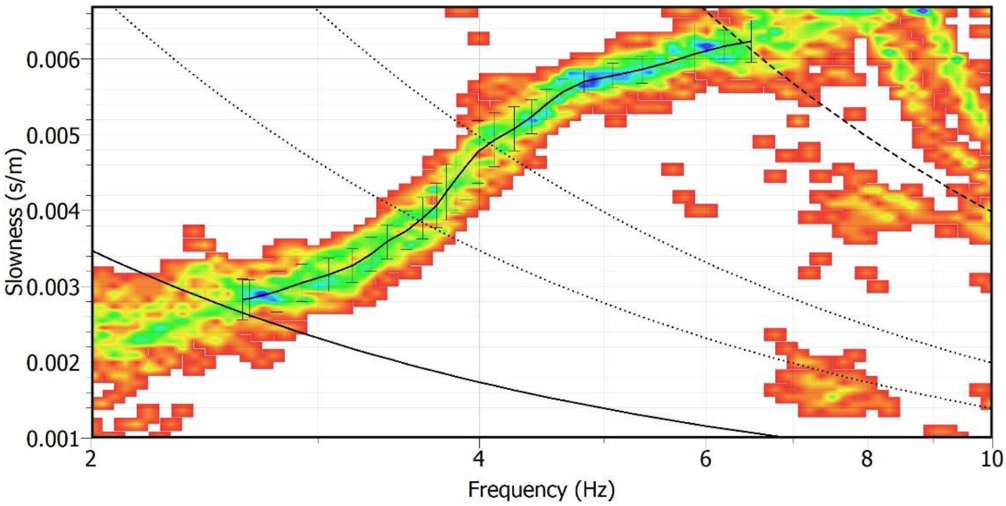
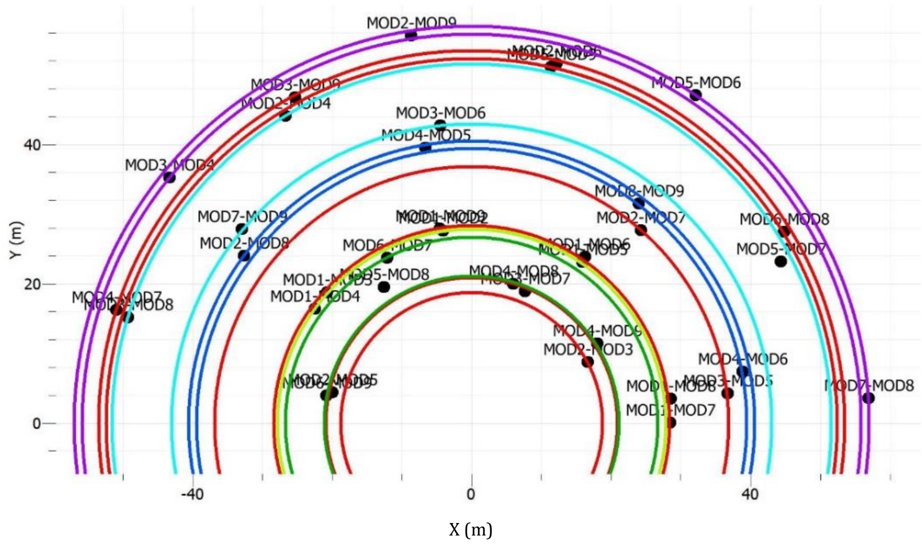


Figure 5: Picked dispersion curve in the slowness domain with the high-resolution FK analysis.

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

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



a)

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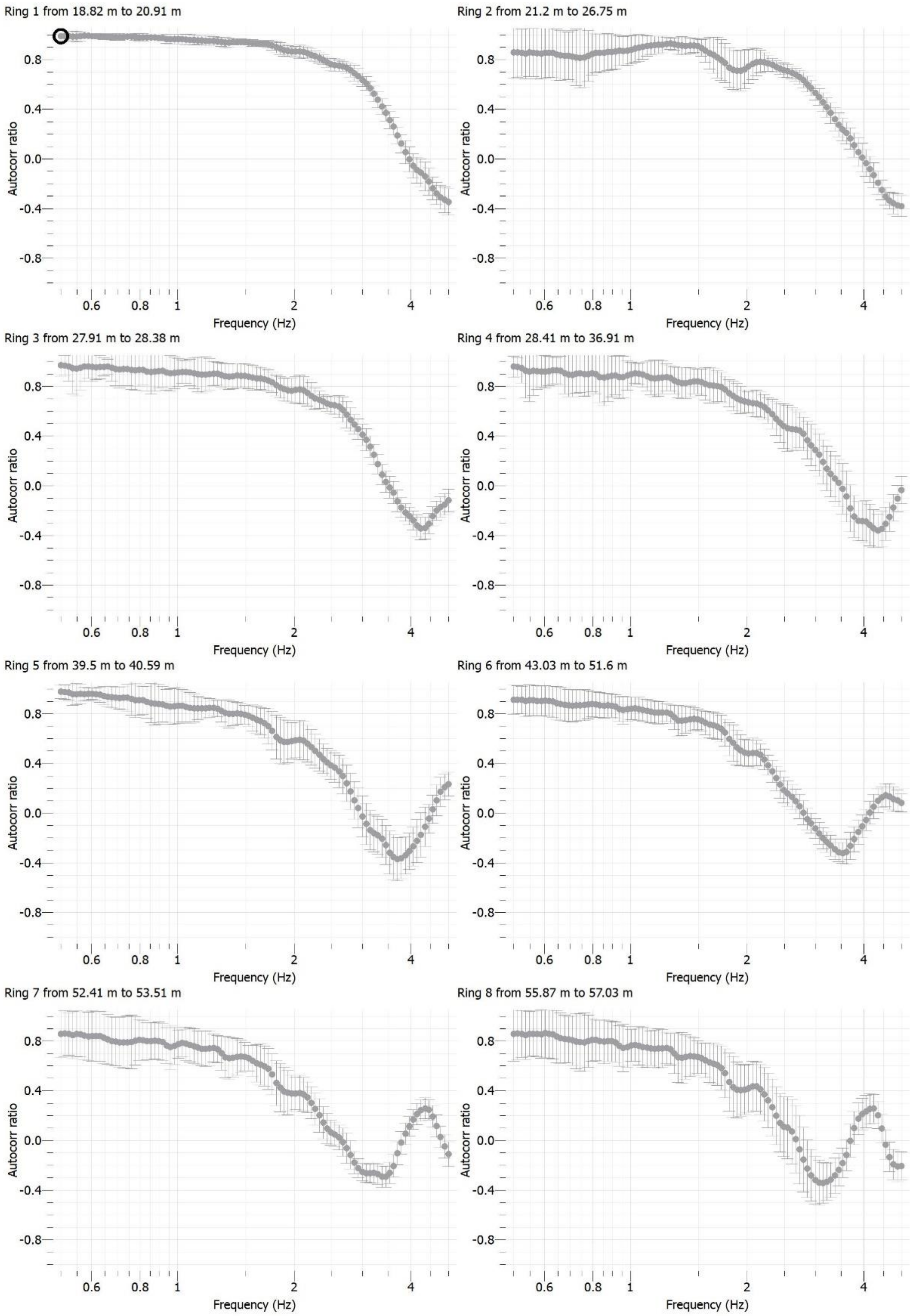

b)

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

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

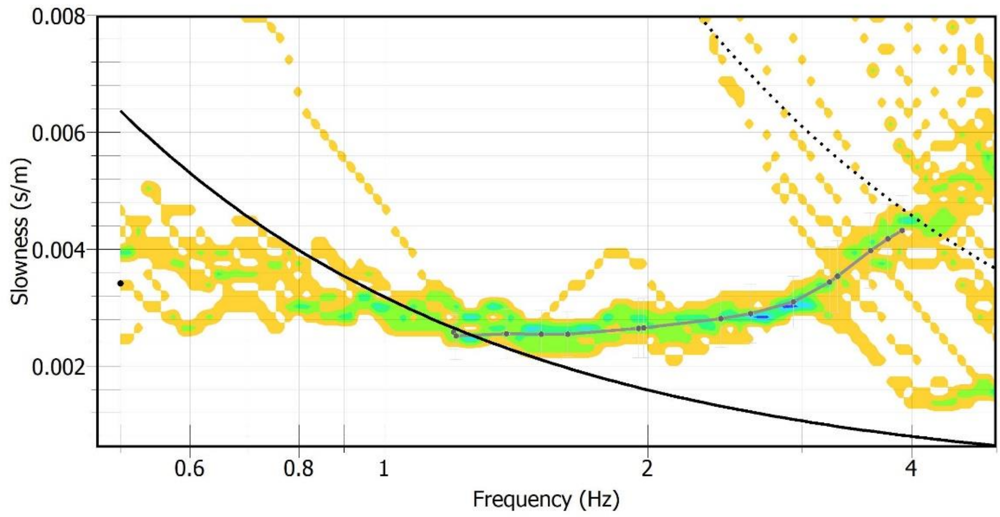

Figure 7: Picked dispersion curve in the slowness domain with the MSPAC method.

3. V_S Model

Comparing the dispersion curves obtained with the FK and MSPAC methods, we observe a good consistency. In particular, the FK dispersion curve extends to higher frequency (2.5-6.5 Hz), whereas the MSPAC dispersion curve extends to lower frequency (1.2-3.6 Hz).
The FK and MSPAC dispersion curves are superimposed in Figure 8a, and the final dispersion curve, adopted for the inversion process, is shown in Figure 8b.

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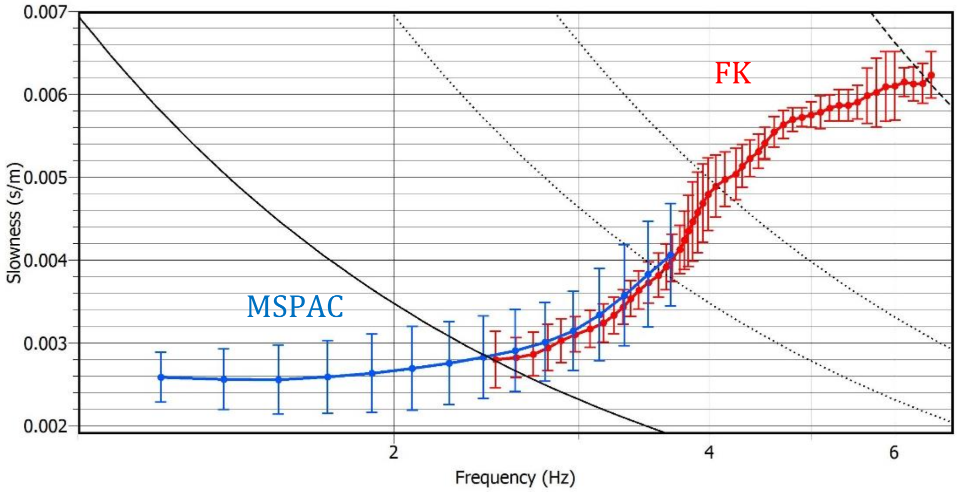
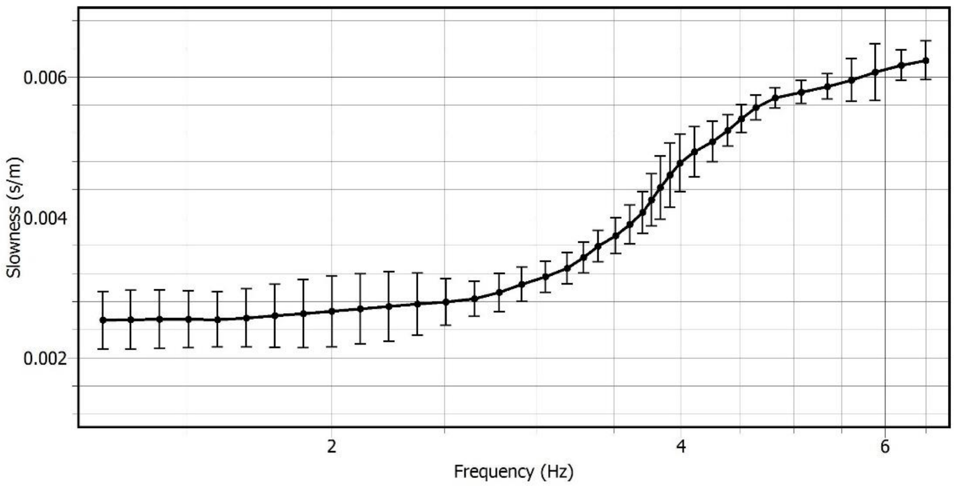


a)



b)

Figure 8: a) Superimposed FK and MSPAC dispersion curves, with the FK validity limits. b) Dispersion curve adopted for the inversion process.

The Vs profile is obtained inverting the Rayleigh wave dispersion curve (fundamental mode) in Figure 8b, from 1.2 to 6.5 Hz (fundamental mode).

Figure 9 shows the comparison between the experimental targets and the ones expected for the best models coming from the inversion process.

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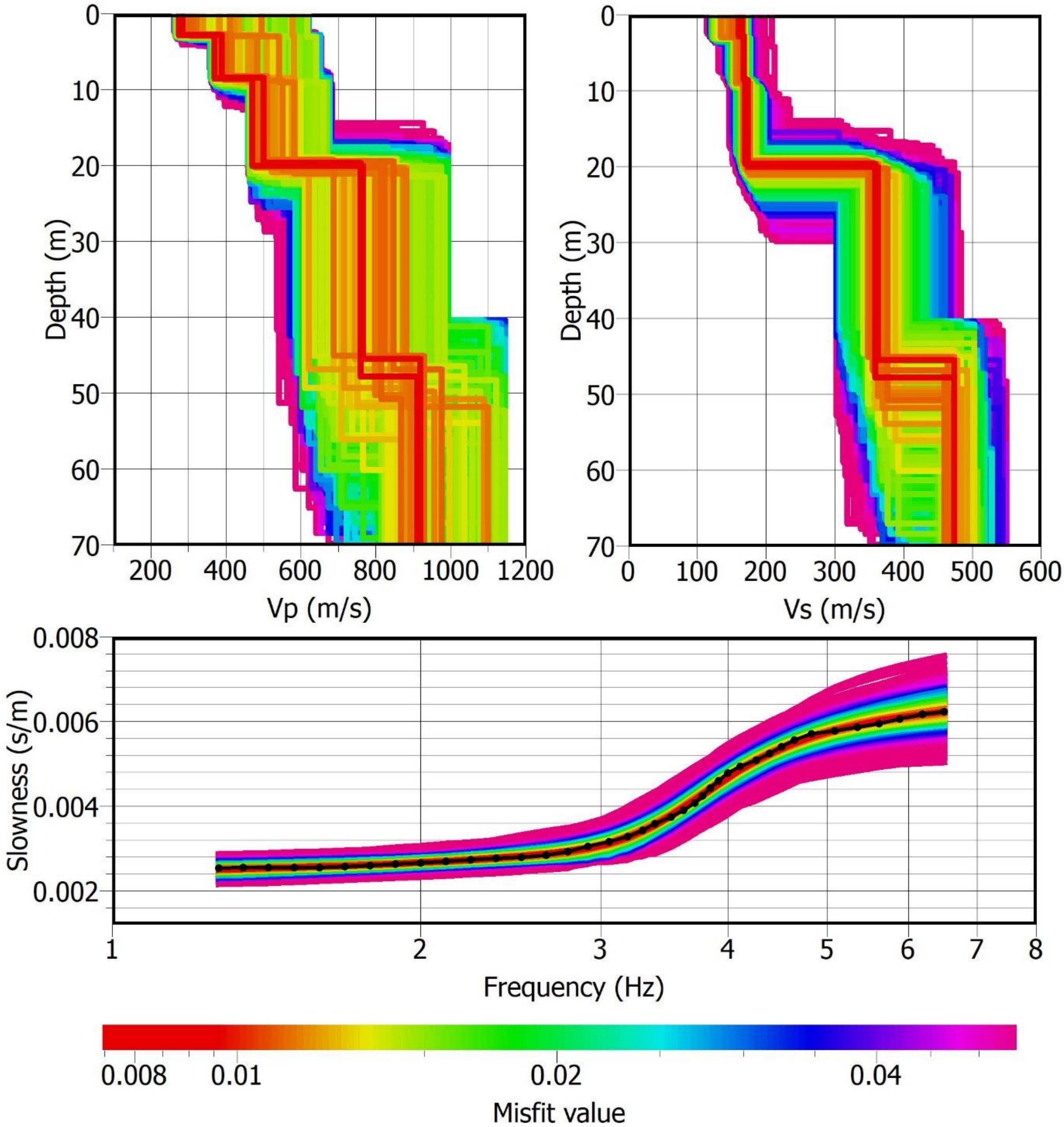

Figure 9: Inversion of the dispersion curve obtained with 2D passive array.

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The best fit models of V_p and V_s are represented in Figure 10 and Tab. 2.

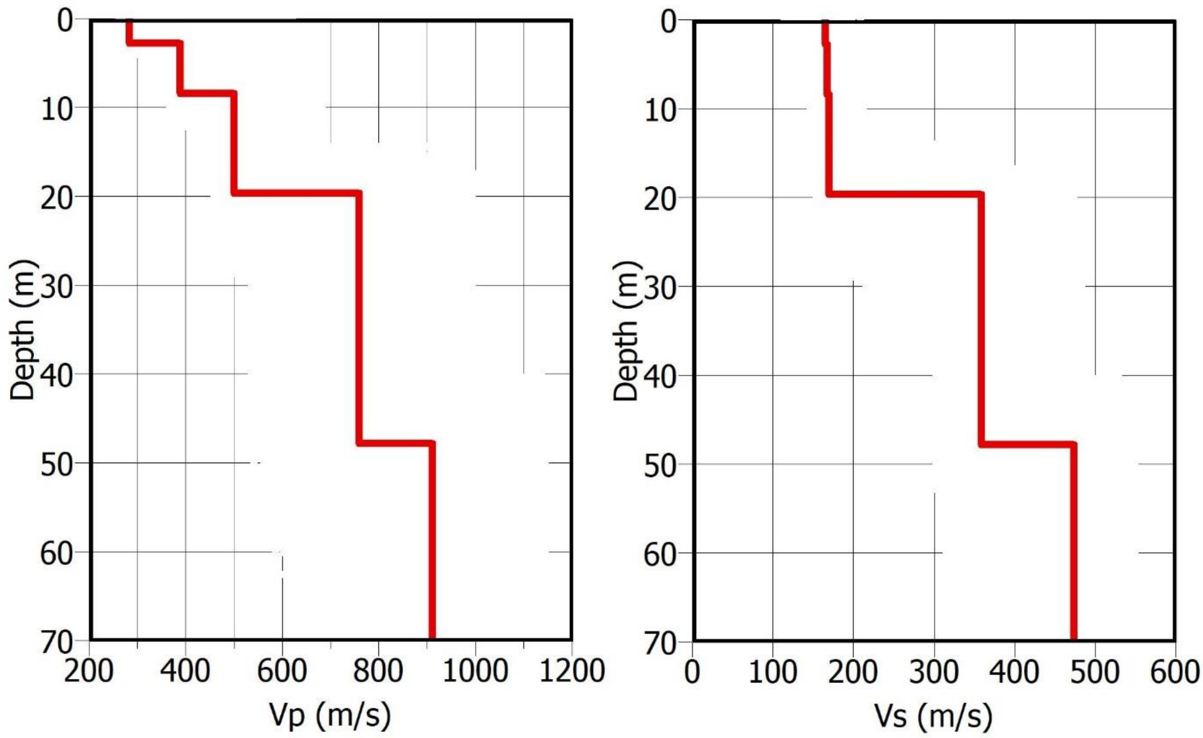

Figure 10: Best-fit models of Vp (left panel) and Vs (right panel) values

From	*To*	*Thickness (m)*	*V_s (m/s)*	*V_p (m/s)*
0	3	3	164	283
3	8	5	165	390
8	20	12	170	497
20	47	27	359	757
47	?	?	473	909

Tab. 2: Best-fit model

4. Conclusions

The H/V analysis for IV.MODE site shows a low frequency peak at 0.15 Hz, not observable from the array recordings.

We can propose an interpretation of the velocity profile based on the geological information in correspondence with the study site (Agreement DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B, Geological report IV.MODE). The increasing velocity at 20 m depth may be linked to the first stratigraphic discontinuity recognized on the geological section at the site (Figure 11). This stratigraphic discontinuity is found at the same depth, in correspondence with the top of the first gravel deposit (base of the AES8 unit). The second minor velocity increase at 47 m depth correlates with a second gravel deposits observed at the same depth on the geological section (Figure 11).

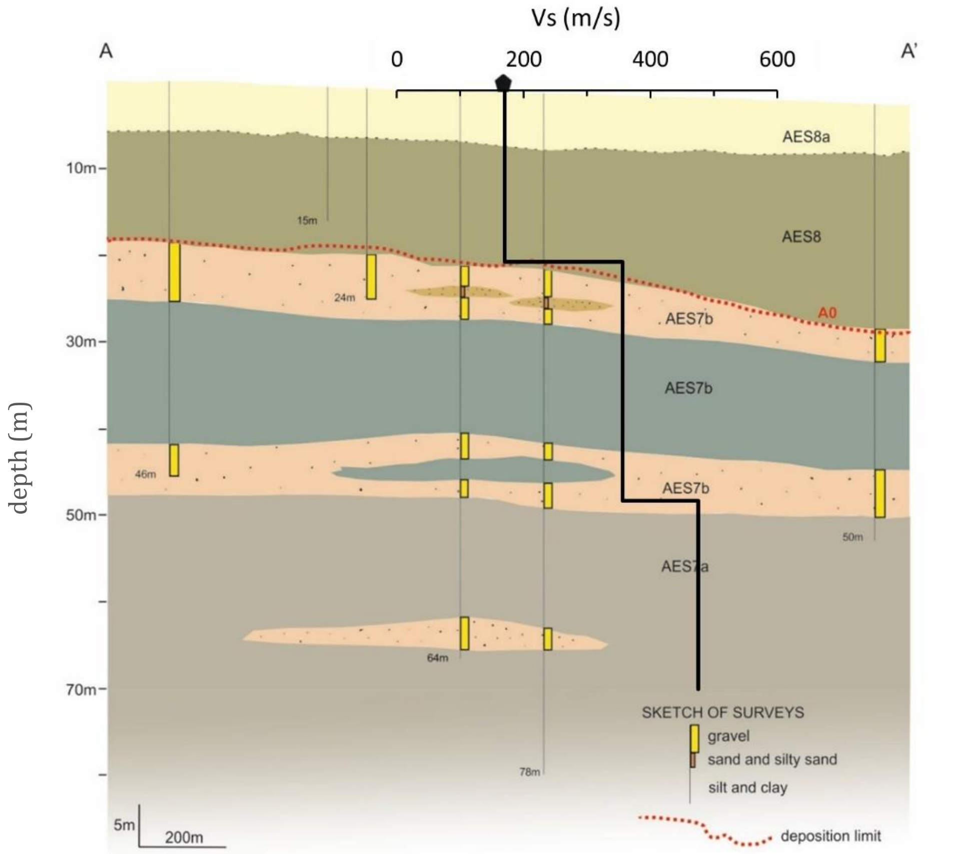

Figure 11: Correlation between the geological and geophysical information at the site IV.MODE (geological section from Agreement DPC-INGV 2018, Allegato B2: Obiettivo 1 - TASK B, Geological report IV.MODE)

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According to the current Italian seismic code (NTC 2018), since the bedrock (V_S > 800 m/s) is > 30 m depth, the $V_{S,eq}$ is defined by the $V_{S,30}$. The $V_{S,30}$ retrieved from the inversion of the dispersion curves is 204 m/s (Tab. 3); therefore IV.MODE is classified in the soil class C of NTC 2018 and EC8 seismic classifications.

***$V_{s,eq}$ = $V_{s,30}$* (m/s)**	***Soil class* (NTC 2018)**	***Soil class* (EC8)**
204	C	C

Tab. 3: Soil Class

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).

Working group INGV "Agreement DPC-INGV 2018, Allegato B2, Obiettivo 1 - TASK B" (2018). Geological report at the seismic station IV.MODE-MODENA.

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