ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

# Geophysical report at the seismic station IT.PGN – Pignataro Interamna (FR)

# Report geofisico per il sito della stazione sismica IT.PGN – Pignataro Interamna (FR)

<table>
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<tr><td colspan="2">Subject: Final report illustrating the geophysical characterization for seismic station IT.PGN</td></tr>
</table>

**Convenzione DPC-INGV 2019-21, All.B2- WP1, Task 2:** "Caratterizzazione siti accelerometrici" (Coord.: G.Cultrera, F. Pacor)
**Cite as:** Working group INGV "Agreement DPC-INGV 2019-21, All.B2- WP1, Task 2", (2021). Site characterization report at the seismic station *IT.PGN – Pignataro* http://hdl.handle.net/2122/15063

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# INTRODUCTION

In this report we present the geophysical measurements and results obtained in the framework of the 2019-2021 agreement between INGV and DPC, called *Allegato B2: Obiettivo 1 - TASK 2: Caratterizzazione siti accelerometrici (Responsabili: G. Cultrera, F. Pacor)* for the site characterization of station IT.PGN (Pignataro).

Location and coordinates are reported in Table 1.

**Table 1.**

| CODE | NAME | LAT [°] | LON [°] | ELEVATION [m] |
|---|---|---|---|---|
| IT.PGN | Pignataro (FR) | 41.45243* | 13.79163* | 74* |
| ADDRESS | Via Ponte San Lorenzo, 03040 Pignataro Interamna (FR) | | | |

* Coordinates and elevation from ITACA (http://itaca.mi.ingv.it, Dec. 2021)

# A. Vs profile

## A1. GEOPHYSICAL INVESTIGATIONS

The collected geophysical measurements consist in: i) a 2D array of 10 seismic stations in passive acquisition in a disused industrial area adjacent to station IT.PGN (distance from the central station of the array 80mt, from the closest station 8mt); ii) a 1D linear array of geophones in the same area of the 2D array in active acquisition (MASW). These measurements provide results in terms of dispersion curves that are inverted to obtain the shear-wave velocity ($V_s$) profile for the studied area. The obtained results are suitable for assigning the soil class according to the current Italian seismic code (NTC18) and the current Eurocode (EC08).

Figure 1 shows the location of the station IT-PGN (Latitude 41.45243, Longitude 13.79163 WGS84) housed in an electrical cabin of the Italian electrical board (Ente Nazionale per l'Energia Elettrica, ENEL). The cabin is a small-size masonry building and the seismic sensor is put on a little pillar isolated from the edifice. In Figure 1 are also represented the stations of the 2D array and the line of geophones used for the MASW.


**Figure 1**: Map of the area of the experiment at Pignataro (image from Google Earth http://www.earth.google.com) showing the position of IT-PGN station (yellow pin), the stations of the passive 2D array (red circles) and the line of 48 geophones (red line) used for the MASW.

The noise of the 2D array has been acquired with a medium-period seismometer (i.e. Lennartz Le3d-5s) and it lasted about two hours and half. The sampling rate was set to 250 sps.
All the analyses have been performed using the *Geopsy* software (http://www.geopsy.org).

Figure 2 shows the Fourier spectra of the three components (EW, NS and UP) for all stations of the array and the corresponding averages. The horizontal components are quite similar with a first peak at about 0.4 Hz also present in the vertical component. Some clear and narrowband peaks are also present in the 1 - 10 Hz frequency range, with a major one at about 1.5 Hz. Analysing the shape of this peak, which shows the same frequency value at both horizontal and vertical components, it is reasonable to associate it to anthropic activities produced in the industrial plant located a few tenths of meters East of the investigated area.
Figure 3 shows the correspondent H/V spectral ratio for all the array stations, along with its average value and standard deviation.

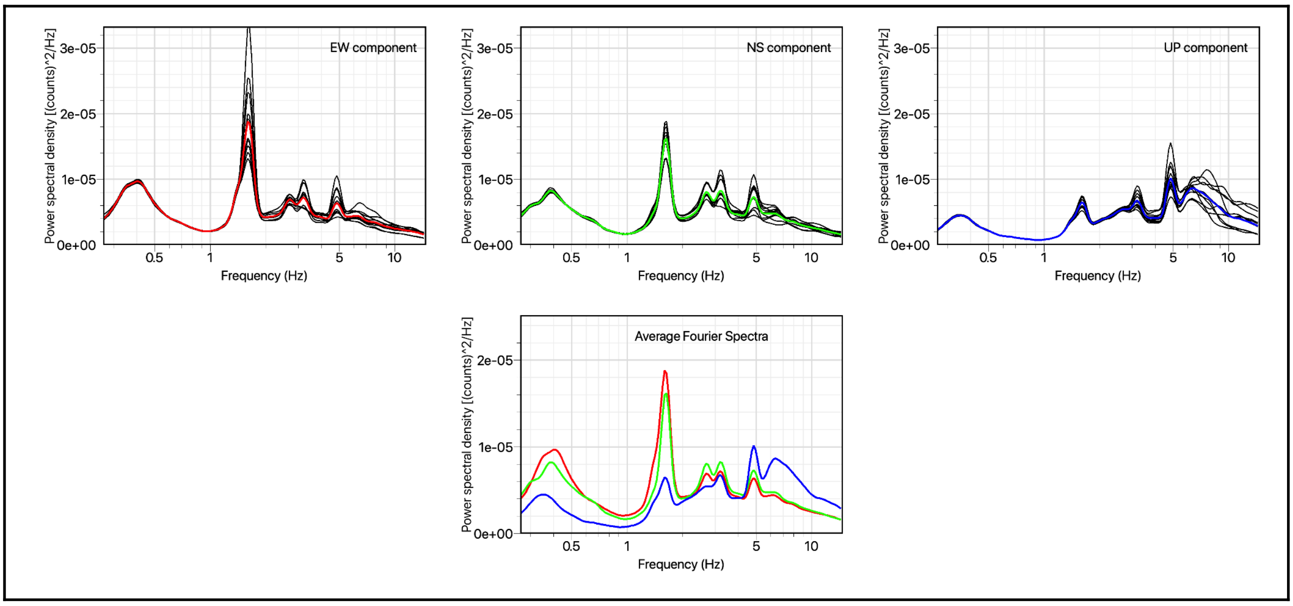


**Figure 2**: Top three panels: average Fourier spectra for the ten stations of the 2D array (in black) overimposed to the mean over all the stations. From left to right is represented: the EW (in red), the NS (in green) and the UP component (in blue). The bottom panel shows the average values for the three components.

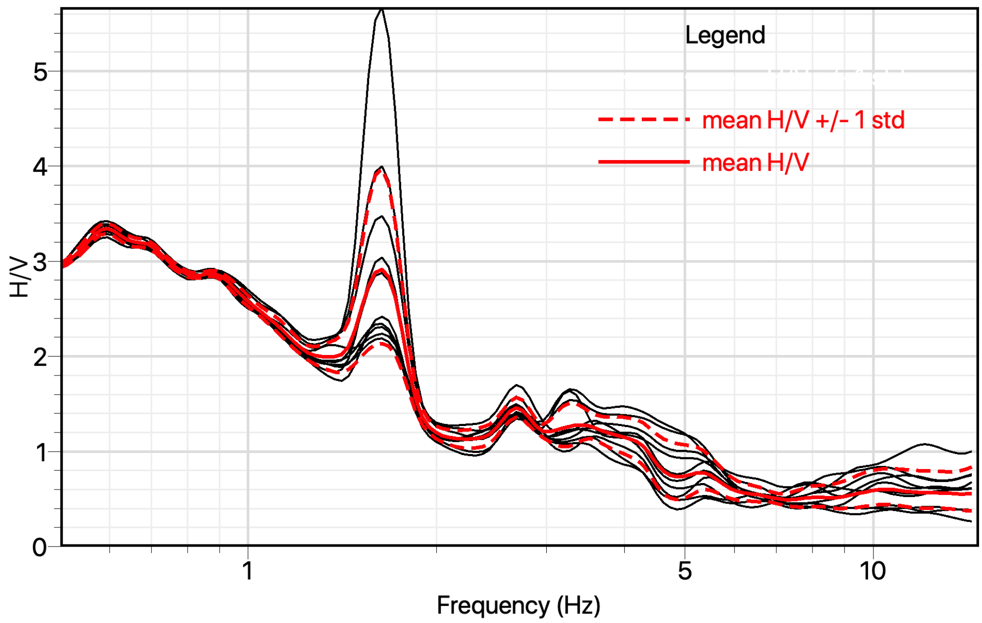


**Figure 3**: H/V calculated for each station of the 2D array (gray curves) and average H/V (in red, mean and mean plus and minus one standard deviation).

The main H/V peak is observed at the frequency $f_0$ = 0.6 Hz. The $f_0$ value, its amplitude and the general shape of the H/V curve are similar to what found at the IT.PGN station (http://itaca.mi.ingv.it/ItacaNet_31//monography_data/IT/IT.PGN/IT.PGN.documents/IT.PGN.station_report.pdf).

The H/V curves (gray curves in Figure 3) are consistent among the ten stations of the array. This observation allows us to consider the 2D array approach used to derive surface waves dispersion curves applicable at the investigated site.

The rotated H/V spectral ratios (Figure 4) do not show any significant polarization effect and are almost similar for each station for the 0.6 Hz frequency peak. Some directional effect can be found for the 1.5 Hz peak confirming the hypothesis of an anthropic origin peak.

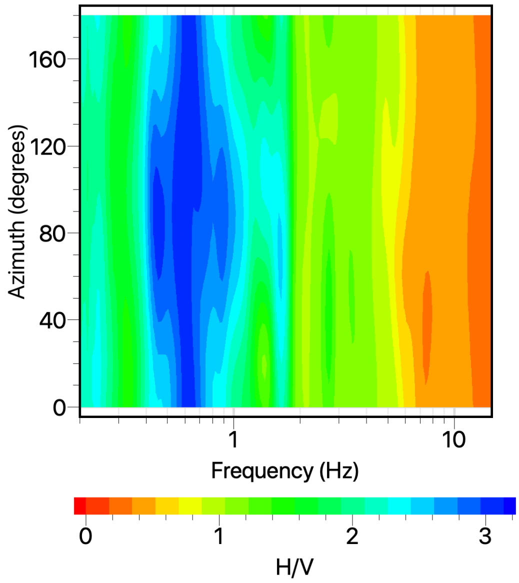


**Figure 4**: Rotated H/V calculated for the central station of the 2D array.

Figure 5 shows the theoretical response of the array, both in terms of Array Transfer Function (AFT) and wavenumber limits kmin and kmax.

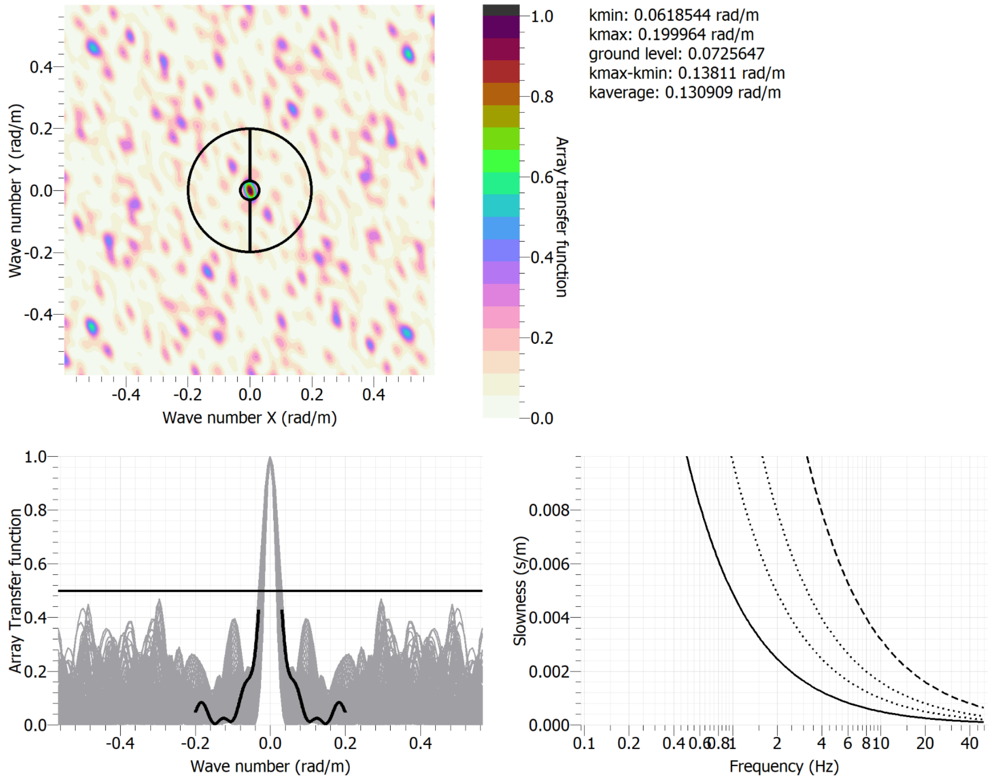


**Figure 5**: Theoretical transfer response of the 2D array

The 1D linear array (Figure 1) consisted of 48 vertical geophones (4.5Hz as natural frequency) placed at 2mt of distance from each other, for a total length of 94mt, with the first geophone located at the SW end of the line. For the active acquisition we used five shot positions: -10, -5 and -2mt from geophone #1, 47mt (middle of the line), +2, +5 and +10mt from geophone #48. We recorded signals with a sampling rate of 8000sps for a duration of 1 second.
The results show low efficiency of signal propagation from the shots to the farthest geophones of the array. This fact is likely due to the high level of anthropic disturbances that exceeds the level of the signals. Dispersion curves are quite flat (not dispersion) in the 10 - 30 Hz frequency range but there is some asymmetry in the dispersion curves obtained for the forward and reverse direction, respectively (Figure 6). In particular, the forward direction shows lower velocity than the reverse one (about 180m/s vs 215m/s). This observation suggests the presence of a lateral variation of the geometry or elastic properties of the soils along the array.

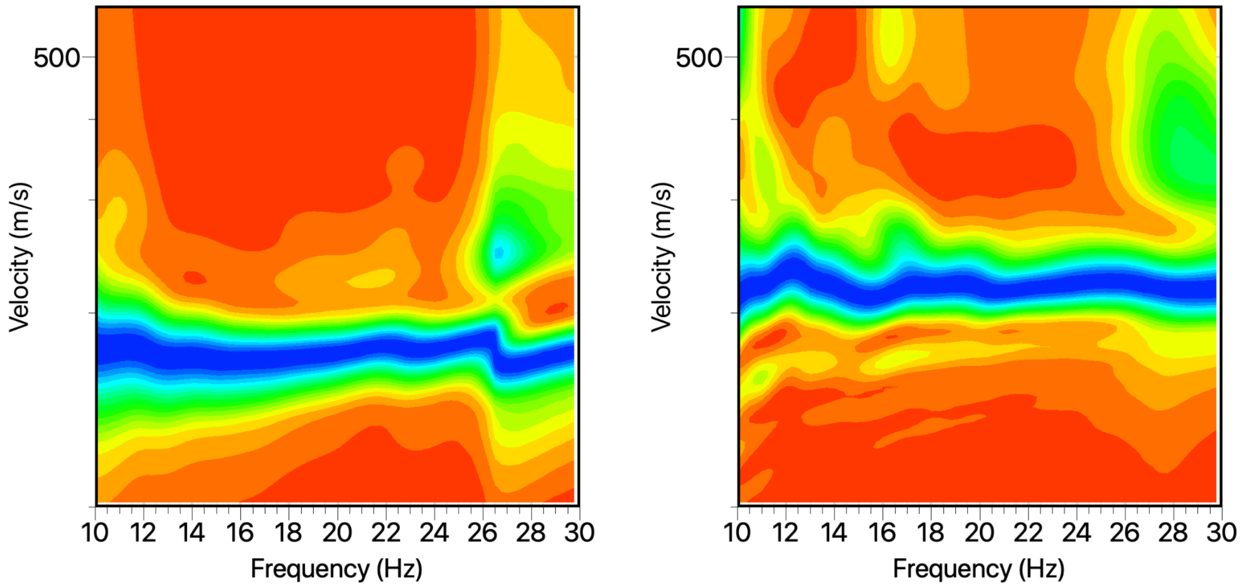


**Figure 6**: FK analysis for: left) shot in the forward direction; right) shot in the reverse direction

For the velocity profile inversion we selected the dispersion curve derived from the first half of deployment and from the forward direction of propagation. In fact, this part of the linear array is closer to the IT.PGN station and more distant from the source of anthropic disturbance. Moreover, as it will be shown later, the selected dispersion curve can be connected quite well to the one obtained with the 2D array at about 10Hz.

Figure 7 shows the High-Resolution FK and ESAC analyses on the data of the 2D array, for Rayleigh waves dispersion curves. The results are quite consistent for both methods allowing to define a dispersion curve in the 2 - 10 Hz frequency range with velocities ranging from about 600m/s at low frequency to about 185 m/s at 10 Hz. The 10Hz velocity value obtained using 2D array data connects quite well with the velocity value derived from MASW data at the same frequency, this allows to reconstruct a dispersion curve well defined in the 2 - 30 Hz frequency interval.

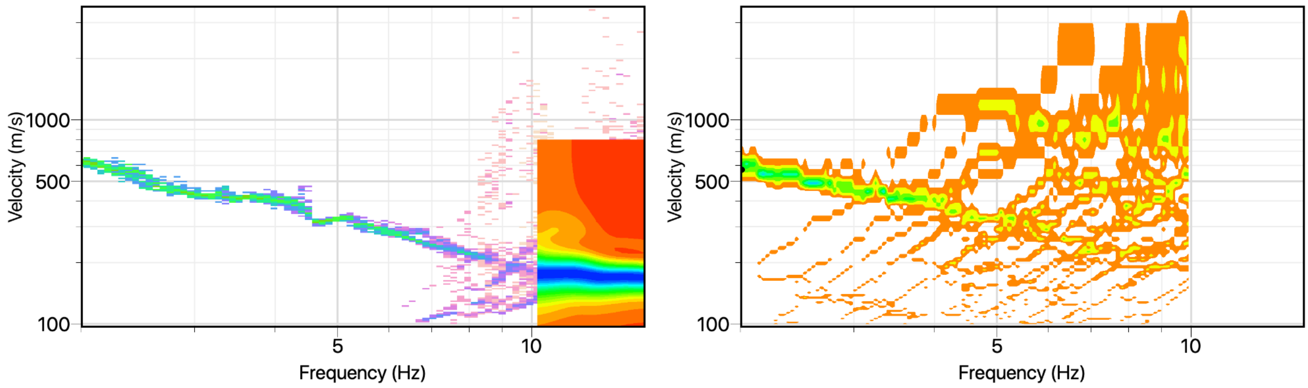


**Figure 7**: Dispersion curves from High Resolution Fk (left panel) and ESAC (right panel) derived using the 2D array data. In the left panel the MASW dispersion curve is superimposed in the 10 - 30 Hz range.

In order to proceed with the inversion process and get a velocity profile, we then picked: a) the Rayleigh dispersion curve in Figure 6 and Figure 7; b) the low frequency peak in the H/V spectral ratio in Figure 3 interpreted as Rayleigh waves ellipticity curve.

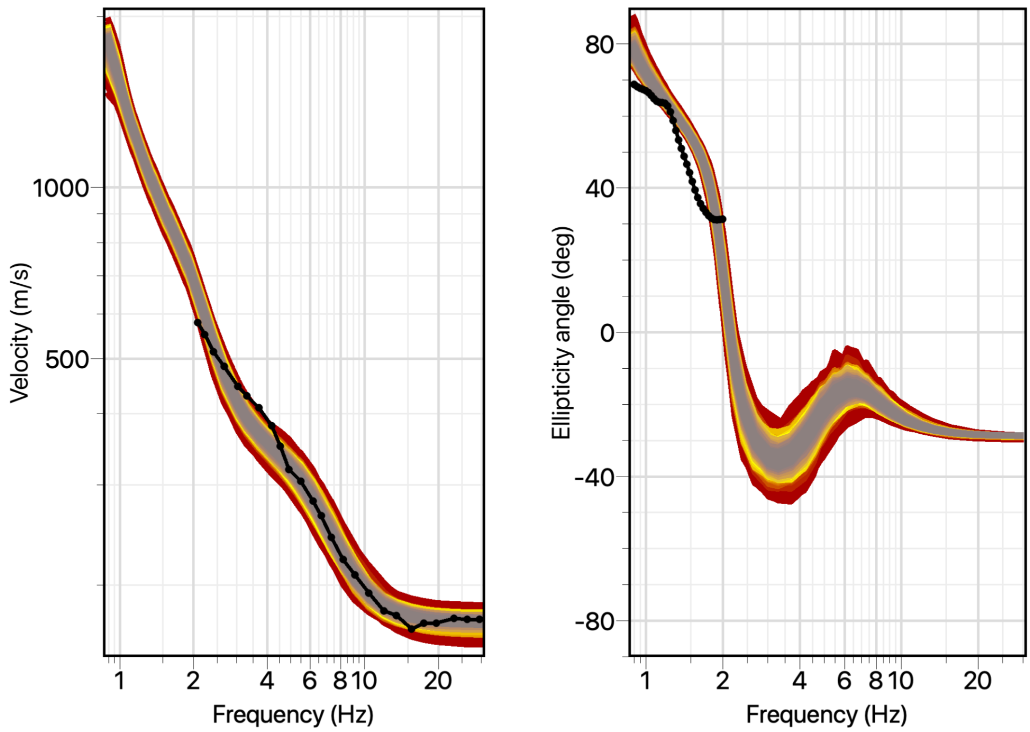


**Figure 8**: Fit between experimental (black line) and inverted data (colored bands) for Rayleigh waves dispersion curves (left panel) and H/V ellipticity curve (right panel).

The combined use of dispersion and ellipticity curves consents to enlarge the investigated frequency range toward lower frequency values and to increase the depth of investigation.
The results of the inversion, compared with experimental data, are presented in Figure 8 in terms of comparison between observed and inverted dispersion and H/V spectral ratio curves.

# A2. SEISMIC VELOCITY MODEL

The geology of the area where the IT-PGN station is installed is summarized by a layered sequence of outcropping silty sands overimposed on sandy clayey silt and alternation of silts, sands and clays. At a depth hypothesized at about 45 meters a seismic stratified substrate is present [1]. A more rigid bedrock can be assumed at higher depth even if no data are available about its depth.

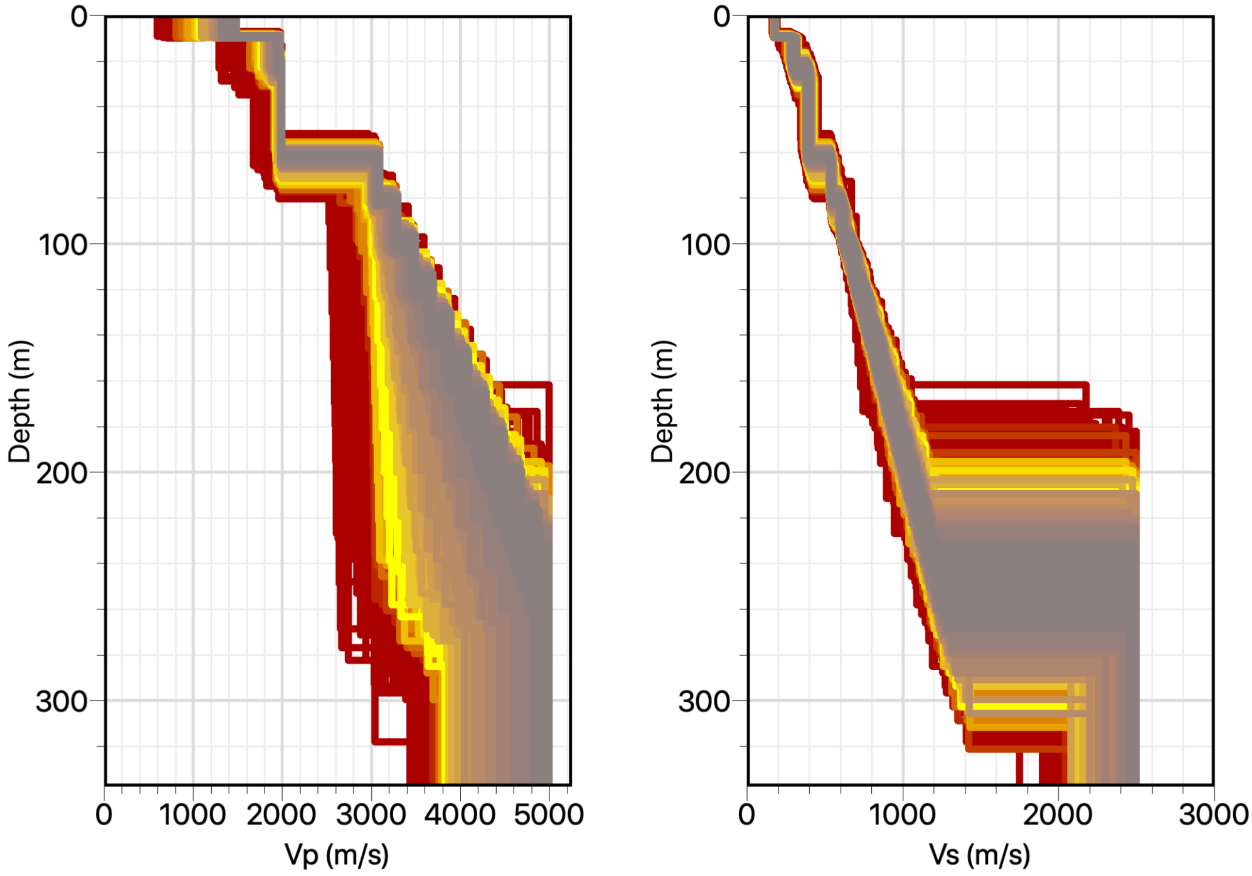


**Figure 9**: Vp and Vs profile obtained through the inversion of the dispersion curve the ellipticity curve of Figure.

This layering model was used to set up the initial parameterization in the inversion process giving to both layers thickness and velocities a wide possibility of variation. The best inverted models are shown in Figures 9 and Figure 10 for both Vp an Vs models. The results for Vs show a sequence of three shallow layers with velocity ranging from about 180 and 380 m/s down to a depth of about 63 meters. This sequence could correspond to the soft soils described in the geological report for the site. Below 63 meters the Vs starts to increase with values higher than 540 m/s and an increasing gradient with Vs values of about 1200 m/s in correspondence to an impedance contrast, located at depth between 220 and 280 meters with a quite poor resolution. This deep impedance contrast is anyway necessary to model the low frequency peak observed in the H/V spectral ratio. The use of a gradient model for the lower layers allows to increase the quality of results as often observed in the inversion processes.

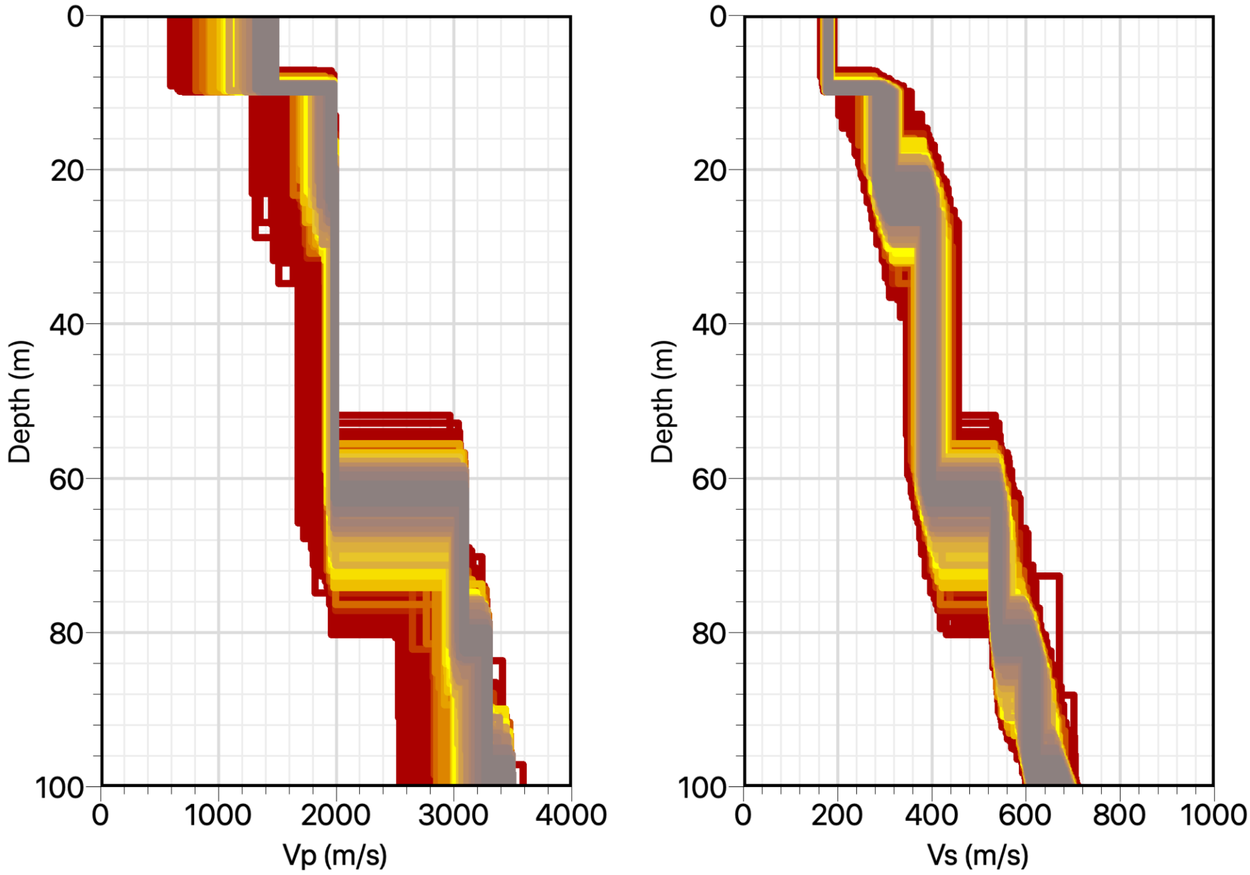


**Figure 10**: Vp and Vs profile obtained through the inversion of the dispersion curve the ellipticity curve of Figure 8 shown for the first 100 meters of the inverted profile.

The best-fit model of $V_s$ is represented in Figure 11 and Table 1. For the fourth layer, characterized by a velocity gradient, the average velocity value is reported.

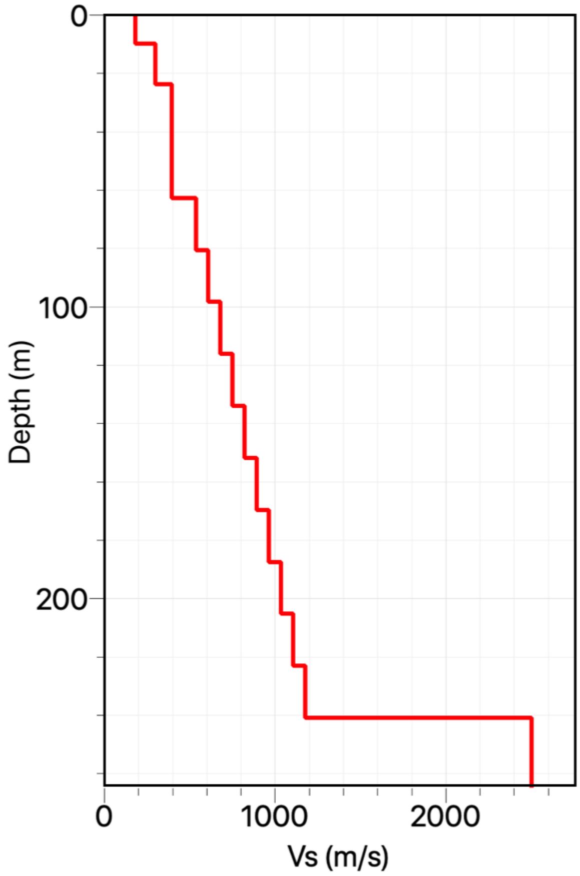


**Figure 11**: Best-fit model of Vs values

| *From* | *To* | *Thickness (m)* | *$V_s$ (m/s)* |
|---|---|---|---|
| 0 | 9.7 | 9.7 | 180 |
| 9.7 | 23.7 | 14.0 | 299 |
| 23.7 | 62.7 | 39.0 | 394 |
| 62.7 | 240.7 | 178 | 856(Mean) |
| 240.7 | - | - | 2500 |

**Table 2**: Best-fit model

# A3. CONCLUSIONS

According to the current Italian seismic code [2], if the bedrock (Vs > 800 m/s) is more than 30m deep, the equivalent velocity ($V_{s,eq}$) is equal to the $V_{S,30}$. From Figure 11, the velocity of 800m/s is reached at depth, higher than 30mt. Therefore there is an equivalence between $V_{s,eq}$ and $V_{S,30}$ at IT.PGN site, where the $V_{S,30}$ retrieved from the inversion of the dispersion curves is of 257 m/s, and the site is classified in the soil category C for both the NTC18 and EC8 [3] seismic classifications (Table 2).

| $V_{s,eq} = V_{s30}$ [m/s] | Soil class (NTC 2018) | Soil class (EC8) |
|---|---|---|
| 257 | C | C |

**Table 2** : Soil Class

# REFERENCES

[1] Zarrilli L., Moschillo R. (2020). Geological report at the seismic station IV.PGN – Pignataro Interamna (FR). http://hdl.handle.net/2122/14056

[2] 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).

[3] 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.

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[1]This document is level 3 as defined in the "Principi della politica dei dati dell'INGV (D.P. n. 200 del 26.04.2016)"

# GENERAL INFORMATION

| Authors | Institutions | Contacts [email] | Compiling date [DD/MM/YY] |
| --- | --- | --- | --- |
| Giuliano Milana | INGV | guliano.milana@ingv.it | 15/12/21 |

## Station description

| Station name | Network code | Latitude [WGS84] | Longitude [WGS84] | Sensor depth [m] |
| --- | --- | --- | --- | --- |
| Pignataro | IT | 41.45243 | 13.79163 | 0 |

## Site characterization summary

| Indicators | | | | |
| --- | --- | --- | --- | --- |
| fo +/ std [Hz] | Value | 0.6+/- 0.05 | Quality index Qi1 | 1 |
| | References | | | |
| | URL of report | http://hdl.handle.net/2122/15063 | | |
| Velocity profiles [YES/NO] | Value | YES | Quality index Qi1 | 0.66 |
| | References | | | |
| | URL of report | http://hdl.handle.net/2122/15063 | | |
| Vs30 +/ std [m/] | Value | 257+/-50 | Quality index Qi1 | 0.66 |
| | References | | | |
| | URL of report | http://hdl.handle.net/2122/15063 | | |
| Surface geology [short description] | Value | Alluvial Flat | Quality index Qi1 | 1 |
| | References | | | |
| | URL of report | http://hdl.handle.net/2122/14056 | | |
| Seismological bedrock depth +/ std [m] | Value | 240+/-50 | Quality index Qi1 | 0.66 |
| | References | | | |
| | URL of report | http://hdl.handle.net/2122/15063 | | |
| Site class EC8 | Value | C | Quality index Qi1 | 1 |
| | References | | | |
| | URL of report | http://hdl.handle.net/2122/15063 | | |
| Engineering bedrock depth +/ std [m] | Value | 150+/-30 | Quality index Qi1 | 0.66 |
| | References | | | |
| | URL of report | http://hdl.handle.net/2122/15063 | | |

| Distance from the seismic station [m] | | Final quality index (Final_QI) | Comments |
| --- | --- | --- | --- |
| min | min | | |
| 9 | 130 | 0.9 | |

# RESONANCE FREQUENCY

| fo +/ STD [Hz] |
|---|
| Quality index 1 |

| Source | Earthquake | Ambient noise |
|---|---|---|

## Ambient noise

| Method | H/V | Ellipticity | Other |
|---|---|---|---|
| fo +/ std [Hz] | 0.6+/-0.05 | | |

| Experiment date [DD/MM/YY] | Distance from station [m] | Lat. [WGS84] | Lon. [WGS84] |
|---|---|---|---|
| 24/11/21 | 66 | 41.4526 | 13.79247 |

### Environment

| | | | |
|---|---|---|---|
| Weather conditions | Sunny | Windy | Rain |
| | X | | |
| Soil sensor coupling | Earth | Asphalt | Artificial |
| | | X | |
| Urbanization | None | Dense | Scattered |
| | | | X |

### Equipment

| | | | |
|---|---|---|---|
| Sensor | Type [acc/vel] | manufacturer | cut off frequency [Hz] |
| | vel | Lennartz | 0.2 |
| Digitizer | Type | Manufacturer | Sampling frequency [Hz] |
| | Marslite-Sara | Lennartz-Sara | 200 |
| Measurement | Number | Duration [min] | |
| | 10 | 180 | |

### Analysis

| Software | |
|---|---|
| Smoothing type (e.g. triangular, Konno Ohmachi, ...) | Window length [s] |
| Konno Ohmachi | 60 |

### Fo uncertainty estimate from

| Fo from individual windows | H/V curve width | Manual picking |
|---|---|---|

## Earthquake

| Method | HVSR | SSR | GIT | Other |
|---|---|---|---|---|
| fo +/ std [Hz] | | | | |

| Recording period [DD/MM/YY] | | Number of earthquakes |
|---|---|---|
| from | to | |
| | | |

| Epicentral distance [km] | | Magnitude range | |
|---|---|---|---|
| from | to | from | to |
| | | | |

### HVSR

| Seismic phase | P | S | Coda | S + coda | All |
|---|---|---|---|---|---|

| window duration [s] | Min | Max |
|---|---|---|

### SSR

| Seismic phase | P | S | Coda | S + coda | All |
|---|---|---|---|---|---|
| Reference station | Lat. (WGS84) | Lon. (WGS84) | | | |

| window duration [s] | Min | Max |
|---|---|---|

### GIT

| Parameters | Free (to be inverted) | Imposed |
|---|---|---|
| Reference paper | | |
| Reference station | Lat. (WGS84) | Lon (WGS84) |

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# Vs30

| Vs30 +/ STD [m/s] |
|---|
| Quality index 1 |

| Source | Geophysical measurements X | Geotechnical measurements | Digital Elevation Model (DEM) | Geology | DEM & Geology |
|---|---|---|---|---|---|

## Geophysical measurements

| Method | Surface waves methods (active, passive methods) | Borehole methods (DH, CH, PS Logging) |
|---|---|---|
| Vs30 +/ STD [m/s] | From Vs(z): 257+/-50 | From Down Hole |
| | From Vr40 | From Cross Hole |
| | From Vsz Vs30 correlation | From PS Logging |
| Reference relationship Vsz Vs30 | | |

## Geotechnical measurements

| Method | N SPT | CPT | Shear strength | OTHER |
|---|---|---|---|---|
| Vs30 +/ STD [m/s] | | | | |

| Experiment date [DD/MM/YY] | Distance from station [m] | Lat. [WGS84] | Lon. [WGS84] |
|---|---|---|---|
| | | | |

| Reference relationship Vs30 geotechnical parameter | |
|---|---|
| | N-SPT |
| | CPT |
| | Shear strength |
| | Other |

## Geology

| Method | Geological map | Stratigraphic log |
|---|---|---|
| Vs30 +/ STD [m/s] | | |
| Geological map scale | | |
| Geological unit name | | |

| Stratigraphic log | Experiment date [DD/MM/YY] | Lat. [WGS84] | Lon. [WGS84] |
|---|---|---|---|
| | | | |

| |
|---|
| Reference relationship Vs30 geology |
| Reference relationship Vs30 Stratigraphic log |

## Digital Elevation Model

| |
|---|
| Vs30 +/ STD [m/s] |
| DEM resolution |

| Slope range (degree) | |
|---|---|
| | from |
| | to |

| |
|---|
| Reference relationship Slope Vs30 |

## DEM & Geology

| |
|---|
| Vs30 +/ STD [m/s] |
| Reference relationship Slope Vs30 geology |

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# Vs profile

| Quality index 1 |
|---|

| Source |
|---|

| Non invasive methods (active and/or passive seismics) | | |
|---|---|---|
| Active surface waves | X | Refraction |
| Passive surface waves | X | Refection |
| HV / ellipticity | X | |

| Invasive methods (measurement in borehole) |
|---|
| Cross-hole / Down-hole |
| Geotechnical methods (CPT, SPT, ...) |
| PS-Logging |

## Non invasive : surface waves methods

| Experiment date [DD/MM/YY] | Distance from station [m] | | Lat. [WGS84] center location | Lon. [WGS84] center location |
|---|---|---|---|---|
| | Min | Max | | |
| 24/11/2021 | 9 | 130 | 41.4526 | 13.79247 |

### Active surface waves acquisition layout

| | |
|---|---|
| Minimum receiver spacing (m) | 2 |
| Profile length (m)* | 94 |
| Geophones number | 48 |
| Number of profiles | 1 |

* Provide the length for the various profiles (e.g. 46 m, 94 m)

| | |
|---|---|
| Geophone cut-off frequency (Hz) | |
| Geophone type (vertical / horizontal) | vertical |
| Geophone manufacturer | geospace |
| Source (hammer, vibrator, ...) | Hammer |
| Digitizer type | Geode |
| Digitizer manufacturer | Geometrics |

| Weather conditions | Sunny | Windy | Rain | Soil sensor coupling | Earth | Asphalt | Artificial | Urbanization | None | Dense | Scattered |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | X | | | | | X | | | | | |

### Passive surface waves acquisition layout

| | |
|---|---|
| Number of sensors | 10 |
| Minimum array aperture | 15 |
| Maximum array aperture | 110 |
| Number of arrays | 1 |
| Minimum duration [min] | 120 |

| | |
|---|---|
| Sensor cut-off frequency (Hz) | 0.2 |
| Sensor type (vertical / horizontal) | vetrical/horizontal |
| Sensor manufacturer | Lennertz |
| Digitizer type | Marslite-Sara |
| Digitizer manufacturer | Lennartz-Sara |

| Weather conditions | Sunny | Windy | Rain | Soil sensor coupling | Earth | Asphalt | Artificial | Urbanization | None | Dense | Scattered |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

### Type of dispersion and/or H/V estimates

| | |
|---|---|
| Rayleigh DC | |
| Love DC | |
| Ellipticity | |
| H/V (DFA, EHVR) | |
| H/V (SH) | |

| Reference paper (Name, Journal, DOI) |
|---|
| |

### Dispersion curves

| | Rayleigh | Love |
|---|---|---|
| Min wavelength (m) | | |
| Max. wavelength (m) | | |
| Min. phase vel. (m/s) | 180 | |
| Max. phase vel. (m/s) | 620 | |
| Modes (R0, L0, ...) | R0 | |

### H/V or Ellipticity curves

| Min. frequency (Hz) | Max. frequency (Hz) |
|---|---|
| 0.6 | 2.0 |

### Inversion

| Rayleigh waves | Love waves | Ellipticity curves | H/V (DFA, EHVR) | H/V (SH) | resonance frequency |
|---|---|---|---|---|---|
| | | | | | |

| A priori information used in inversion | seismic refraction | stratigraphic log | geotechnical information | water table depth |
|---|---|---|---|---|
| | | | | |

| | |
|---|---|
| Inversion algorithm/code | |
| Reference | Wathelet, Marc. (2008). An improved neighborhood algorithm: Parameter conditions and dynamic scaling. Geophysical Research Letters - GEOPHYS RES LETT. 35. |

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# Non invasive : body waves methods

| Experiment date [DD/MM/YY] | Distance from station [m] | | Lat. [WGS84] center location | Lon. [WGS84] center location |
|---|---|---|---|---|
| | Min | Max | | |

## Acquisition layout

| |
|---|
| Receiver spacing (m) |
| Profile length (m)* |
| Geophones number |
| Number of profiles |
| Shot spacing (m) - reflection meas. |

* Provide the length for the various profiles (e.g. 46 m, 94 m)

| |
|---|
| Geophone cut-off frequency (Hz) |
| Geophone type (vertical / horizontal) |
| Geophone manufacturer |
| Source (hammer, vibrator, ...) |
| Digitizer type |
| Digitizer manufacturer |

| Weather conditions | Sunny | Windy | Rain | Soil sensor coupling | Earth | Asphalt | Artificial | Urbanization | None | Dense | Scattered |
|---|---|---|---|---|---|---|---|---|---|---|---|

## Processing methods

| | Reference paper (Name, Journal, DOI) |
|---|---|
| classical refraction | |
| refraction tomography | |
| classical reflection | |
| advanced method | |

# Invasive methods

| | Down Hole | Cross Hole | PS Logging | SPT | CPT | OTHER |
|---|---|---|---|---|---|---|
| Borehole depth (m) | | | | | | |
| Geophone type | | | | | | |
| Source type | | | | | | |
| Distance between wells | | | | | | |
| Depth resolution (m) | | | | | | |
| Latitude (WGS84) | | | | | | |
| Longitude (WGS84) | | | | | | |
| Distance from station (m) | | | | | | |
| P-wave velocity | | | | | | |
| S-wave velocity | | | | | | |

## Processing methods

| | Reference paper (Name, Journal, DOI) or ASTM norm |
|---|---|
| Down-Hole | |
| Cross-Hole | |
| PS-Logging | |
| SPT | |
| CPT | |
| OTHER | |

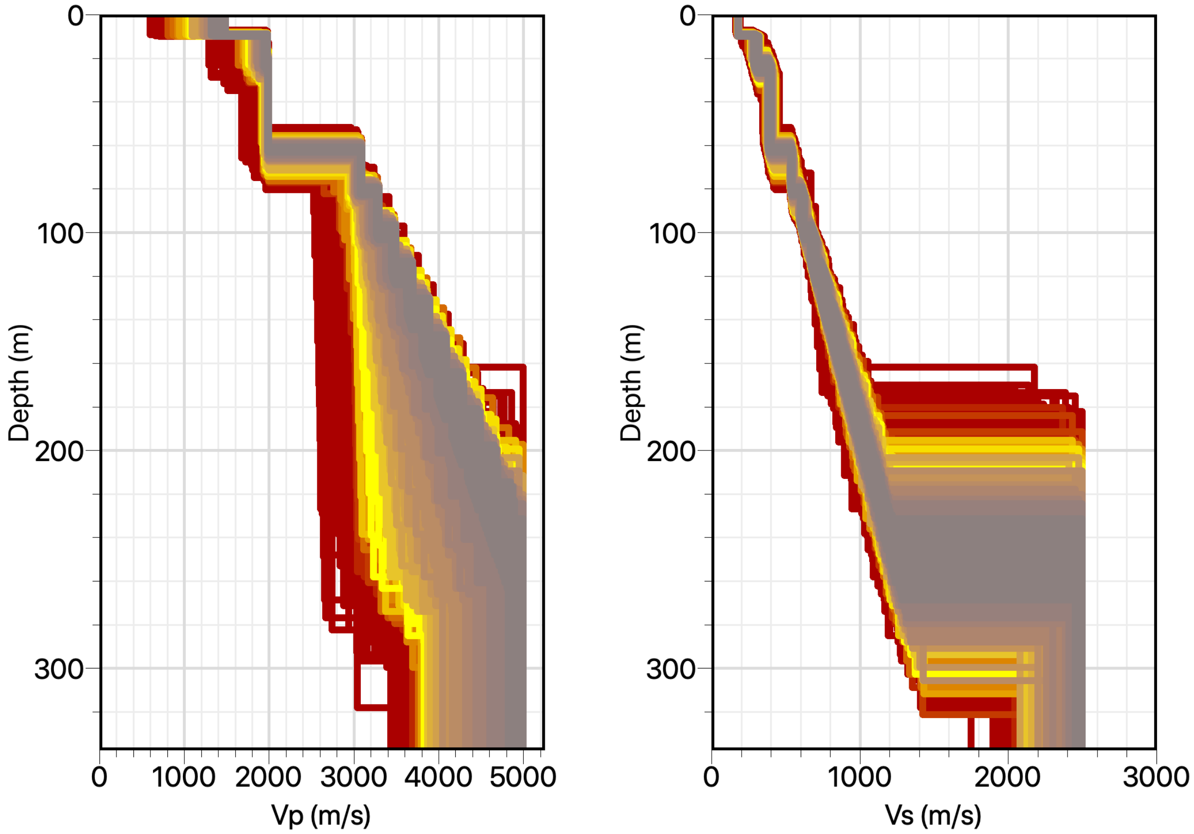
## Authoritative velocity profile

Note: You do not have to fill in all the columns. You can provide either single values for Vp or Vs (e.g. profiles derived from borehole measurements) or either a range for Vp and Vs (e.g. profiles derived from stochastic surface waves inversion)

| Is Vs derived from Vp ? | Yes | No |
|---|---|---|

| Top depth (m) | Bottom depth (m) | Vp (m/s) | STD Vp (m/s) | Vs (m/s) | STD Vs (m/s) | Vs range: Vs min (m/s) | Vs range: Vs max (m/s) | Vp range: Vp min (m/s) | Vp range: Vp max (m/s) |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 9.7 | | | 180 | | | | | |
| 9.7 | 23.7 | | | 299 | | | | | |
| 23.7 | 62.7 | | | 394 | | | | | |
| 62.7 | 240.7 | | | 856 | | | | | |
| 240.7 | …… | | | 2500 | | | | | |

Figure with authoritative velocity profiles



# Surface geology

Quality index 1

| Source | Cartography (geological, lithological, ...) | Field survey | Stratigraphic log |
|---|---|---|---|

## Geological map

| | |
|---|---|
| Map reference | |
| Map scale | |
| Map sheet | |
| Predominent geologic/lithologic unit | Name : |
| | Description : |
| | Age : |
| | Thickness : |
| | Rock mass structure : |
| Fault presence | |
| Weathering | |
| Cross section | |

## Field survey

| | |
|---|---|
| Map reference | |
| Map scale | |
| Predominent geologic/lithologic unit | Name : |
| | Description : |
| | Age : |
| | Thickness : |
| | Rock mass structure : |
| Fault presence | |
| Weathering | |
| Cross section | |

## Stratigraphic log

| log depth (m) |
|---|

| Top depth (m) | Bottom depth (m) | Stratigraphic description |
|---|---|---|

# Surface geology

## Map

# Site class

| Site class |
| --- |
| Quality index 1 |

Reference building code for site classification (EC8 1, EC8 2, NEHRP, national code, ...)

| Source | Geophysical measurements | X | Geotechnical measurements | Digital Elevation Model (DEM) | Geology | DEM & Geology |
| --- | --- | --- | --- | --- | --- | --- |

| | |
| --- | --- |
| Reference relationship geology soil class | 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 |
| Reference relationship slope from DEM soil class | |
| Reference relationship slope from DEM geology soil class | |

| | |
| --- | --- |
| Parameters for deriving soil class as prescribed in building code | Vs30 (Vseq) and bedrock depth |

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# Seismological bedrock depth

| | |
|---|---|
| Depth +/ STD [m] | 240+/-50 |
| Quality index 1 | 0.66 |

| | | | | |
|---|---|---|---|---|
| Source | Vs profiles | | Geology | Other (gravity, seismic refraction, TDEM, ...) |
| | Resonance frequency | X | Stratigraphic log | |

## Vs profile

| | Non invasive methods | Invasive seismic methods | Geotechnical methods |
|---|---|---|---|
| Bedrock depth +/ STD(m) | 240+/-50 | | |
| Bedrock Vs +/ STD(m) | 2500+/-200 | | |
| Bedrock Vp +/ STD(m) | | | |
| Is Vs derived from Vp ? | Yes | No X | |

## Resonance frequency

| | |
|---|---|
| Bedrock depth +/ STD(m) | |
| Reference relationship Fo bedrock depth | |

## Geology

| | |
|---|---|
| Bedrock depth +/ STD(m) | |
| Bedrock geological unit | |
| Reference | |

## Stratigraphic log

| | |
|---|---|
| Bedrock depth +/ STD(m) | |
| Bedrock geological unit | |
| Reference | |

## Other methods

| | Bedrock depth +/ STD(m) | Reference |
|---|---|---|
| Gravity | | |
| Seismic refraction | | |
| Seismic reflection | | |
| TDEM | | |

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# Engineering bedrock depth

| | |
|---|---|
| Depth +/ STD [m] | 150+/-30 |
| Quality index 1 | 0.66 |

| Reference Vs related to engineering bedrock in m/s | | Reference building code for site classification (EC8 1, EC8 2, NEHRP, national code, ...) | |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Source | Vs profile X | Geology | Stratigraphic log |

## Vs profile

| | Non invasive methods | Invasive seismic methods | Geotechnical methods |
|---|---|---|---|
| Bedrock depth +/ STD(m) | 150+/-30 | | |

| | | |
|---|---|---|
| Is Vs derived from Vp ? | Yes | No X |

## Geology

| | |
|---|---|
| Bedrock depth +/ STD(m) | |
| Bedrock geological unit | |
| Reference | |

## Stratigraphic log

| | |
|---|---|
| Bedrock depth +/ STD(m) | |
| Bedrock geological unit | |
| Reference | |