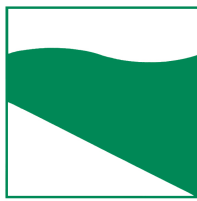




PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile



Regione Emilia-Romagna



CONFERENZA DELLE REGIONI E
DELLE PROVINCE AUTONOME

Attuazione dell'articolo 11 dalla legge 24 giugno 2009, n.77

MICROZONAZIONE SISMICA

Livello 2

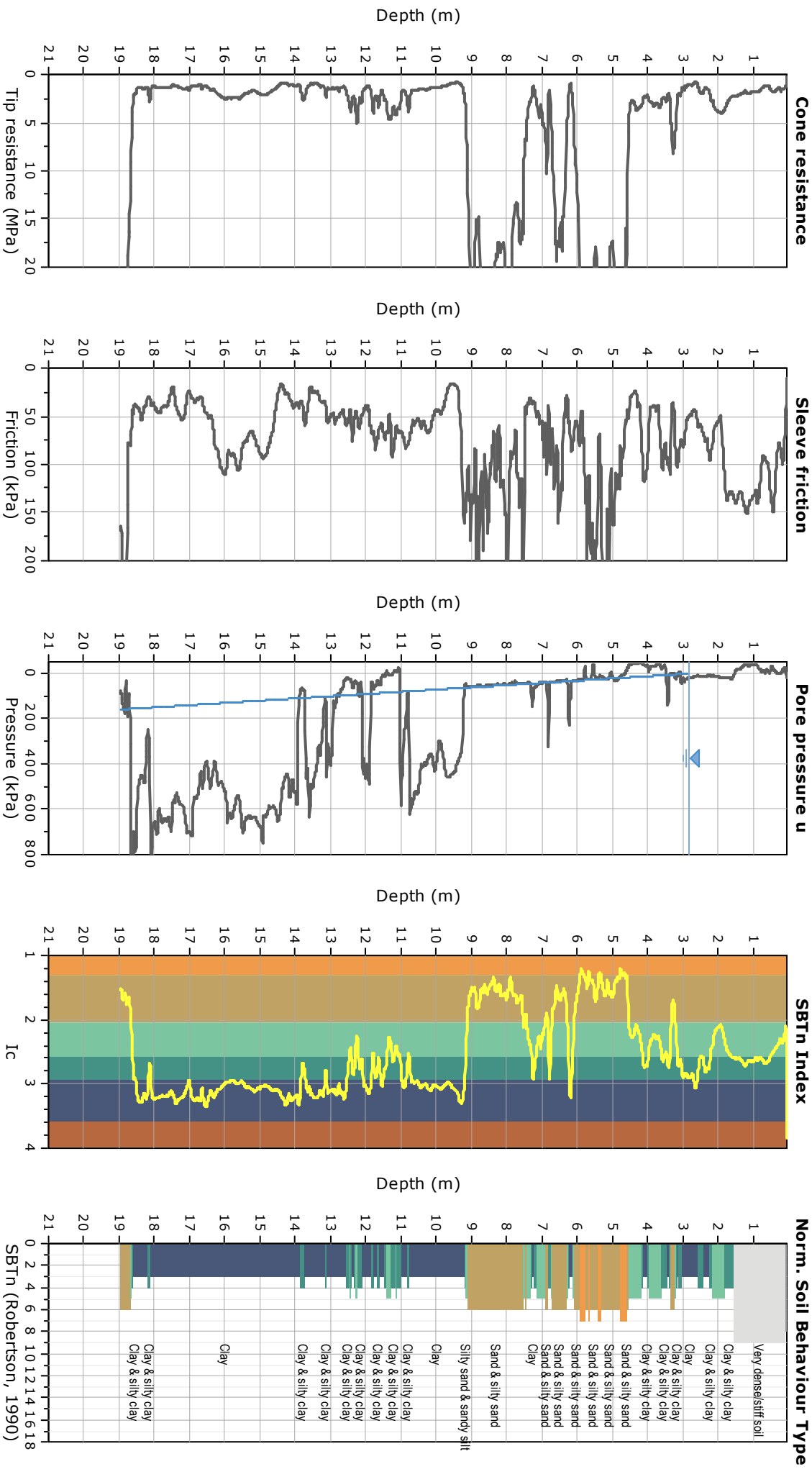
Allegato 2 – Report delle indagini

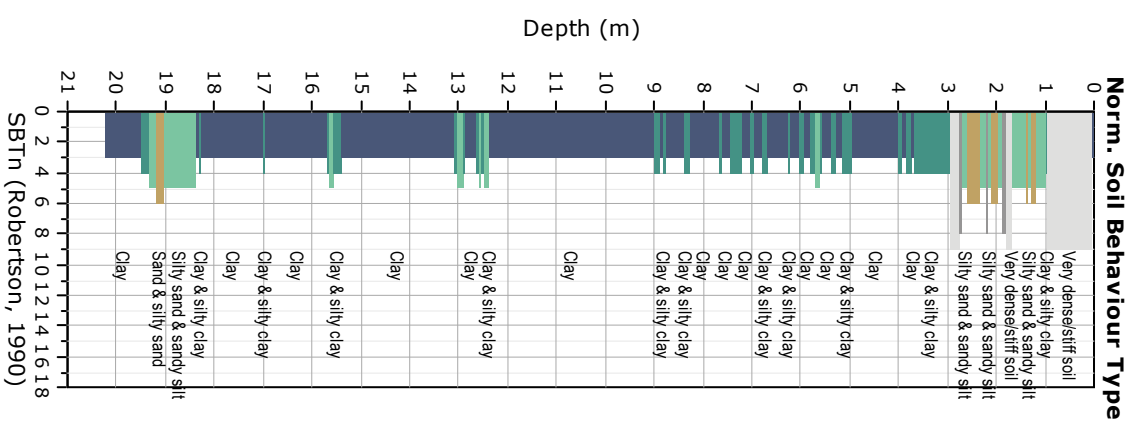
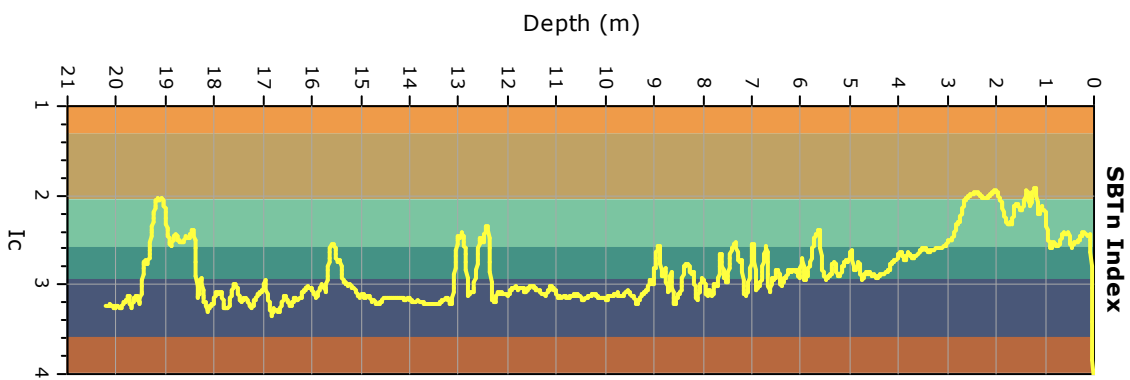
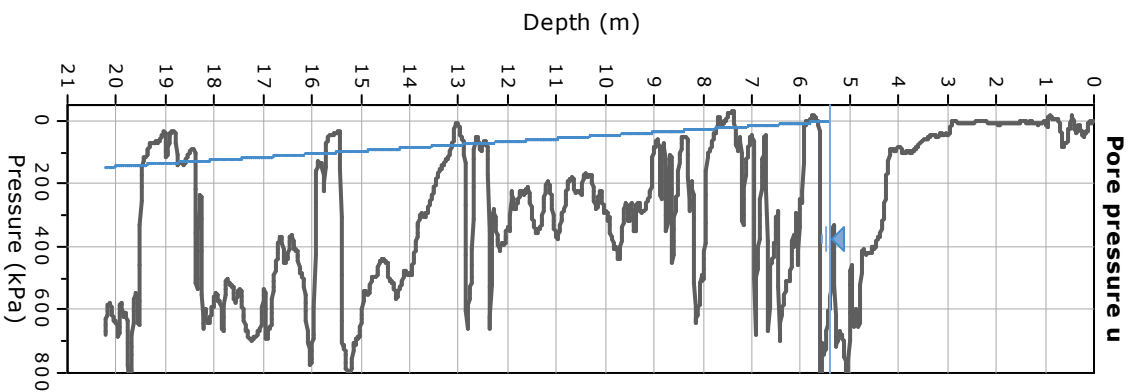
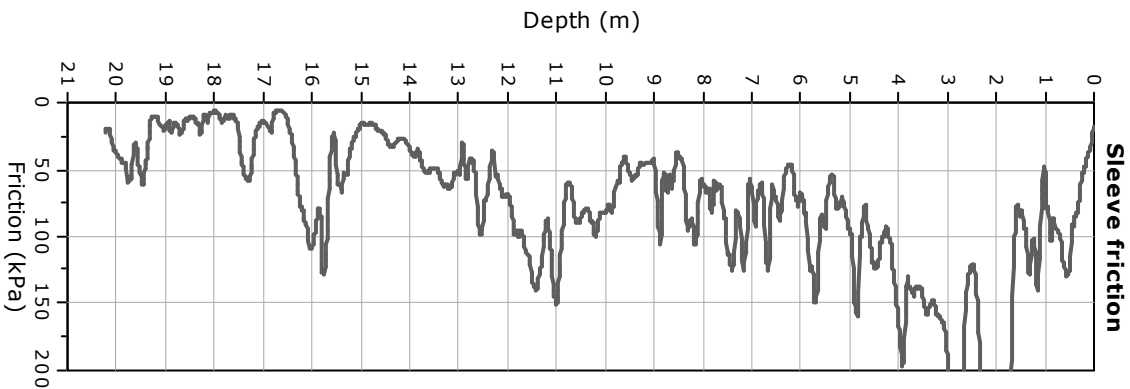
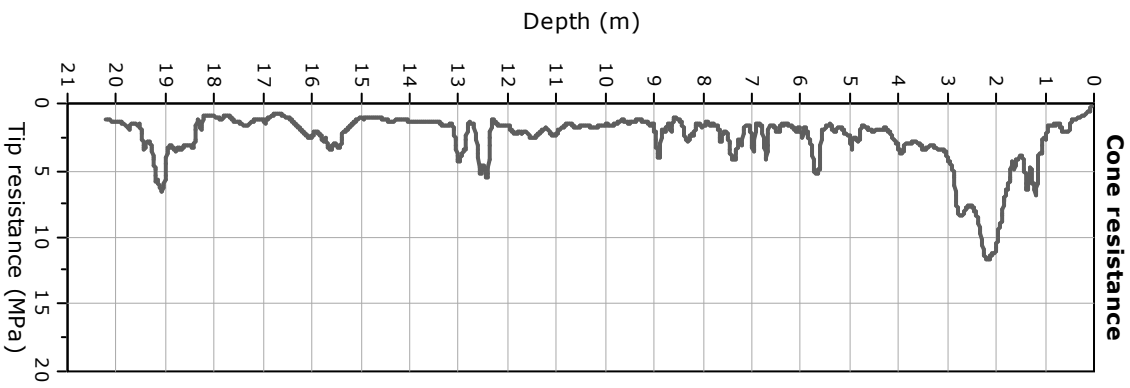
Regione Emilia–Romagna

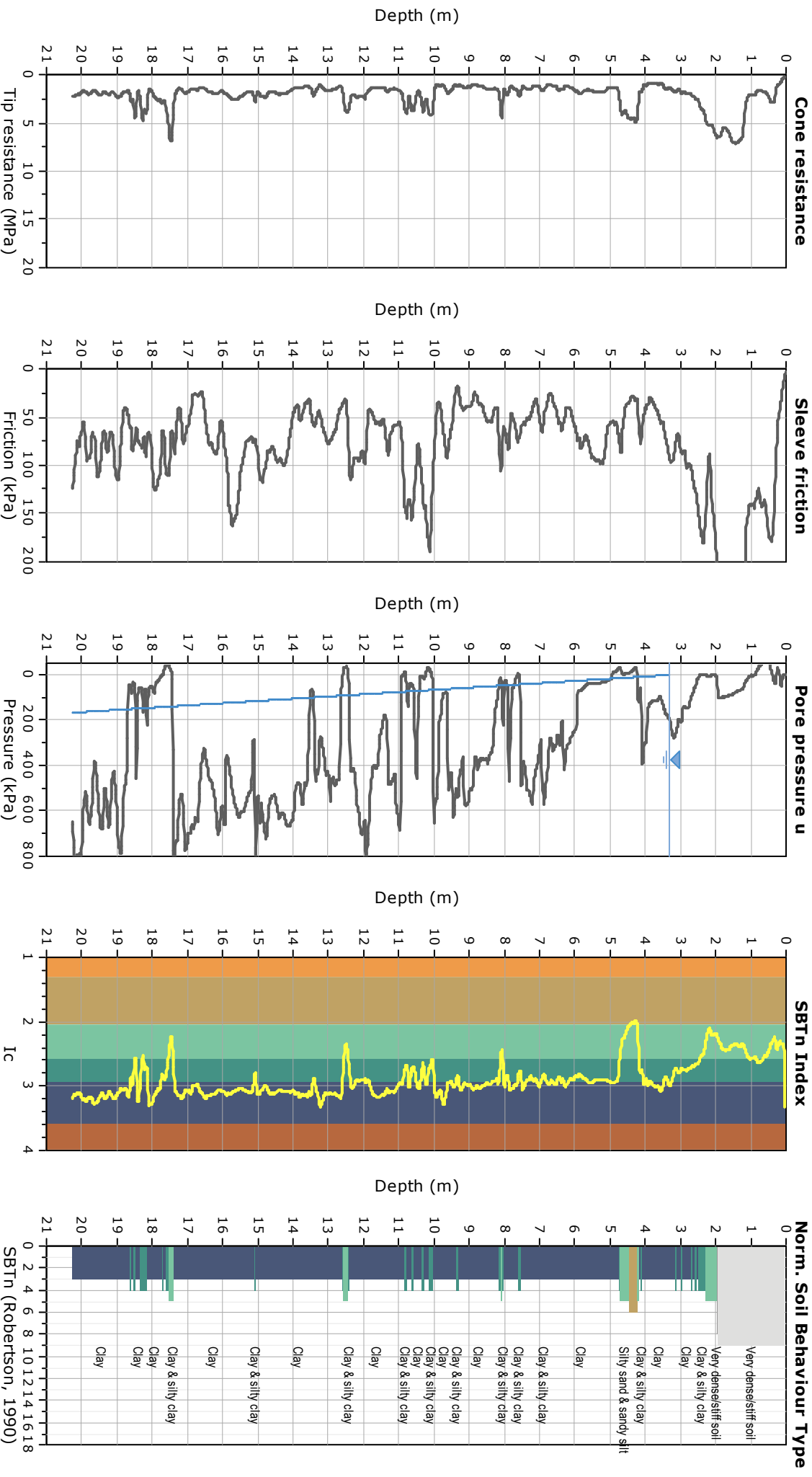
Comune di Castenaso

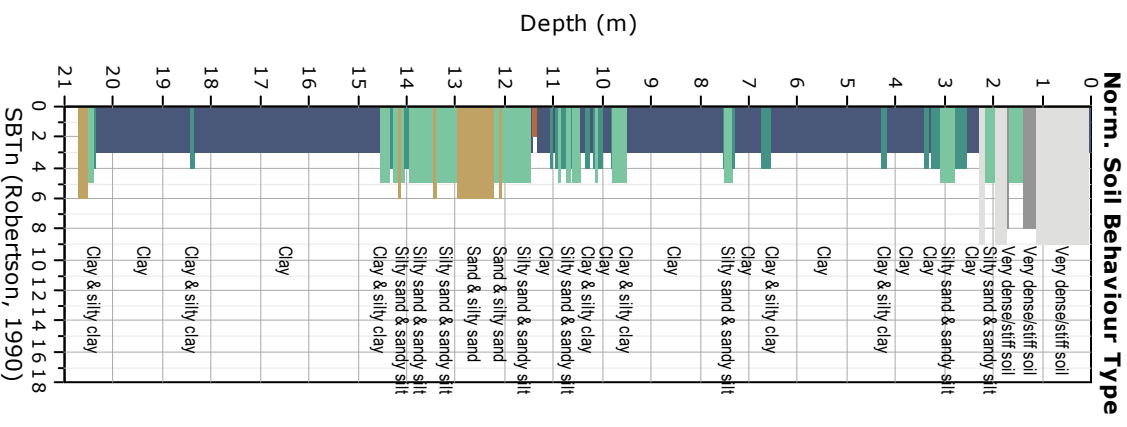
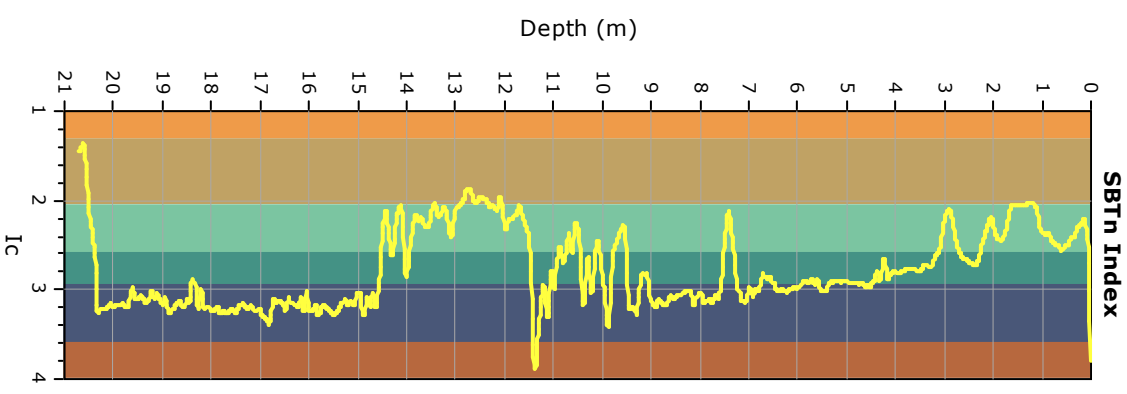
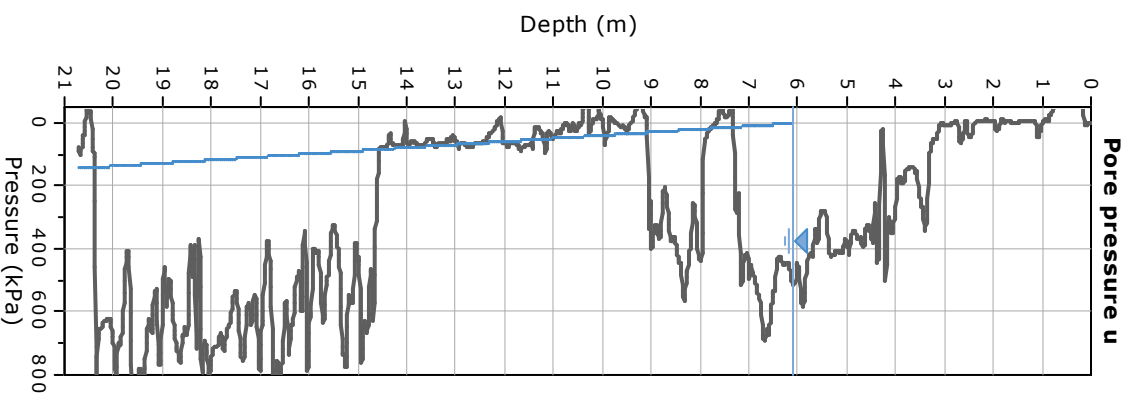
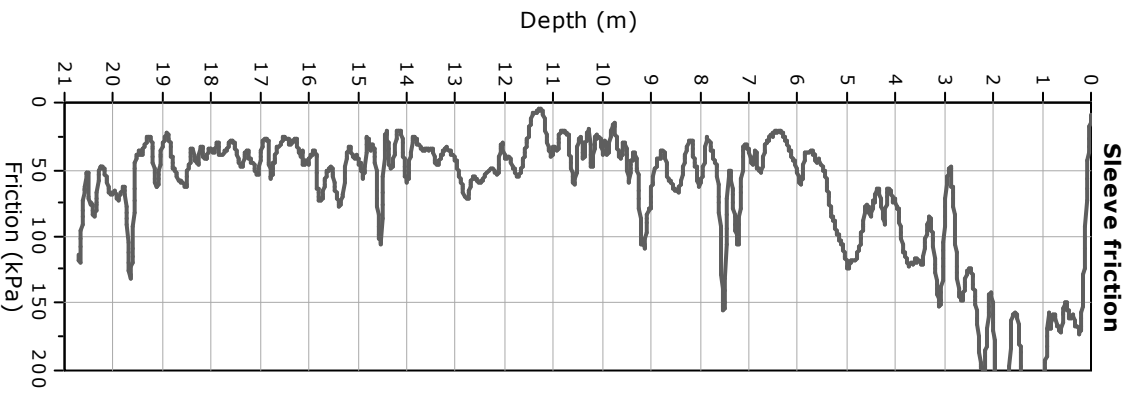
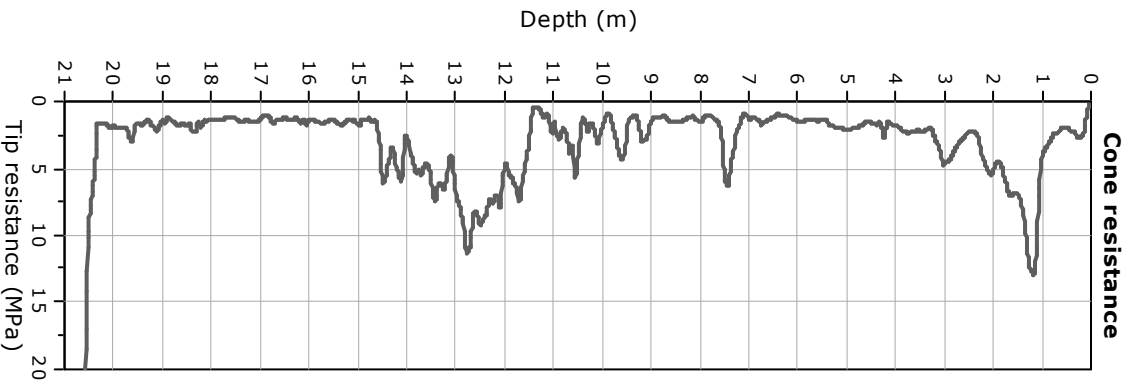


| Regione | Soggetto realizzatore | Data |
|--|--------------------------------|------------|
| EMILIA–ROMAGNA | | |
| Studio realizzato con il contributo di cui all'OCPDC 675/2020 recepita con DGR 1238/2020 | Dott. geologo Samuel Sangiorgi | Marzo 2023 |









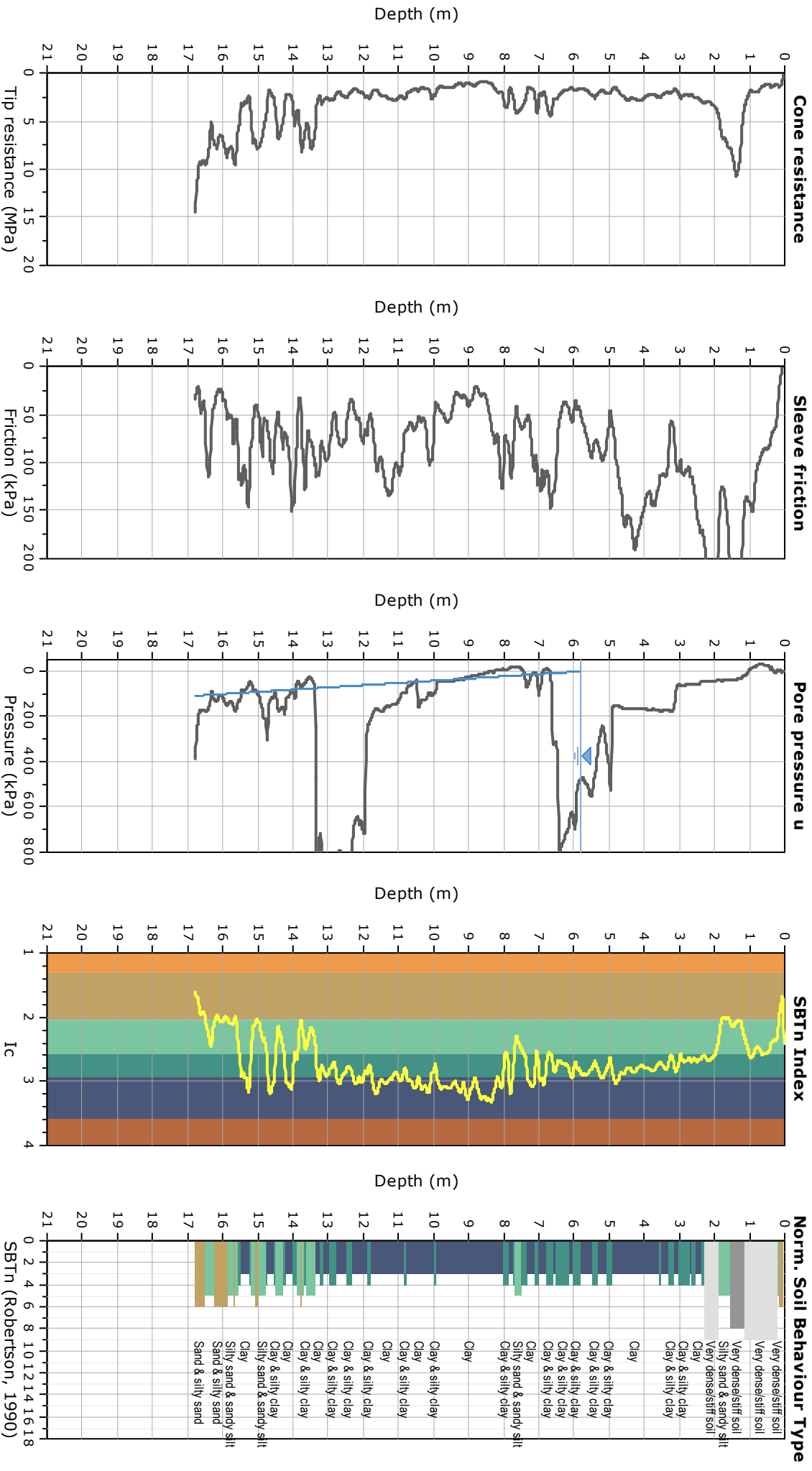


Studio Samuel Sangiorgi
 Via Valsellustra 32, 40060 - Dozza (BO)
 info@studiosamuelsangiorgi.eu
 Tel. 0542-640279

037021P37499CPTU531

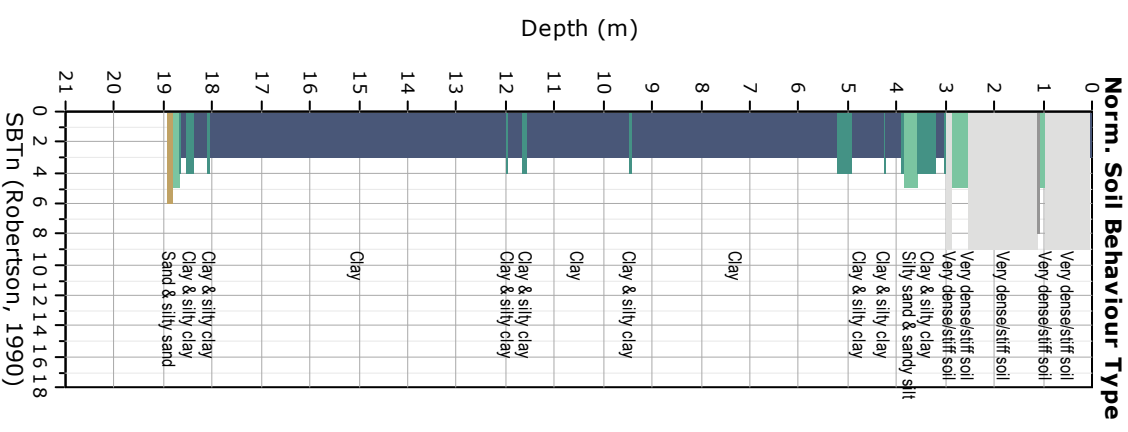
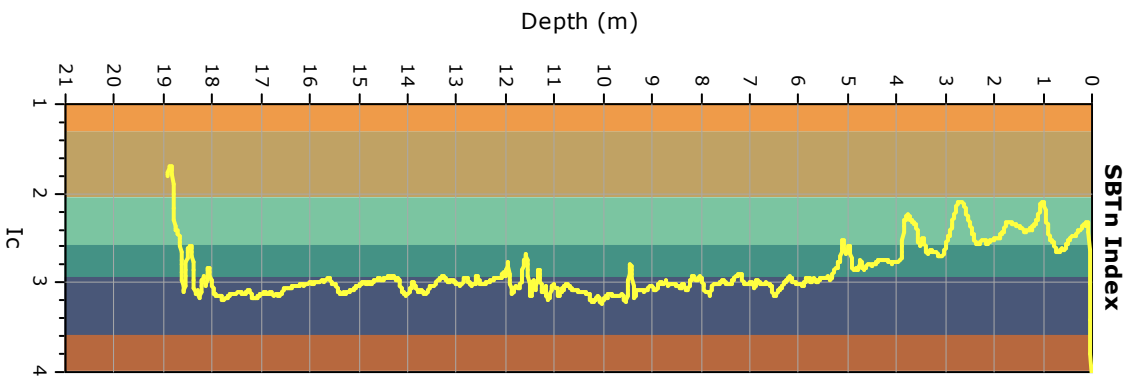
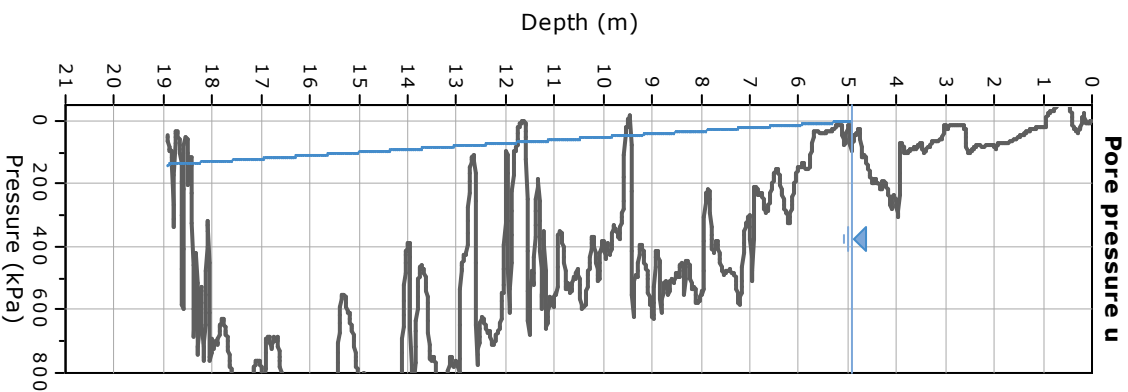
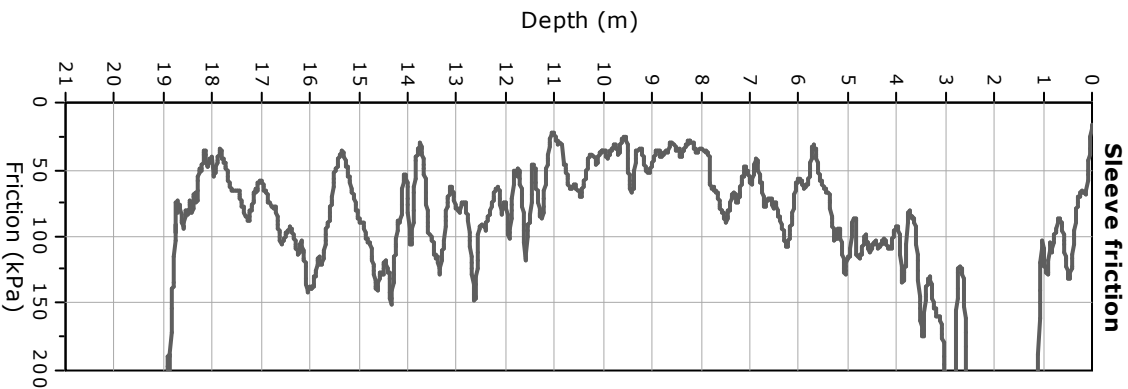
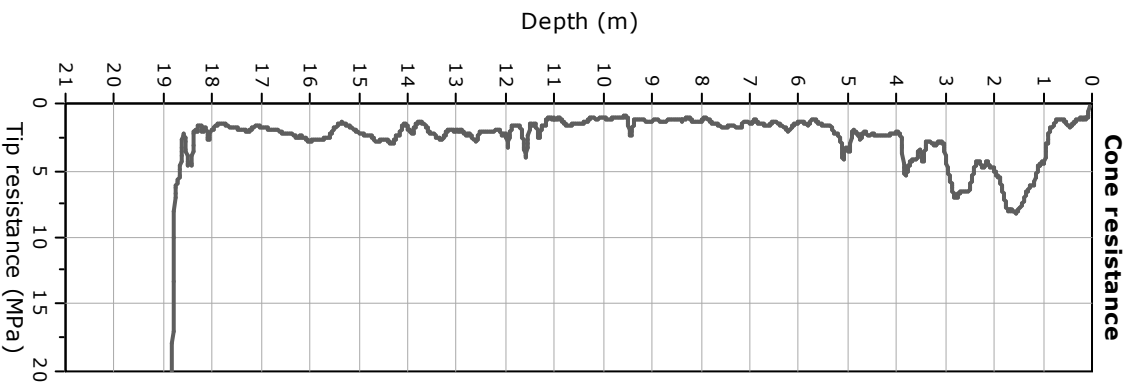
Project: Microzonazione Sismica Livello 2
Location: Castenaso (BO)

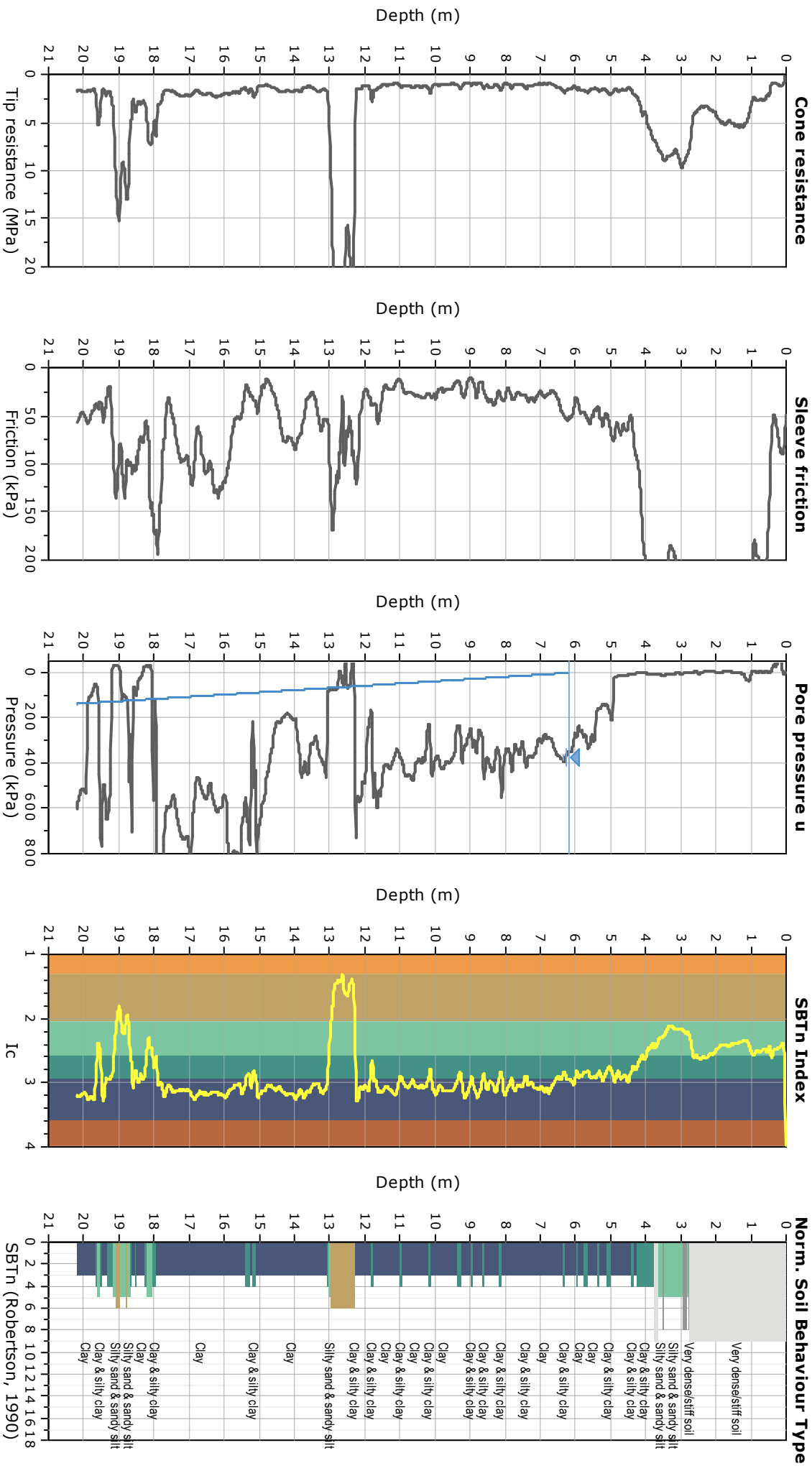
CPT: CPTUS
 Total depth: 16.79 m, Date: 23/12/2021



Project: Microzonazione Sismica Livello 2
Location: Castenaso (BO)

CPT: CPTU6
Total depth: 18.91 m, Date: 23/12/2021



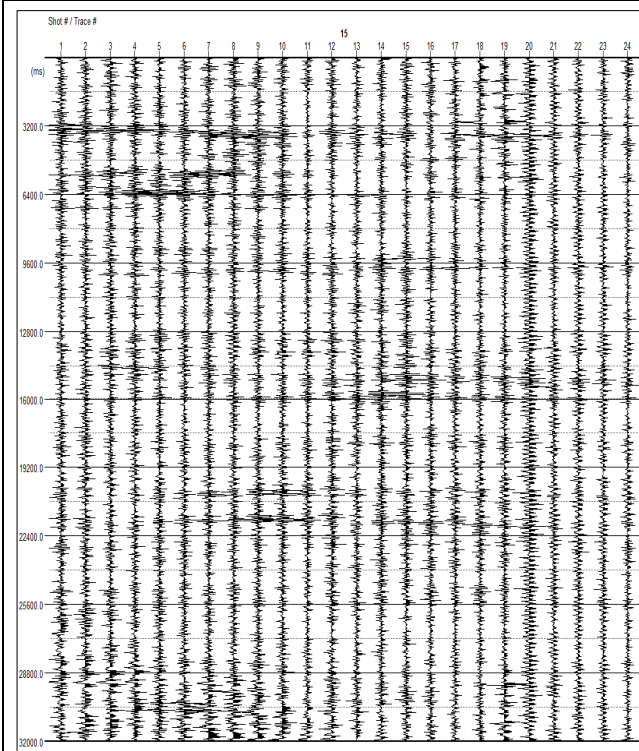


PROSPEZIONE SISMICA CON METODOLOGIA ESAC

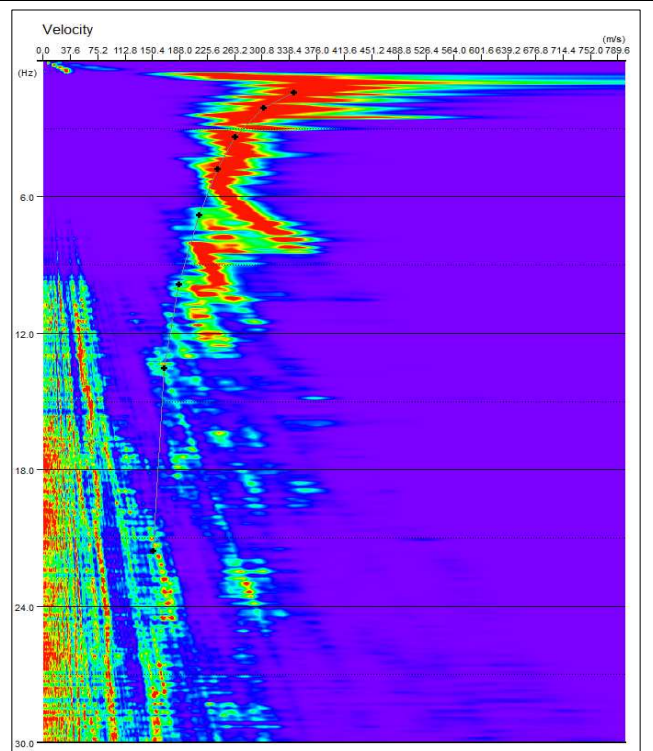
“Parco della Resistenza”, Comune di Castenaso (BO) - 037021P37501ESAC_SPAC533

| n° tracce | Δt (ms) | T (s) |
|-----------|-----------------|-------|
| 25 | 2,0 | 32,0 |

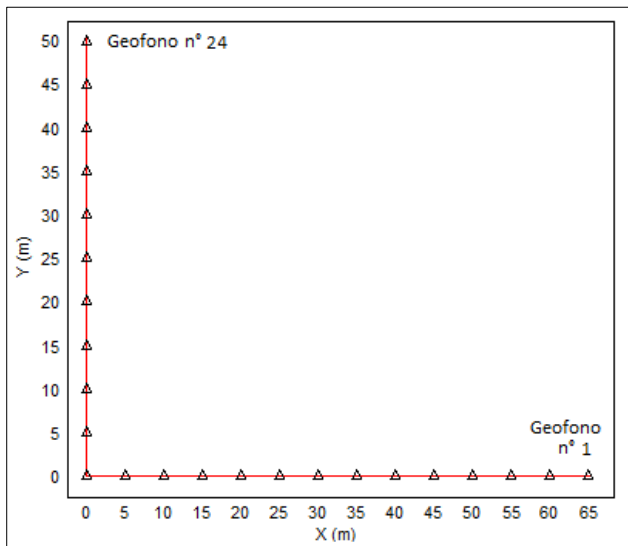
Δt : passo di campionamento; T: durata registrazione.



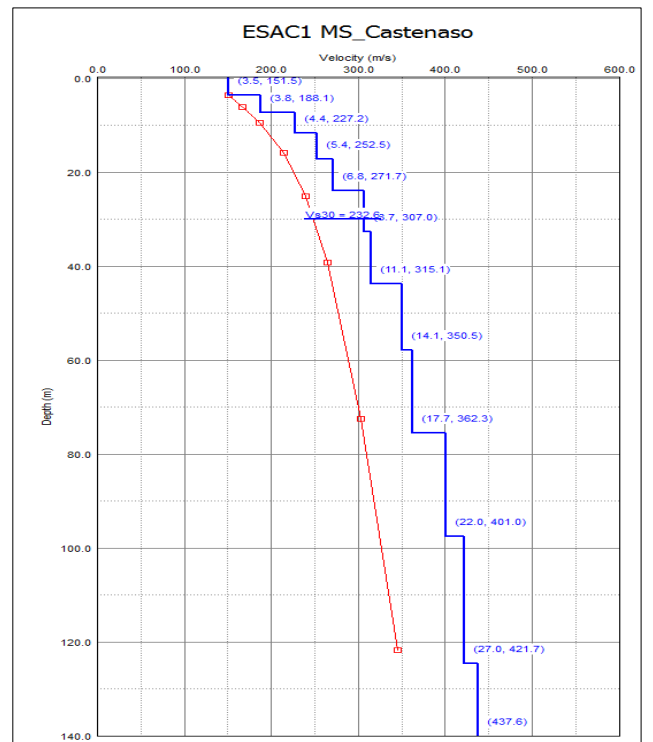
Sismogramma registrato durante le acquisizioni di microtremore sismico. In ascissa il numero dei geofoni, in ordinata il tempo (ms).



Spettro di potenza nel dominio $f-v$ e Picking della curva sperimentale delle onde R (croci nere).



Geometria dello stendimento sismico bidimensionale.



Modello di sottosuolo (1D) descritti in termini di V_s e spessore dei sismostrati (spezzata blu) e curva di dispersione sperimentale delle onde R (curva rossa).

Tabella di sintesi

| n. strato | Profondità letto (m dal p.c.) | Spessore (m) | V _s (m/s) |
|-----------|-------------------------------|--------------|----------------------|
| 1 | 3.5 | 3.5 | 151.5 |
| 2 | 7.3 | 3.8 | 188.1 |
| 3 | 11.7 | 4.4 | 227.2 |
| 4 | 17.1 | 5.4 | 252.5 |
| 5 | 23.9 | 6.8 | 271.7 |
| 6 | 32.6 | 8.7 | 307.0 |
| 7 | 43.7 | 11.1 | 315.1 |
| 8 | 57.8 | 14.1 | 350.5 |
| 9 | 75.5 | 17.7 | 362.3 |
| 10 | 97.5 | 22.0 | 401.0 |
| 11 | 124.5 | 27.0 | 421.7 |
| 12 | ∞ | ∞ | 437.6 |

$$V_{s30} = 232.6 \pm 10\% \text{ [m/s]}$$

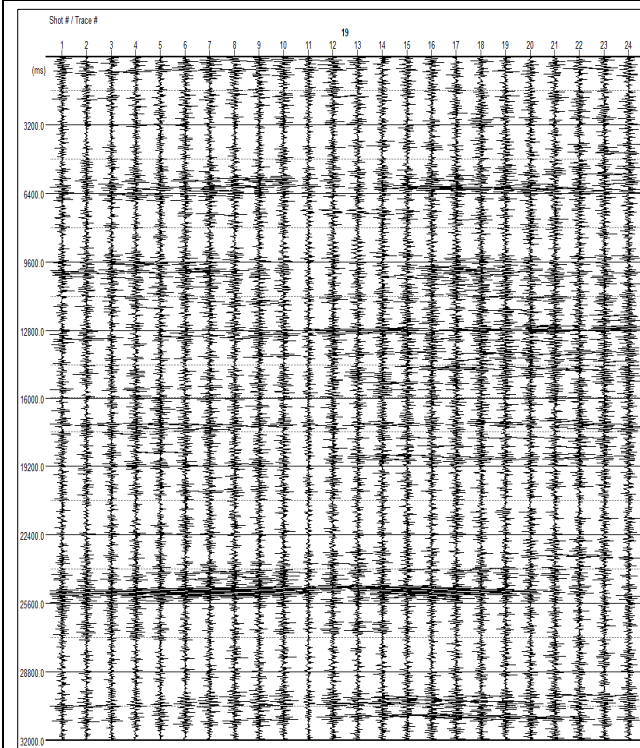
Sintesi dei parametri del modello di sottosuolo ottenuto e Valore di Vs30 calcolato.

PROSPEZIONE SISMICA CON METODOLOGIA ESAC

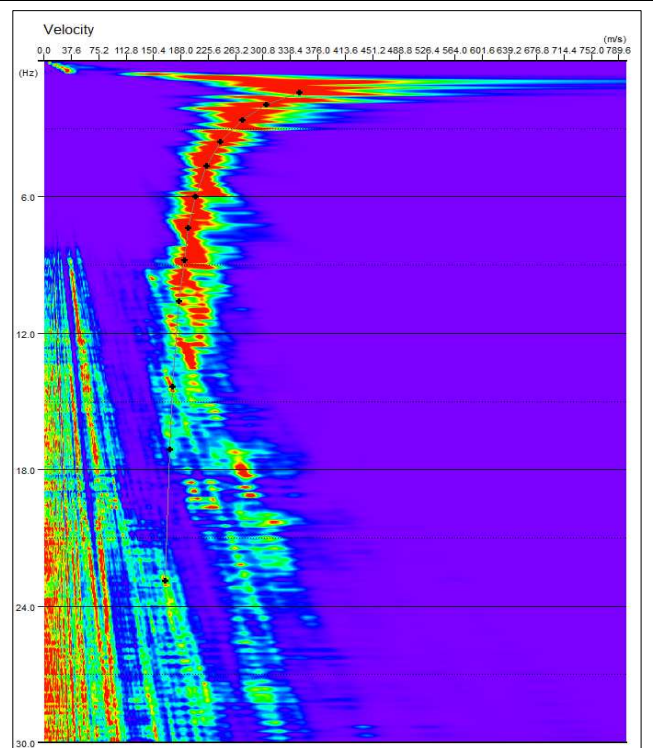
Via Fiumana Sinistra, loc. Villanova di Castenaso (BO) - 037021P37502ESAC_SPAC534

| n° tracce | Δt (ms) | T (s) |
|-----------|-----------------|-------|
| 25 | 2,0 | 32,0 |

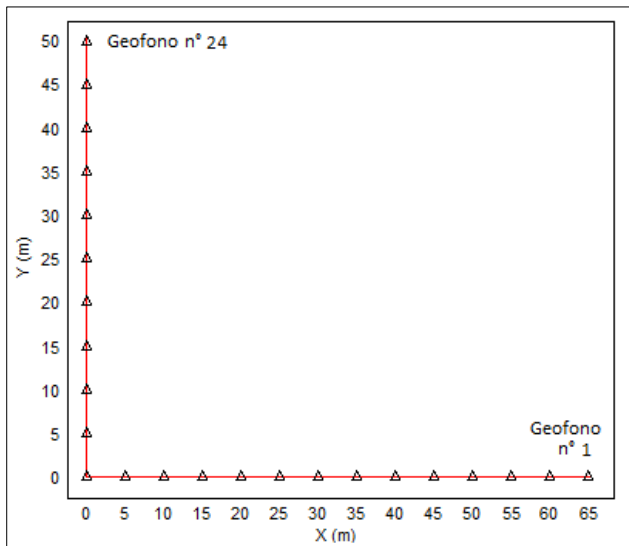
Δt : passo di campionamento; T: durata registrazione.



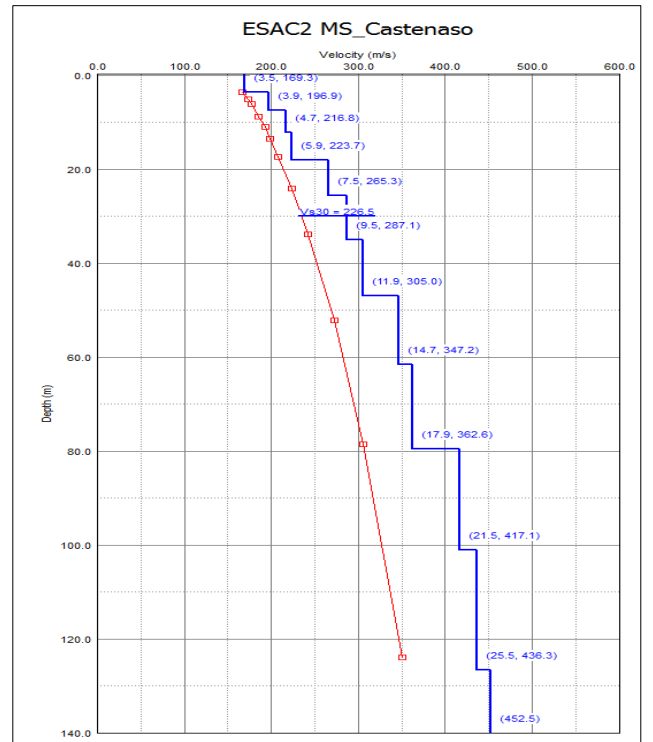
Sismogramma registrato durante le acquisizioni di microtremore sismico. In ascissa il numero dei geofoni, in ordinata il tempo (ms).



Spettro di potenza nel dominio $f-v$ e Picking della curva sperimentale delle onde R (croci nere).



Geometria dello stendimento sismico bidimensionale.



Modello di sottosuolo (1D) descritti in termini di V_s e spessore dei sismostrati (spezzata blu) e curva di dispersione sperimentale delle onde R (curva rossa).

Tabella di sintesi

| n. strato | Profondità letto (m dal p.c.) | Spessore (m) | V _s (m/s) |
|-----------|-------------------------------|--------------|----------------------|
| 1 | 3.5 | 3.5 | 169.3 |
| 2 | 7.4 | 3.9 | 196.9 |
| 3 | 12.1 | 4.7 | 216.8 |
| 4 | 18.0 | 5.9 | 223.7 |
| 5 | 25.5 | 7.5 | 265.3 |
| 6 | 35.0 | 9.5 | 287.1 |
| 7 | 46.9 | 11.9 | 305.0 |
| 8 | 61.6 | 14.7 | 347.2 |
| 9 | 79.5 | 17.9 | 362.6 |
| 10 | 101.0 | 21.5 | 417.1 |
| 11 | 126.5 | 25.5 | 436.3 |
| 12 | ∞ | ∞ | 452.5 |

$$V_{s30} = 226.5 \pm 10\% \text{ [m/s]}$$

Sintesi dei parametri del modello di sottosuolo ottenuto e Valore di Vs30 calcolato.

CASTENASO_MS, TR1 FRULLO

037021P37504HVSR536

Instrument: TRZ-0108/01-10

Start recording: 18/01/02 10:37:18 End recording: 18/01/02 11:37:19

Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN

Trace length: 1h00'00". Analyzed 95% trace (manual window selection)

Sampling rate: 128 Hz

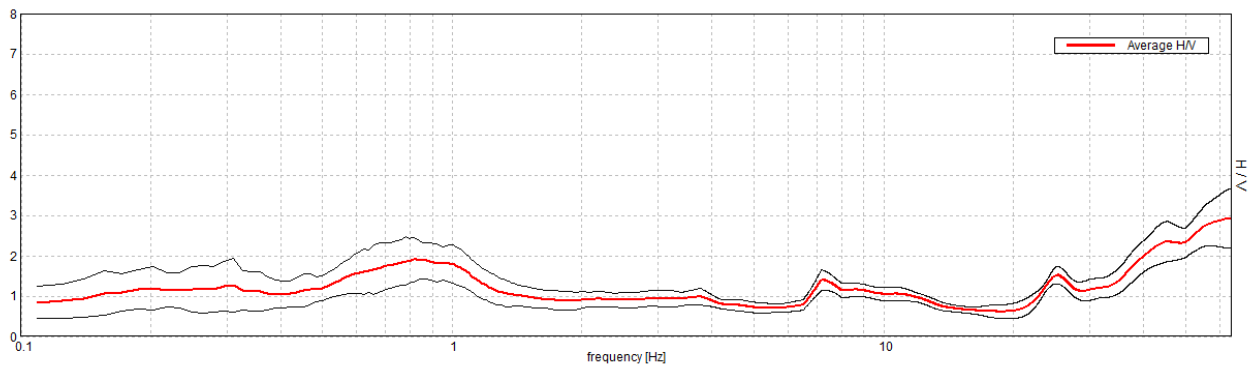
Window size: 60 s

Smoothing type: Triangular window

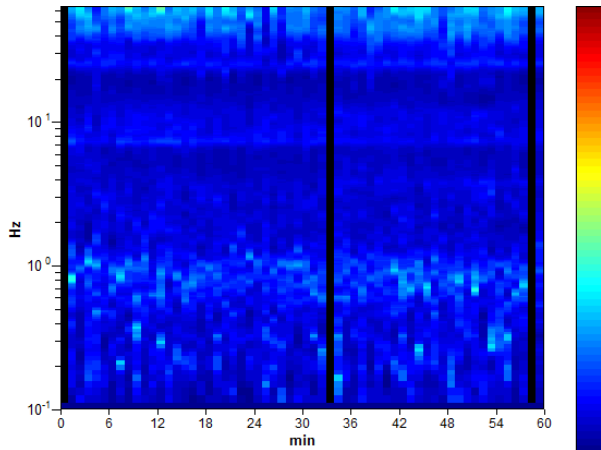
Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

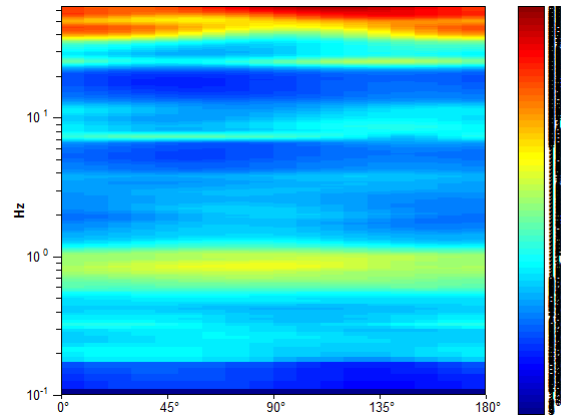
Max. H/V at 0.83 ± 0.02 Hz. (In the range 0.1 - 20.0 Hz).



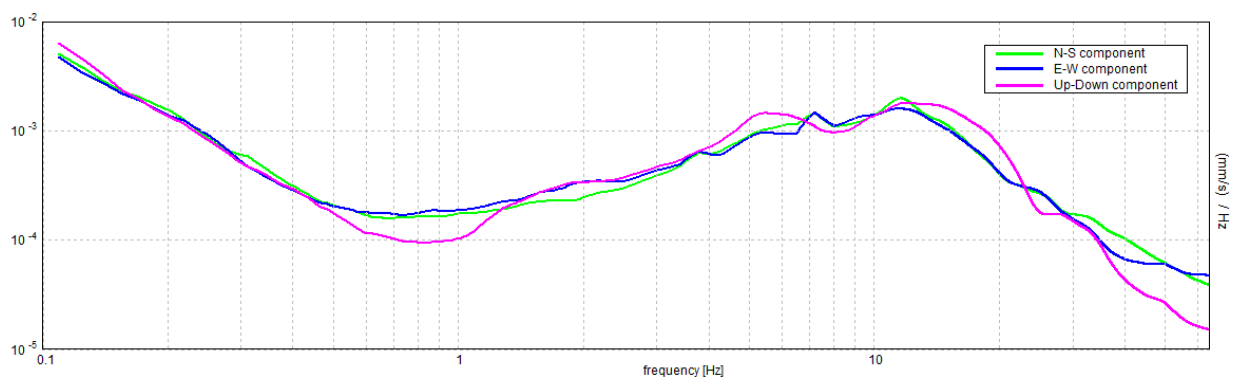
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.83 ± 0.02 Hz (in the range 0.1 - 20.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

| | | | |
|--|----------------------------|----|--|
| $f_0 > 10 / L_w$ | $0.83 > 0.17$ | OK | |
| $n_c(f_0) > 200$ | $2832.2 > 200$ | OK | |
| $\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$ | Exceeded 0 out of 80 times | OK | |

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

| | | | |
|---|---------------------|----|----|
| Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$ | | | NO |
| Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$ | 1.547 Hz | OK | |
| $A_0 > 2$ | $1.91 > 2$ | | NO |
| $f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$ | $ 0.01016 < 0.05$ | OK | |
| $\sigma_f < \varepsilon(f_0)$ | $0.00841 < 0.12422$ | OK | |
| $\sigma_A(f_0) < \theta(f_0)$ | $0.2597 < 2.0$ | OK | |

| | |
|------------------------|---|
| L_w | window length |
| n_w | number of windows used in the analysis |
| $n_c = L_w n_w f_0$ | number of significant cycles |
| f | current frequency |
| f_0 | H/V peak frequency |
| σ_f | standard deviation of H/V peak frequency |
| $\varepsilon(f_0)$ | threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$ |
| A_0 | H/V peak amplitude at frequency f_0 |
| $A_{H/V}(f)$ | H/V curve amplitude at frequency f |
| f^- | frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$ |
| f^+ | frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$ |
| $\sigma_A(f)$ | standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided |
| $\sigma_{\log H/V}(f)$ | standard deviation of $\log A_{H/V}(f)$ curve |
| $\theta(f_0)$ | threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$ |

Threshold values for σ_f and $\sigma_A(f_0)$

| Freq. range [Hz] | < 0.2 | 0.2 – 0.5 | 0.5 – 1.0 | 1.0 – 2.0 | > 2.0 |
|---|------------|-----------|------------|------------|------------|
| $\varepsilon(f_0)$ [Hz] | $0.25 f_0$ | $0.2 f_0$ | $0.15 f_0$ | $0.10 f_0$ | $0.05 f_0$ |
| $\theta(f_0)$ for $\sigma_A(f_0)$ | 3.0 | 2.5 | 2.0 | 1.78 | 1.58 |
| $\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$ | 0.48 | 0.40 | 0.30 | 0.25 | 0.20 |

CASTENASO_MS, TR2 VILLANOVA

037021P37505HVSR537

Instrument: TRZ-0108/01-10

Start recording: 16/12/01 09:54:20 End recording: 16/12/01 10:54:20

Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN

Trace length: 1h00'00". Analyzed 88% trace (manual window selection)

Sampling rate: 128 Hz

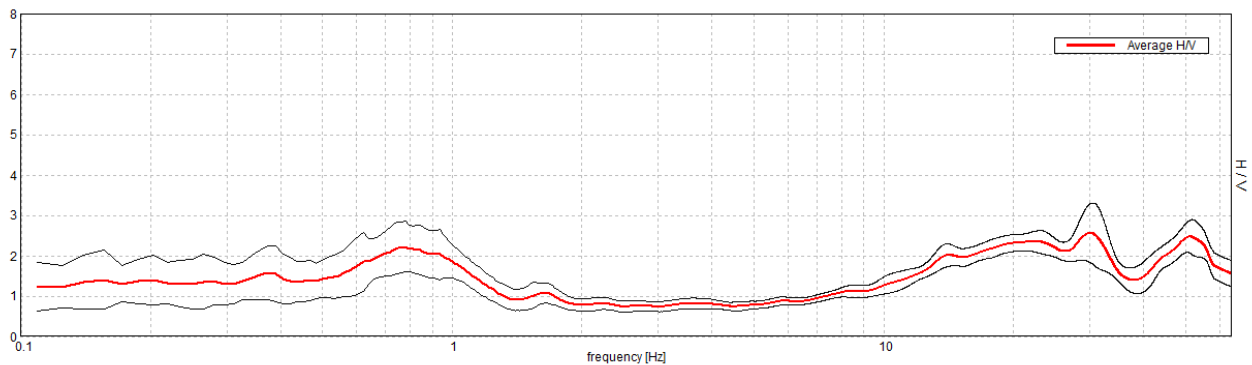
Window size: 60 s

Smoothing type: Triangular window

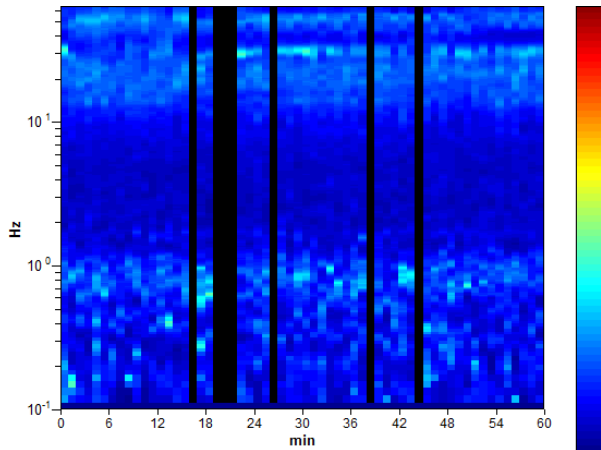
Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

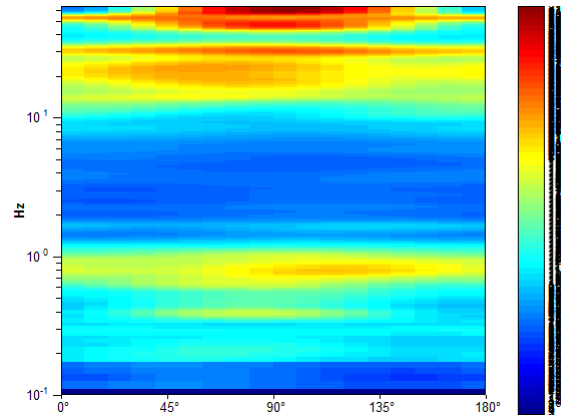
Max. H/V at 19.98 ± 1.32 Hz (in the range 0.1 - 20.0 Hz).



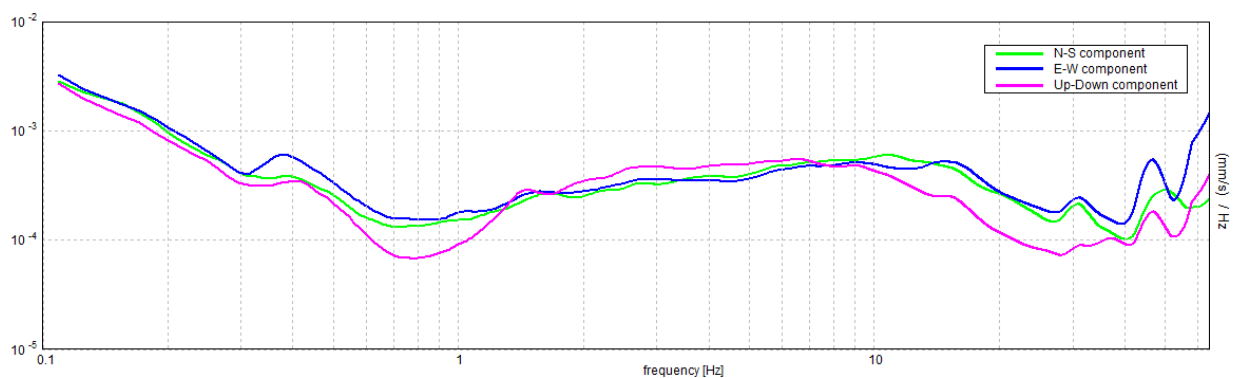
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 19.98 ± 1.32 Hz (in the range 0.1 - 20.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

| | | | |
|--|------------------------------|----|--|
| $f_0 > 10 / L_w$ | 19.98 > 0.17 | OK | |
| $n_c(f_0) > 200$ | 63550.3 > 200 | OK | |
| $\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$ | Exceeded 0 out of 1920 times | OK | |

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

| | | | |
|---|-------------------|----|----|
| Exists f^- in $[f_0/4, f_0]$ $A_{H/V}(f^-) < A_0 / 2$ | 9.438 Hz | OK | |
| Exists f^+ in $[f_0, 4f_0]$ $A_{H/V}(f^+) < A_0 / 2$ | | | NO |
| $A_0 > 2$ | 2.31 > 2 | OK | |
| $f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$ | $ 0.0325 < 0.05$ | OK | |
| $\sigma_f < \varepsilon(f_0)$ | 0.64947 < 0.99922 | OK | |
| $\sigma_A(f_0) < \theta(f_0)$ | 0.1035 < 1.58 | OK | |

| | |
|------------------------|---|
| L_w | window length |
| n_w | number of windows used in the analysis |
| $n_c = L_w n_w f_0$ | number of significant cycles |
| f | current frequency |
| f_0 | H/V peak frequency |
| σ_f | standard deviation of H/V peak frequency |
| $\varepsilon(f_0)$ | threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$ |
| A_0 | H/V peak amplitude at frequency f_0 |
| $A_{H/V}(f)$ | H/V curve amplitude at frequency f |
| f^- | frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$ |
| f^+ | frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$ |
| $\sigma_A(f)$ | standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided |
| $\sigma_{\log H/V}(f)$ | standard deviation of $\log A_{H/V}(f)$ curve |
| $\theta(f_0)$ | threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$ |

Threshold values for σ_f and $\sigma_A(f_0)$

| Freq. range [Hz] | < 0.2 | 0.2 – 0.5 | 0.5 – 1.0 | 1.0 – 2.0 | > 2.0 |
|---|------------|-----------|------------|------------|------------|
| $\varepsilon(f_0)$ [Hz] | 0.25 f_0 | 0.2 f_0 | 0.15 f_0 | 0.10 f_0 | 0.05 f_0 |
| $\theta(f_0)$ for $\sigma_A(f_0)$ | 3.0 | 2.5 | 2.0 | 1.78 | 1.58 |
| $\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$ | 0.48 | 0.40 | 0.30 | 0.25 | 0.20 |

CASTENASO_MS, TR3 MARANO

037021P37506HVSR538

Instrument: TRZ-0108/01-10

Start recording: 16/12/01 11:58:32 End recording: 16/12/01 12:58:33

Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN

Trace length: 1h00'00". Analyzed 97% trace (manual window selection)

Sampling rate: 128 Hz

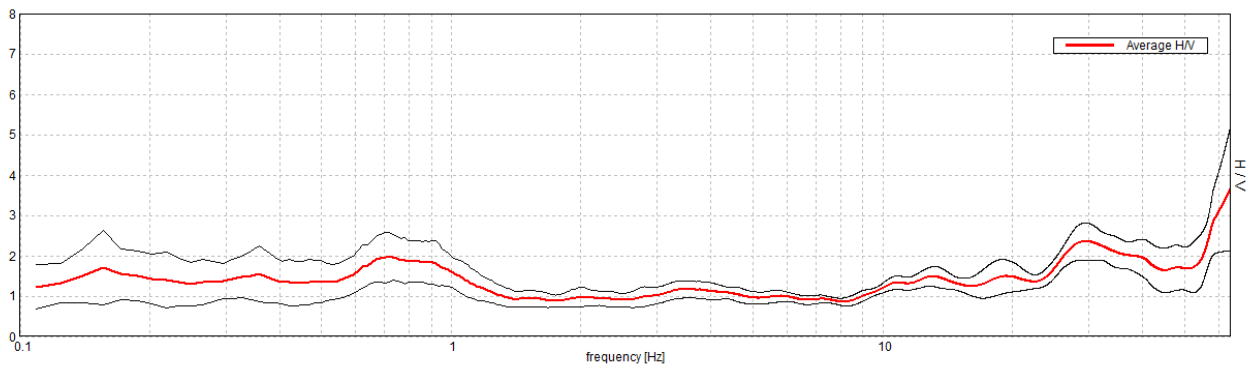
Window size: 60 s

Smoothing type: Triangular window

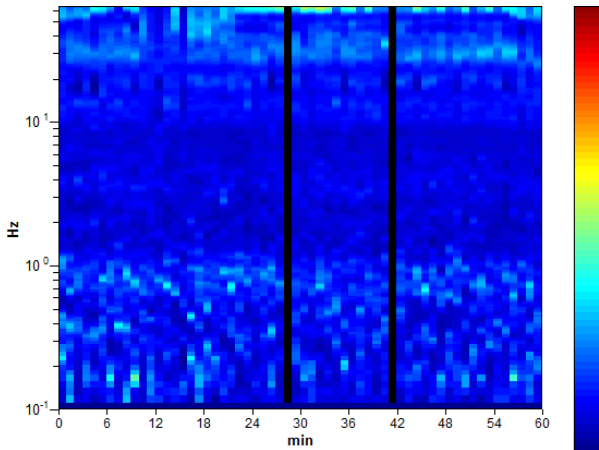
Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

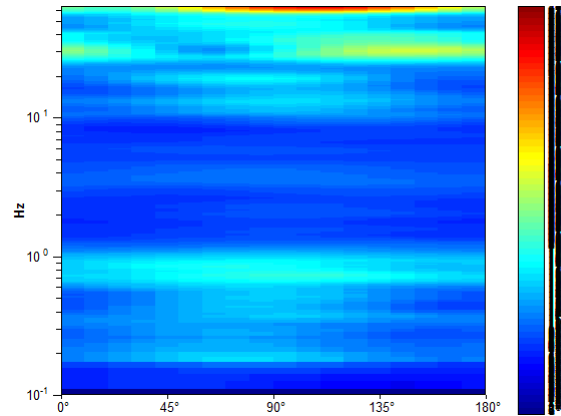
Max. H/V at 0.72 ± 0.04 Hz (in the range 0.1 - 20.0 Hz).



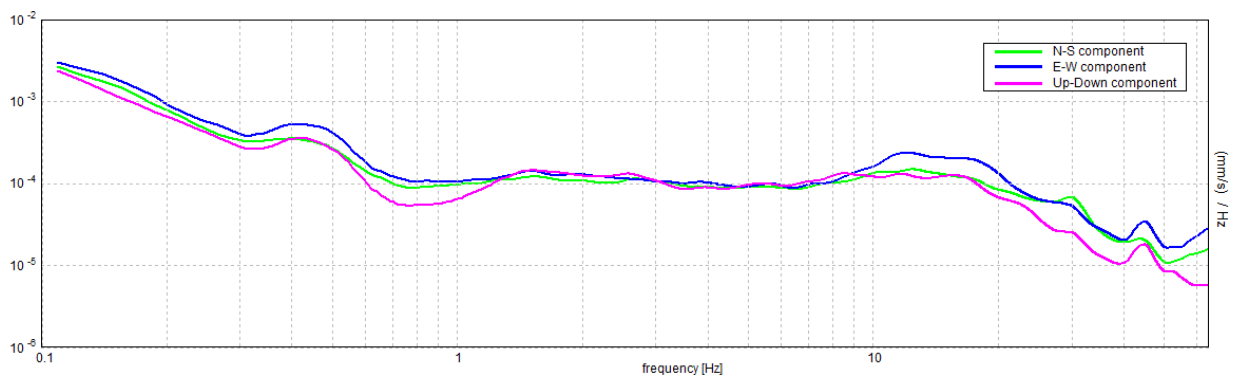
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.72 ± 0.04 Hz (in the range 0.1 - 20.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

| | | | |
|--|----------------------------|----|--|
| $f_0 > 10 / L_w$ | $0.72 > 0.17$ | OK | |
| $n_c(f_0) > 200$ | $2501.3 > 200$ | OK | |
| $\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$ | Exceeded 0 out of 70 times | OK | |

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

| | | | |
|---|---------------------|----|----|
| Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$ | | | NO |
| Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$ | 1.328 Hz | OK | |
| $A_0 > 2$ | $1.97 > 2$ | | NO |
| $f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$ | $ 0.02999 < 0.05$ | OK | |
| $\sigma_f < \varepsilon(f_0)$ | $0.02156 < 0.10781$ | OK | |
| $\sigma_A(f_0) < \theta(f_0)$ | $0.3031 < 2.0$ | OK | |

| | |
|------------------------|---|
| L_w | window length |
| n_w | number of windows used in the analysis |
| $n_c = L_w n_w f_0$ | number of significant cycles |
| f | current frequency |
| f_0 | H/V peak frequency |
| σ_f | standard deviation of H/V peak frequency |
| $\varepsilon(f_0)$ | threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$ |
| A_0 | H/V peak amplitude at frequency f_0 |
| $A_{H/V}(f)$ | H/V curve amplitude at frequency f |
| f^- | frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$ |
| f^+ | frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$ |
| $\sigma_A(f)$ | standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided |
| $\sigma_{\log H/V}(f)$ | standard deviation of $\log A_{H/V}(f)$ curve |
| $\theta(f_0)$ | threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$ |

Threshold values for σ_f and $\sigma_A(f_0)$

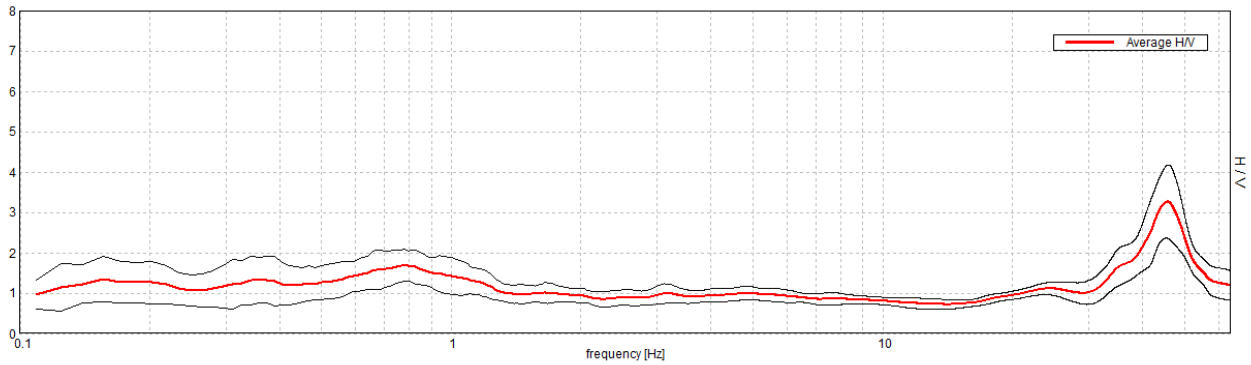
| Freq. range [Hz] | < 0.2 | 0.2 – 0.5 | 0.5 – 1.0 | 1.0 – 2.0 | > 2.0 |
|---|------------|-----------|------------|------------|------------|
| $\varepsilon(f_0)$ [Hz] | $0.25 f_0$ | $0.2 f_0$ | $0.15 f_0$ | $0.10 f_0$ | $0.05 f_0$ |
| $\theta(f_0)$ for $\sigma_A(f_0)$ | 3.0 | 2.5 | 2.0 | 1.78 | 1.58 |
| $\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$ | 0.48 | 0.40 | 0.30 | 0.25 | 0.20 |

CASTENASO_MS, TR4 VIA DELLO SPORT 037021P37507HVSR539

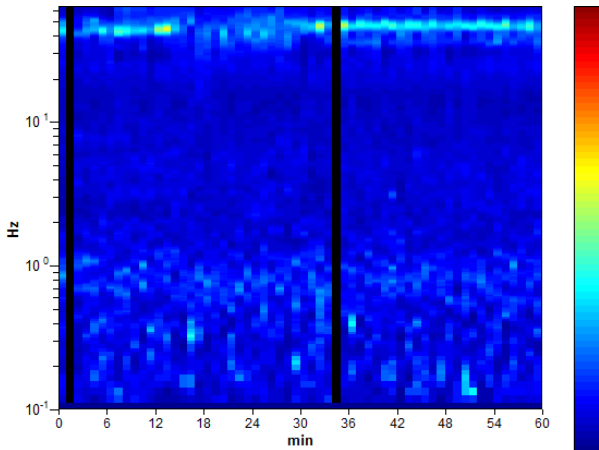
Instrument: TRZ-0108/01-10
 Start recording: 16/12/01 14:22:24 End recording: 16/12/01 15:22:24
 Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
 Trace length: 1h00'00". Analyzed 97% trace (manual window selection)
 Sampling rate: 128 Hz
 Window size: 60 s
 Smoothing type: Triangular window
 Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

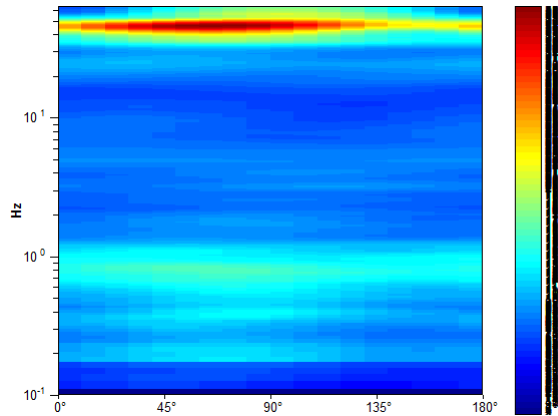
Max. H/V at 0.78 ± 0.03 Hz. (In the range 0.1 - 20.0 Hz).



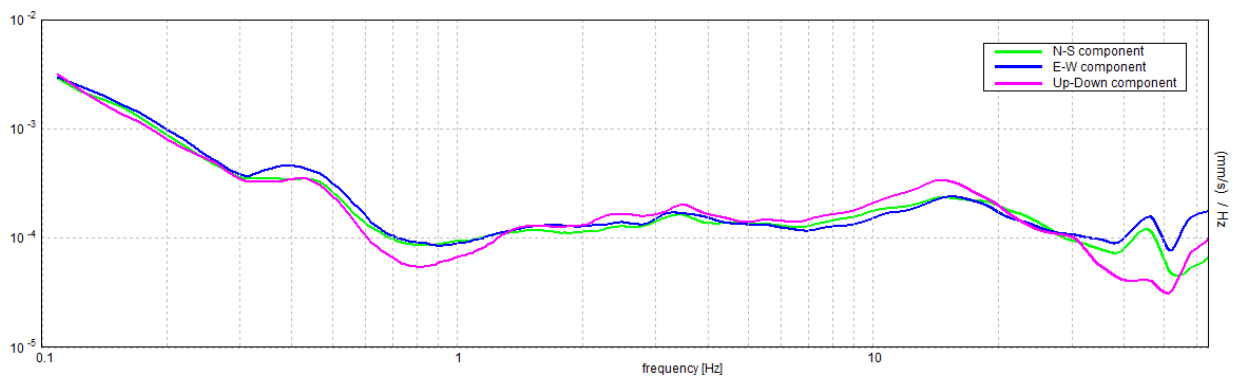
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.78 ± 0.03 Hz (in the range 0.1 - 20.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

| | | | |
|--|----------------------------|----|--|
| $f_0 > 10 / L_w$ | $0.78 > 0.17$ | OK | |
| $n_c(f_0) > 200$ | $2718.8 > 200$ | OK | |
| $\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$ | Exceeded 0 out of 76 times | OK | |

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

| | | | |
|---|---------------------|----|----|
| Exists f^- in $[f_0/4, f_0]$ $A_{H/V}(f^-) < A_0 / 2$ | | | NO |
| Exists f^+ in $[f_0, 4f_0]$ $A_{H/V}(f^+) < A_0 / 2$ | | | NO |
| $A_0 > 2$ | $1.68 > 2$ | | NO |
| $f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$ | $ 0.01755 < 0.05$ | OK | |
| $\sigma_f < \varepsilon(f_0)$ | $0.01371 < 0.11719$ | OK | |
| $\sigma_A(f_0) < \theta(f_0)$ | $0.1971 < 2.0$ | OK | |

| | |
|------------------------|---|
| L_w | window length |
| n_w | number of windows used in the analysis |
| $n_c = L_w n_w f_0$ | number of significant cycles |
| f | current frequency |
| f_0 | H/V peak frequency |
| σ_f | standard deviation of H/V peak frequency |
| $\varepsilon(f_0)$ | threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$ |
| A_0 | H/V peak amplitude at frequency f_0 |
| $A_{H/V}(f)$ | H/V curve amplitude at frequency f |
| f^- | frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$ |
| f^+ | frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$ |
| $\sigma_A(f)$ | standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided |
| $\sigma_{\log H/V}(f)$ | standard deviation of $\log A_{H/V}(f)$ curve |
| $\theta(f_0)$ | threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$ |

Threshold values for σ_f and $\sigma_A(f_0)$

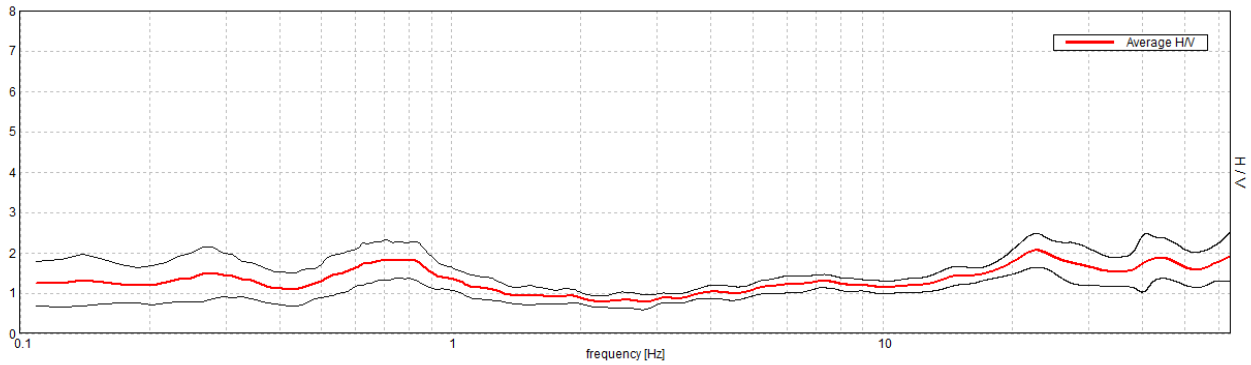
| Freq. range [Hz] | < 0.2 | 0.2 – 0.5 | 0.5 – 1.0 | 1.0 – 2.0 | > 2.0 |
|---|------------|-----------|------------|------------|------------|
| $\varepsilon(f_0)$ [Hz] | $0.25 f_0$ | $0.2 f_0$ | $0.15 f_0$ | $0.10 f_0$ | $0.05 f_0$ |
| $\theta(f_0)$ for $\sigma_A(f_0)$ | 3.0 | 2.5 | 2.0 | 1.78 | 1.58 |
| $\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$ | 0.48 | 0.40 | 0.30 | 0.25 | 0.20 |

CASTENASO_MS, TR5 VIA EINSTEIN 037021P37508HVSR540

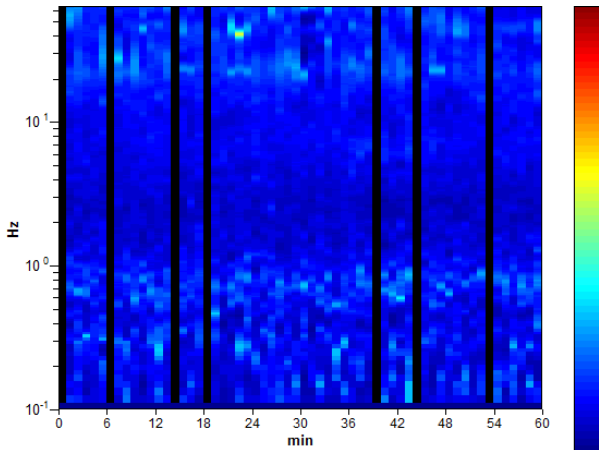
Instrument: TRZ-0108/01-10
 Start recording: 18/01/02 14:08:14 End recording: 18/01/02 15:08:15
 Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
 Trace length: 1h00'00". Analyzed 88% trace (manual window selection)
 Sampling rate: 128 Hz
 Window size: 60 s
 Smoothing type: Triangular window
 Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

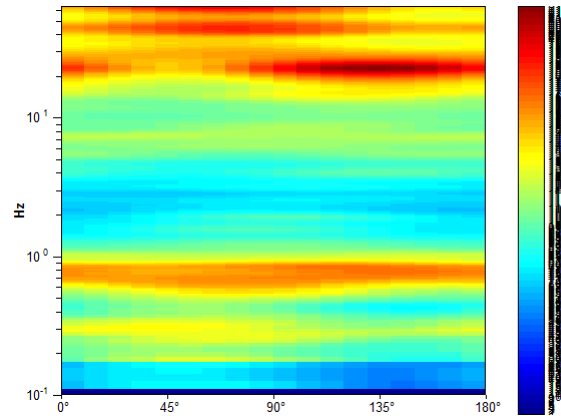
Max. H/V at 0.77 ± 4.03 Hz (in the range 0.1 - 20.0 Hz).



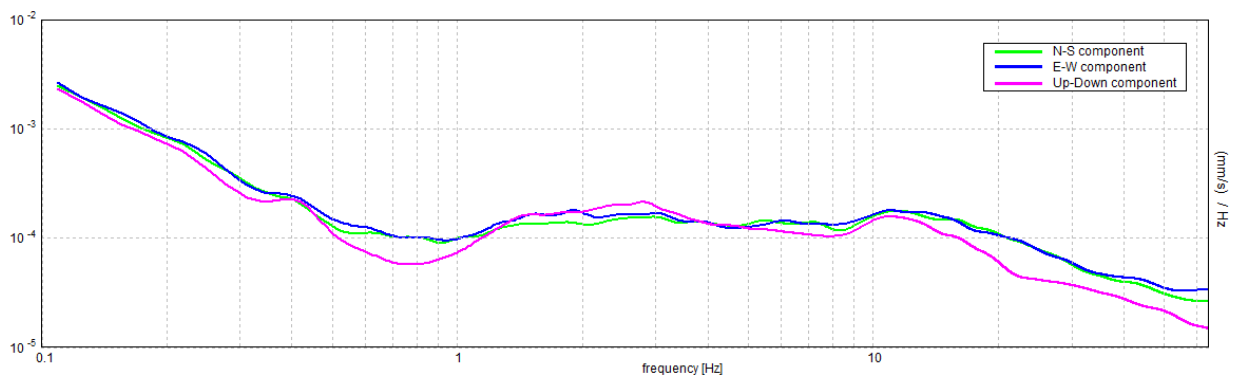
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the Grilla manual before interpreting the following tables.]

Max. H/V at 0.77 ± 4.03 Hz (in the range 0.1 - 20.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

| | | | |
|--|----------------------------|----|--|
| $f_0 > 10 / L_w$ | $0.77 > 0.17$ | OK | |
| $n_c(f_0) > 200$ | $2434.7 > 200$ | OK | |
| $\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$ | Exceeded 0 out of 74 times | OK | |

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

| | | | |
|---|---------------------|----|----|
| Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$ | | | NO |
| Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$ | 1.719 Hz | OK | |
| $A_0 > 2$ | $1.82 > 2$ | | NO |
| $f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$ | $ 2.59629 < 0.05$ | | NO |
| $\sigma_f < \varepsilon(f_0)$ | $1.98779 < 0.11484$ | | NO |
| $\sigma_A(f_0) < \theta(f_0)$ | $0.2179 < 2.0$ | OK | |

| | |
|------------------------|---|
| L_w | window length |
| n_w | number of windows used in the analysis |
| $n_c = L_w n_w f_0$ | number of significant cycles |
| f | current frequency |
| f_0 | H/V peak frequency |
| σ_f | standard deviation of H/V peak frequency |
| $\varepsilon(f_0)$ | threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$ |
| A_0 | H/V peak amplitude at frequency f_0 |
| $A_{H/V}(f)$ | H/V curve amplitude at frequency f |
| f^- | frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$ |
| f^+ | frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$ |
| $\sigma_A(f)$ | standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided |
| $\sigma_{\log H/V}(f)$ | standard deviation of $\log A_{H/V}(f)$ curve |
| $\theta(f_0)$ | threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$ |

Threshold values for σ_f and $\sigma_A(f_0)$

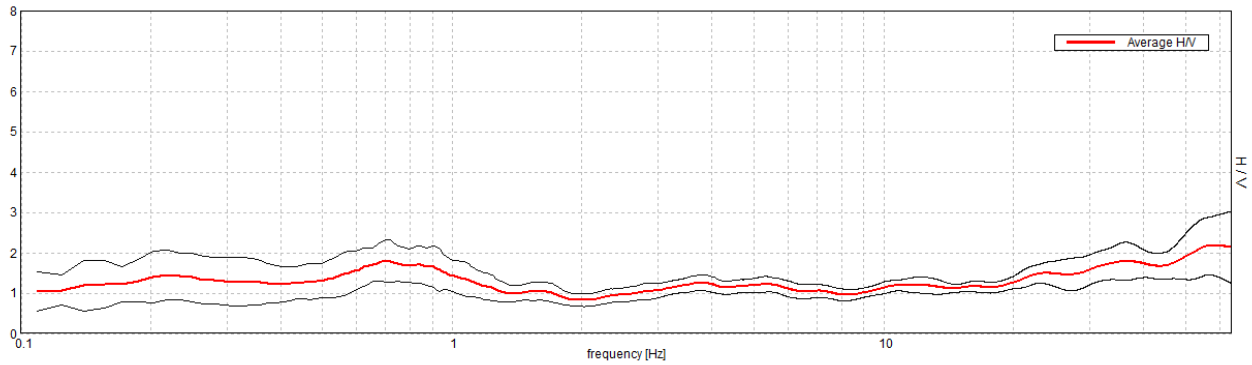
| Freq. range [Hz] | < 0.2 | 0.2 – 0.5 | 0.5 – 1.0 | 1.0 – 2.0 | > 2.0 |
|---|------------|-----------|------------|------------|------------|
| $\varepsilon(f_0)$ [Hz] | $0.25 f_0$ | $0.2 f_0$ | $0.15 f_0$ | $0.10 f_0$ | $0.05 f_0$ |
| $\theta(f_0)$ for $\sigma_A(f_0)$ | 3.0 | 2.5 | 2.0 | 1.78 | 1.58 |
| $\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$ | 0.48 | 0.40 | 0.30 | 0.25 | 0.20 |

CASTENASO_MS, TR6 VIA BENTIVOGLI 037021P37509HVSR541

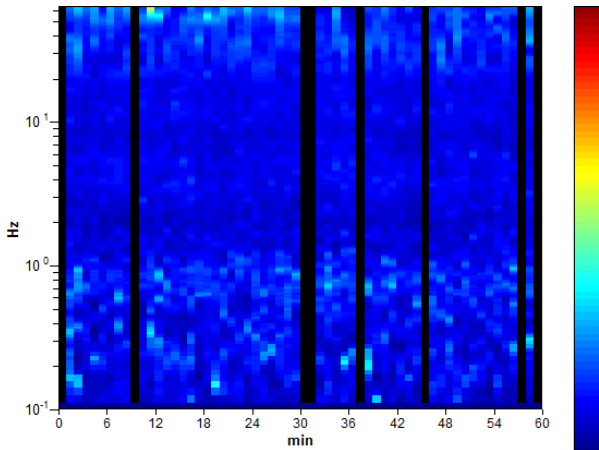
Instrument: TRZ-0108/01-10
 Start recording: 19/01/02 11:31:33 End recording: 19/01/02 12:31:34
 Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN
 Trace length: 1h00'00". Analyzed 87% trace (manual window selection)
 Sampling rate: 128 Hz
 Window size: 60 s
 Smoothing type: Triangular window
 Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

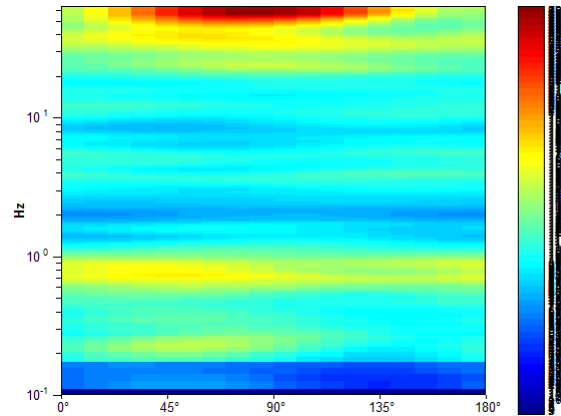
Max. H/V at 0.7 ± 0.04 Hz. (In the range 0.1 - 20.0 Hz).



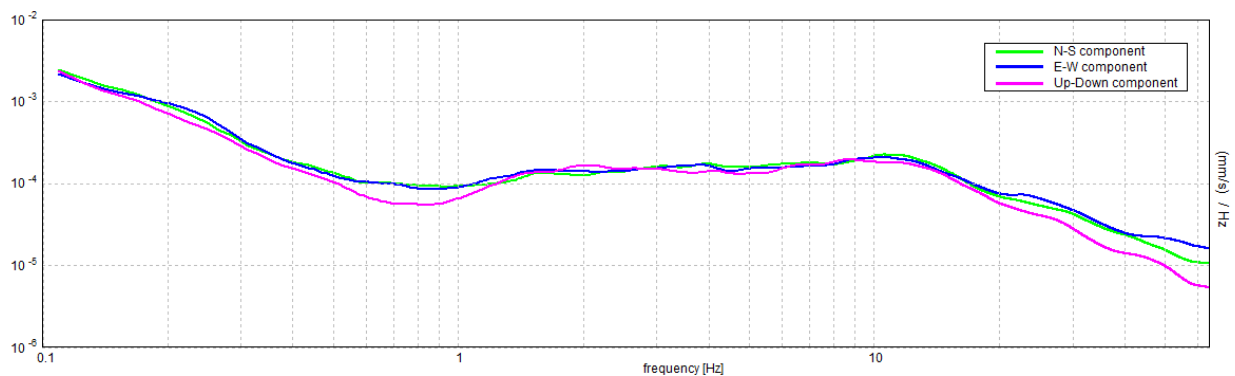
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.7 ± 0.04 Hz (in the range 0.1 - 20.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

| | | | |
|--|----------------------------|----|--|
| $f_0 > 10 / L_w$ | $0.70 > 0.17$ | OK | |
| $n_c(f_0) > 200$ | $2193.8 > 200$ | OK | |
| $\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$ | Exceeded 0 out of 68 times | OK | |

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

| | | | |
|---|---------------------|----|----|
| Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$ | | | NO |
| Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$ | 1.813 Hz | OK | |
| $A_0 > 2$ | $1.79 > 2$ | | NO |
| $f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$ | $ 0.0263 < 0.05$ | OK | |
| $\sigma_f < \varepsilon(f_0)$ | $0.01849 < 0.10547$ | OK | |
| $\sigma_A(f_0) < \theta(f_0)$ | $0.2571 < 2.0$ | OK | |

| | |
|------------------------|---|
| L_w | window length |
| n_w | number of windows used in the analysis |
| $n_c = L_w n_w f_0$ | number of significant cycles |
| f | current frequency |
| f_0 | H/V peak frequency |
| σ_f | standard deviation of H/V peak frequency |
| $\varepsilon(f_0)$ | threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$ |
| A_0 | H/V peak amplitude at frequency f_0 |
| $A_{H/V}(f)$ | H/V curve amplitude at frequency f |
| f^- | frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$ |
| f^+ | frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$ |
| $\sigma_A(f)$ | standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided |
| $\sigma_{\log H/V}(f)$ | standard deviation of $\log A_{H/V}(f)$ curve |
| $\theta(f_0)$ | threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$ |

Threshold values for σ_f and $\sigma_A(f_0)$

| Freq. range [Hz] | < 0.2 | 0.2 – 0.5 | 0.5 – 1.0 | 1.0 – 2.0 | > 2.0 |
|---|------------|-----------|------------|------------|------------|
| $\varepsilon(f_0)$ [Hz] | $0.25 f_0$ | $0.2 f_0$ | $0.15 f_0$ | $0.10 f_0$ | $0.05 f_0$ |
| $\theta(f_0)$ for $\sigma_A(f_0)$ | 3.0 | 2.5 | 2.0 | 1.78 | 1.58 |
| $\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$ | 0.48 | 0.40 | 0.30 | 0.25 | 0.20 |

CASTENASO_MS, TR7 FIESSO

037021P37510HVSR542

Instrument: TRZ-0108/01-10

Start recording: 18/01/02 15:22:28 End recording: 18/01/02 16:22:29

Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN

Trace length: 1h00'00". Analyzed 93% trace (manual window selection)

Sampling rate: 128 Hz

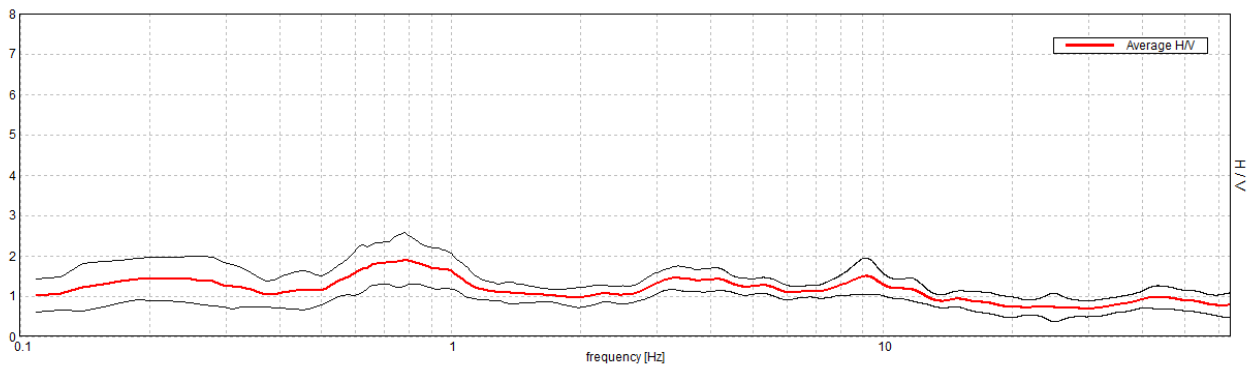
Window size: 60 s

Smoothing type: Triangular window

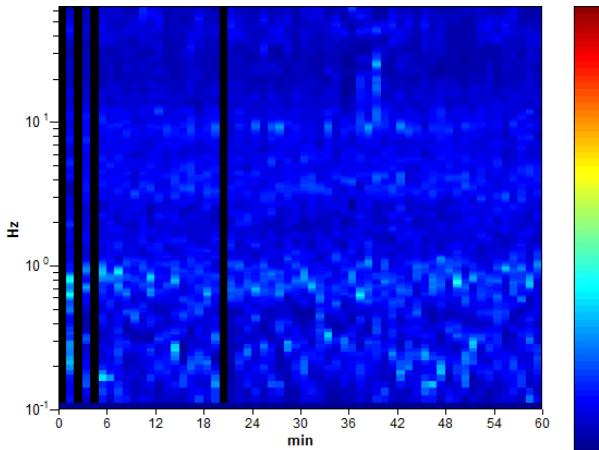
Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

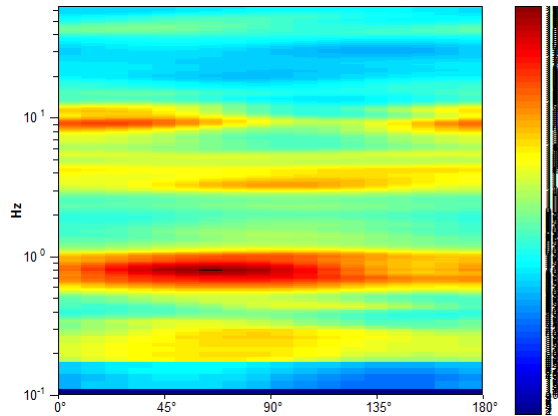
Max. H/V at 0.78 ± 0.02 Hz. (In the range 0.1 - 20.0 Hz).



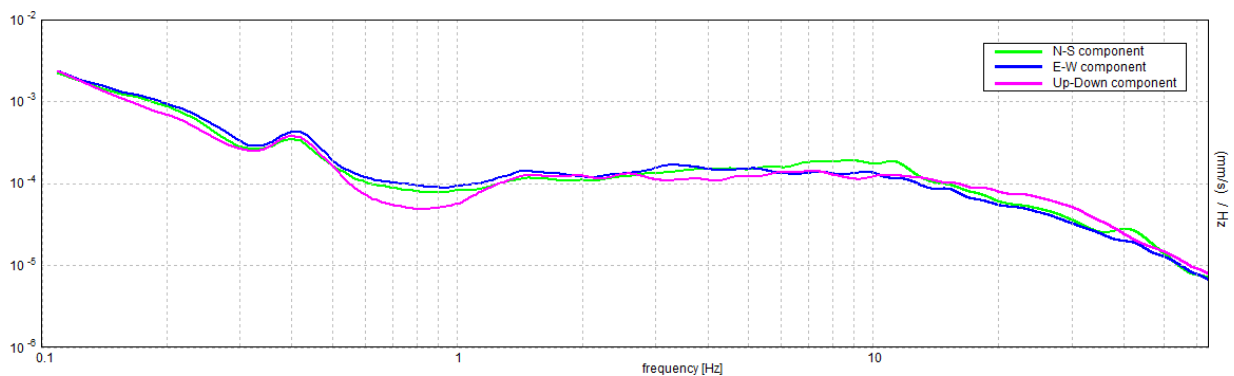
H/V TIME HISTORY



DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.78 ± 0.02 Hz (in the range 0.1 - 20.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

| | | | |
|--|----------------------------|----|--|
| $f_0 > 10 / L_w$ | $0.78 > 0.17$ | OK | |
| $n_c(f_0) > 200$ | $2625.0 > 200$ | OK | |
| $\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$ | Exceeded 0 out of 76 times | OK | |

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

| | | | |
|---|---------------------|----|----|
| Exists f^- in $[f_0/4, f_0]$ $A_{H/V}(f^-) < A_0 / 2$ | | | NO |
| Exists f^+ in $[f_0, 4f_0]$ $A_{H/V}(f^+) < A_0 / 2$ | | | NO |
| $A_0 > 2$ | $1.91 > 2$ | | NO |
| $f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$ | $ 0.01001 < 0.05$ | OK | |
| $\sigma_f < \varepsilon(f_0)$ | $0.00782 < 0.11719$ | OK | |
| $\sigma_A(f_0) < \theta(f_0)$ | $0.3338 < 2.0$ | OK | |

| | |
|------------------------|---|
| L_w | window length |
| n_w | number of windows used in the analysis |
| $n_c = L_w n_w f_0$ | number of significant cycles |
| f | current frequency |
| f_0 | H/V peak frequency |
| σ_f | standard deviation of H/V peak frequency |
| $\varepsilon(f_0)$ | threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$ |
| A_0 | H/V peak amplitude at frequency f_0 |
| $A_{H/V}(f)$ | H/V curve amplitude at frequency f |
| f^- | frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$ |
| f^+ | frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$ |
| $\sigma_A(f)$ | standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided |
| $\sigma_{\log H/V}(f)$ | standard deviation of $\log A_{H/V}(f)$ curve |
| $\theta(f_0)$ | threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$ |

Threshold values for σ_f and $\sigma_A(f_0)$

| Freq. range [Hz] | < 0.2 | 0.2 – 0.5 | 0.5 – 1.0 | 1.0 – 2.0 | > 2.0 |
|---|------------|-----------|------------|------------|------------|
| $\varepsilon(f_0)$ [Hz] | $0.25 f_0$ | $0.2 f_0$ | $0.15 f_0$ | $0.10 f_0$ | $0.05 f_0$ |
| $\theta(f_0)$ for $\sigma_A(f_0)$ | 3.0 | 2.5 | 2.0 | 1.78 | 1.58 |
| $\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$ | 0.48 | 0.40 | 0.30 | 0.25 | 0.20 |

CASTENASO_MS, TR8 FOSSAMARZA

037021P37511HVSR543

Instrument: TRZ-0108/01-10

Start recording: 08/04/02 12:27:38 End recording: 08/04/02 13:27:39

Channel labels: NORTH SOUTH; EAST WEST ; UP DOWN

Trace length: 1h00'00". Analyzed 88% trace (manual window selection)

Sampling rate: 128 Hz

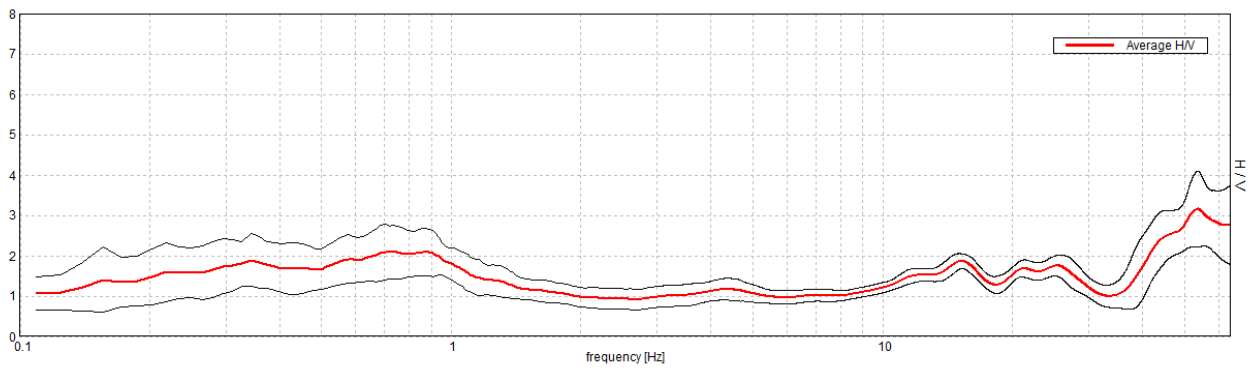
Window size: 60 s

Smoothing type: Triangular window

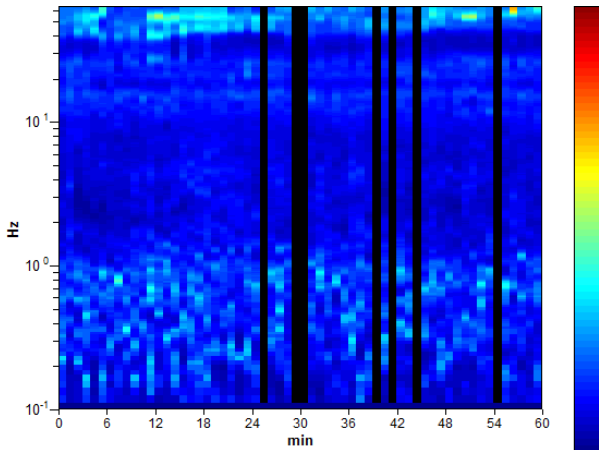
Smoothing: 10%

HORIZONTAL TO VERTICAL SPECTRAL RATIO

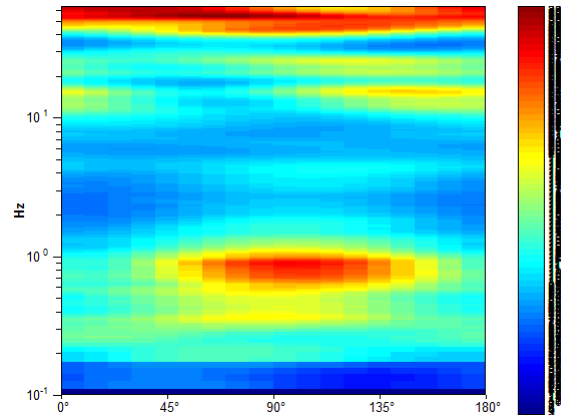
Max. H/V at 0.86 ± 0.04 Hz (in the range 0.1 - 20.0 Hz).



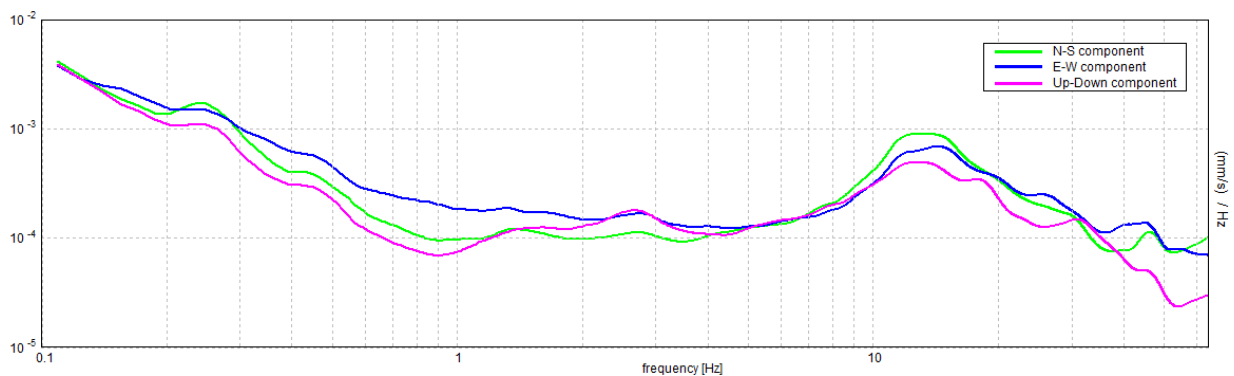
H/V TIME HISTORY



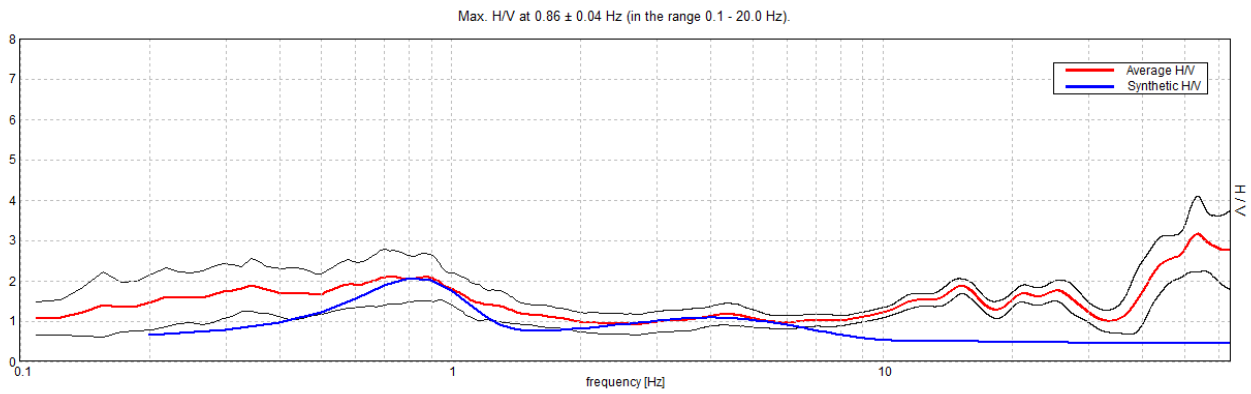
DIRECTIONAL H/V



SINGLE COMPONENT SPECTRA

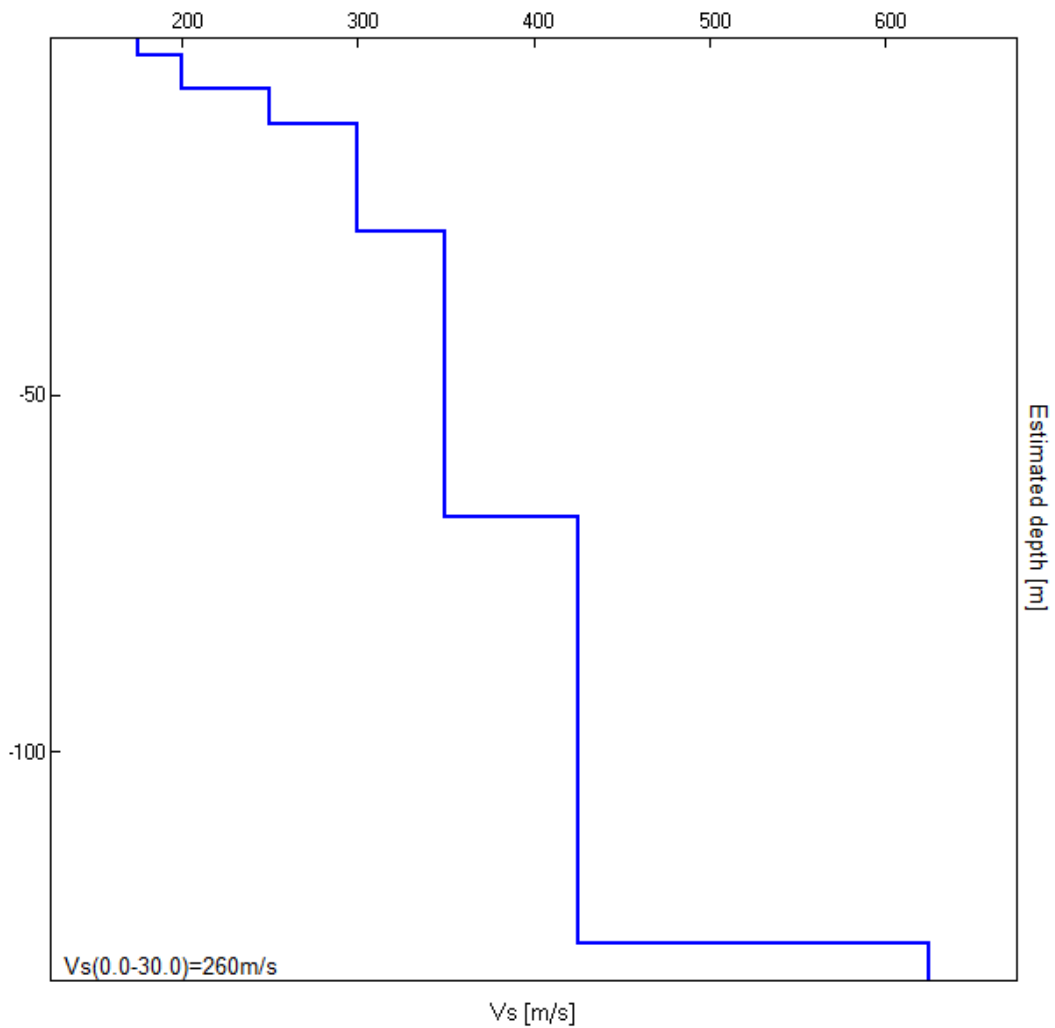


EXPERIMENTAL vs. SYNTHETIC H/V



| Depth at the bottom of the layer [m] | Thickness [m] | Vs [m/s] |
|--------------------------------------|---------------|----------|
| 2.50 | 2.50 | 175 |
| 7.00 | 4.50 | 200 |
| 12.00 | 5.00 | 250 |
| 27.00 | 15.00 | 300 |
| 67.00 | 40.00 | 350 |
| 127.00 | 60.00 | 425 |
| inf. | inf. | 625 |

Vs(0.0-30.0)=260m/s



[According to the SESAME, 2005 guidelines. Please read carefully the *Grilla* manual before interpreting the following tables.]

Max. H/V at 0.86 ± 0.04 Hz (in the range 0.1 - 20.0 Hz).

Criteria for a reliable H/V curve

[All 3 should be fulfilled]

| | | | |
|--|----------------------------|----|--|
| $f_0 > 10 / L_w$ | $0.86 > 0.17$ | OK | |
| $n_c(f_0) > 200$ | $2732.8 > 200$ | OK | |
| $\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5\text{Hz}$ $\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5\text{Hz}$ | Exceeded 0 out of 84 times | OK | |

Criteria for a clear H/V peak

[At least 5 out of 6 should be fulfilled]

| | | | |
|---|---------------------|----|-----------|
| Exists f^- in $[f_0/4, f_0] \mid A_{H/V}(f^-) < A_0 / 2$ | | | NO |
| Exists f^+ in $[f_0, 4f_0] \mid A_{H/V}(f^+) < A_0 / 2$ | 1.859 Hz | OK | |
| $A_0 > 2$ | $2.09 > 2$ | OK | |
| $f_{\text{peak}}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$ | $ 0.02399 < 0.05$ | OK | |
| $\sigma_f < \varepsilon(f_0)$ | $0.02062 < 0.12891$ | OK | |
| $\sigma_A(f_0) < \theta(f_0)$ | $0.2925 < 2.0$ | OK | |

| | |
|------------------------|---|
| L_w | window length |
| n_w | number of windows used in the analysis |
| $n_c = L_w n_w f_0$ | number of significant cycles |
| f | current frequency |
| f_0 | H/V peak frequency |
| σ_f | standard deviation of H/V peak frequency |
| $\varepsilon(f_0)$ | threshold value for the stability condition $\sigma_f < \varepsilon(f_0)$ |
| A_0 | H/V peak amplitude at frequency f_0 |
| $A_{H/V}(f)$ | H/V curve amplitude at frequency f |
| f^- | frequency between $f_0/4$ and f_0 for which $A_{H/V}(f^-) < A_0/2$ |
| f^+ | frequency between f_0 and $4f_0$ for which $A_{H/V}(f^+) < A_0/2$ |
| $\sigma_A(f)$ | standard deviation of $A_{H/V}(f)$, $\sigma_A(f)$ is the factor by which the mean $A_{H/V}(f)$ curve should be multiplied or divided |
| $\sigma_{\log H/V}(f)$ | standard deviation of $\log A_{H/V}(f)$ curve |
| $\theta(f_0)$ | threshold value for the stability condition $\sigma_A(f) < \theta(f_0)$ |

Threshold values for σ_f and $\sigma_A(f_0)$

| Freq. range [Hz] | < 0.2 | 0.2 – 0.5 | 0.5 – 1.0 | 1.0 – 2.0 | > 2.0 |
|---|------------|-----------|------------|------------|------------|
| $\varepsilon(f_0)$ [Hz] | $0.25 f_0$ | $0.2 f_0$ | $0.15 f_0$ | $0.10 f_0$ | $0.05 f_0$ |
| $\theta(f_0)$ for $\sigma_A(f_0)$ | 3.0 | 2.5 | 2.0 | 1.78 | 1.58 |
| $\log \theta(f_0)$ for $\sigma_{\log H/V}(f_0)$ | 0.48 | 0.40 | 0.30 | 0.25 | 0.20 |