Shear Wave Structure of Umbria and Marche, Italy, Strong Motion Seismometer Sites Affected by the 1997 Umbria-Marche, Italy, Earthquake Sequence

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Shear Wave Structure of Umbria and Marche, Italy, Strong Motion Seismometer Sites Affected by the 1997-98 Umbria-Marche, Italy, Earthquake Sequence

INTRODUCTION

A long sequence of earthquakes, eight with magnitudes between 5 and 6, struck the Umbria and Marche regions of central Italy between September 26, 1997 and July 1998. The earthquake swarm caused severe structural damage, particularly to masonry buildings, and resulted in the loss of twelve lives and about 150 injuries. The source of the events was a single seismogenic structure that consists of several faults with a prevailing northwest-southeast strike and crosses the Umbria-Marche border. The focal mechanism of the largest shocks indicates that the events were the product of shallow extensional normal faulting along a NE-SW extension perpendicular to the trend of the Apennines.

The network of analog seismometer stations in the Umbria and Marche regions recorded motions of the main September and October 1997 events and a dense array of mobile digital stations, installed since September 29, recorded most of the swarm. The permanent national network Rete Accelerometrica Nazionale (RAN) is administered and maintained by Dipartimento delle Protezione Civile (DPC: Civil Protection Department); the temporary array was managed by Servizio Sismico Nazionale (SSN) in cooperation with small agencies and Universities (SSN, 2002) . ENEA, the operator of many seismometer stations in Umbria, is the public Italian National Agency for New Technologies, Energy and the Environment.

Many of the temporary and permanent stations in the Italian seismic network have little or no characterization of seismic velocities (Scarserra, et al. 2008; Scarserra, et al. in press). In this study, we investigated 17 Italian sites using an active-source approach that employs low frequency harmonic waves to measure the dispersive nature of surface waves in the ground. We used the Spectral Analysis of Surface Wave (SASW) approach, coupled with an array of harmonic-wave electro-mechanical sources that are driven in-phase to excite the ground. An inversion algorithm using a non-linear least-squares best-fit method is used to compute shear wave velocities for up to 100 meters of the soil column. A draft report was published in the summer of 2008, followed by a comment period, lengthy discussions with Italian colleagues, and improved knowledge of the subsurface at the sites from soil logs. Four of the sites were reprocessed in order to correct issues with phase unwrapping of the field dispersion curves that complicated the velocity profile calculations at the lowest velocity sites. This report presents the final results from the reprocessing effort.

1997-98 Umbria-Marche, Italy, Earthquake Sequence

The regions of Umbria and Marche were shaken by two strong motion events on September 26, 1997 near Colfiorito on the Umbria-Marche border. Temporary stations were deployed in the epicentral region and recorded two large shocks on October 3 and 6. Later on October 12, 14, and November 9, swarms of quakes occurred in the vicinity of the town of Sellano.

After almost five months of relative seismic quiescence, two strong motion events occurred in the northern part of Umbria (Gualdo Tadino area) on March 26 and April 3 1998 (Decanini et al., 2002) with magnitudes of 5.6 and 5.3. The September events were the largest with magnitudes of M5.8 and M6.0. The two October quakes near Colfiorito were of M5.3 and the Sellano swarm had several major shocks that ranged from M4.5 to 5.7. In Colfiorito, the largest peak accelerations recorded were 0.38g and 0.44g horizontal and 0.33g vertical. In Nocera Umbra, the largest peak accelerations were 0.56g and 0.50g horizontal and 0.42g vertical (Trobiner et al., 1997).

The geologic setting of the rock in the mountainous Apennines of the Umbria-Marche regions consists of folded and thrust-faulted Mesozoic and Cenozoic marl, marl clays, and limestone. Valley alluvium of Pleistocene and Holocene age fill the drainages and lowland areas. In general, the region is dissected by a suite of NNW-trending Cenozoic thrust faults, now undergoing extension. The setting of faulted marine units has been the source of over a score of shallow damaging earthquakes in the past 800 years.

The Umbria-Marche earthquake swarm severely damaged hundreds of architecturally and culturally important structures, including the Basilica of St. Francesco in the town of Assisi, as well as palaces, towers, churches and historically important residences. In Foligno and Nocera Umbra, the towns' medieval towers collapsed, and numerous city gates were damaged. Severe damage was found, almost exclusively, in the stone masonry constructed structures. Strong-motion stations located within these towns, and the temporary stations set up after the initial events in more rural settings, were the object of our SASW testing program. All of the sites tested using SASW were temporary and permanent stations set up in or near the hilltop towns, or surrounding agricultural fields.

Velocity Measurements

The 17 strong-motion instrument sites were measured for velocity structure using a controlled sine wave source and the spectral analysis of surface waves (SASW) method. The SASW method of testing is a portable, inexpensive, and efficient means of non-invasively estimating the stiffness properties of the ground to depths up to 100 meters. Prior to the development of non-invasive surface wave methods, shear waves were measured in cased boreholes in rock or by penetration tests, both costly methods, using a conventional travel-time approach. For many of the sites we studied in Umbria and Marche regions, the penetration method could not sound to useful depths, and limited borehole data are available. The surface wave test apparatus is highly portable allowing us to measure in remote locations where only small all-wheel-drive vehicles can go: for example, site 263GBB, Gubbio Park Collo.

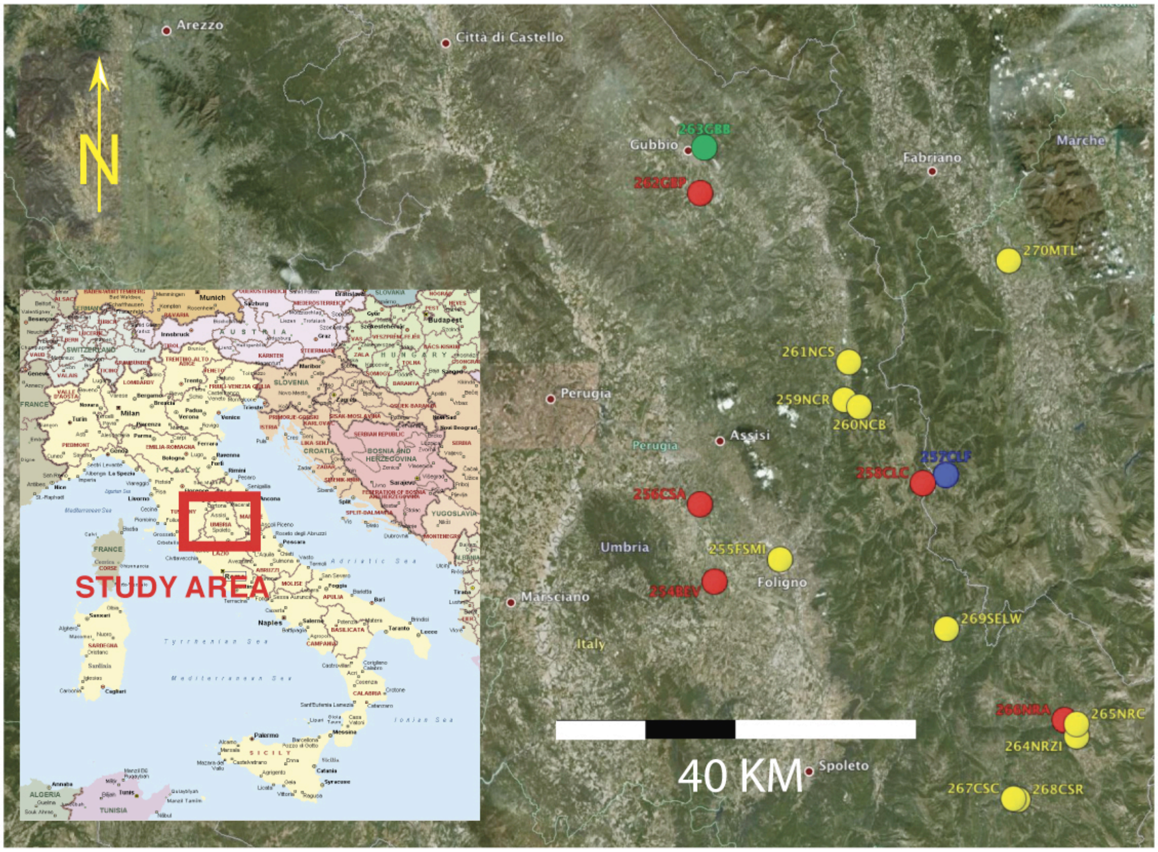

Figure 1. The seventeen Italian sites tested in this study are located in the regions of Umbria and Marche. The Google Map color of the site marker indicates NEHRP classifications for E (Blue), D (Red), C (Yellow), and B (Green) V_{s30} velocities.. Refer to Table 1 for site and velocity classification data

For the seventeen Italian sites, we use a surface wave testing system and a crew of two people to collect dispersion data. The test apparatus consist of 1-Hz seismometers, a low frequency spectrum analyzer, two computer-controlled electro-mechanical harmonic-wave sources (shakers) and their amplifiers, cables and approximately 4.0 kW of total electrical output from generators made available in each test region. The 1-Hz Kinemetrics receivers we use are designed for capturing vertical motions and cover the frequency range of interest in the active-source surface-wave test. For a source, the spectrum analyzer produces a sine wave signal that is split into a parallel circuit and by two separate power amplifiers to produce an in-phase continuous harmonic-wave. Two arrayed APS Dynamics Model 400 electro-mechanical shakers receive the input waveform and oscillate in vertical motion to excite the ground. The receivers record the waves and a fast Fourier transform (FFT) is performed on each of the two receiver signals. In near-real time, the linear spectra, cross-power spectra, and coherence are computed. The ability to perform near real-time frequency domain calculations and monitor the progress and quality of the test allows us to adjust various aspects of the test to optimize the capture of the phase data. These aspects include the source-wave generation, frequency step-size between each sine-wave burst, number of cycles-per-frequency, total frequency range of all the steps, and receiver spacing.

The dual shaker-sources are arrayed orthogonally to the SASW seismometer line. The test steps through a suite of frequencies, and for each frequency phase computations are made. This method of swept-sine surface wave testing sweeps through a broad range of low frequencies in order to capture the surface wave-dispersion characteristics of the ground. This approach is a modification of the Continuous Sine Wave Source Spectral Analysis of Surface Waves (CSS-SASW) test presented by Kayen and others (2004a; 2005).

Spacing of the receivers stepped geometrically from 1 meter to 160 meters. The two seismometers are separated by a given distance, d, and the source is usually placed at a distance of d from the inner seismometer (Figure 6). Rayleigh wave wavelengths (λ) are computed by relating the seismometer spacing (δ) and the phase angle (θ, in radians determined from the peak of the cross-power spectrum) between the seismometers:

$$\lambda = 2\pi d/\theta \quad (1)$$

The Rayleigh wave surface wave velocity, V_r, is computed as the product of the frequency and its associated wavelength:

$$V_r = f\lambda \quad (2)$$

Figure 2. Configuration of the USGS surface wave testing system at site 262GBP Gubbio Piana Soil Site (43.314°N,12.59°E) composed of 1-Hz vertical motion sensors and two-100 kg electro-mechanical harmonic wave shakers. The shaker apparatus are arrayed in a parallel circuit and synchronized in phase.

Computing the average dispersion curve for a site requires that we collect a suite of individual data sets that relate Rayleigh wave phase velocities to their corresponding frequencies and wave-lengths. Regardless of the array dimensions, we routinely compute phase velocities for phase angles between 120 degrees and 1080 degrees, corresponding to wavelengths of 3d and d/3 respectively. If the data are noisy, the range is narrowed to 180 degrees and 720 degrees, or 2d and d/2. For example, if the array separation was 3 meters, velocities are inverted for Rayleigh wavelengths of 1m-to-9meters. Longer wavelengths sound more deeply into the ground and are needed to extend profile depths. These long wavelength data are associated with low frequencies. Figure 3 presents a plot of a group of eight individual dispersion curves that together cover a range of wavelengths from 0.6 meters–to-400 meters. The averaged dispersion curve from these eight profiles is used to invert the velocity structure of the ground.

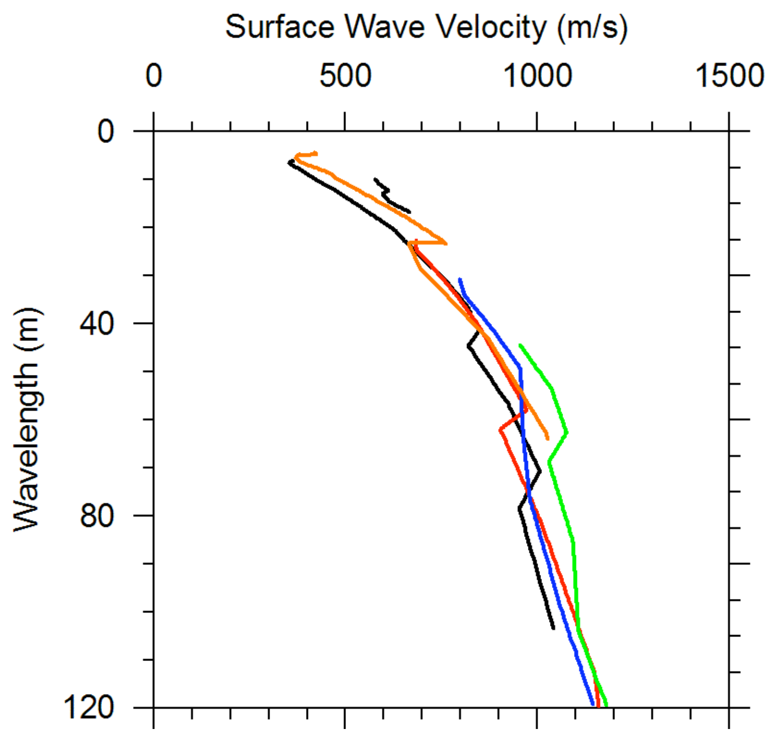

Figure 3. A group of eight dispersion curves covering a wavelength range of 1 meter to 120 meters (Site 267CSC, Cascia, Umbria).

The inversion process is used to estimate the soil stiffness model having a computed *theoretical*-dispersion curve that is a best-fit with the experimental dispersion data collected in the field. That is, we invert shear wave velocity profiles using an inversion code that hunts for the best-fit shear wave velocity profile whose theoretical dispersion curve is the closest match with the averaged field dispersion curve.

The term “best-fit” refers to the minimum sum of the squares of residuals from the differences between the theoretical and experimental dispersion curves. Several inversion algorithms are used to compute theoretical shear wave velocity profiles. The inversion algorithm, WaveEq of OYO Corp. (Hayashi and Kayen, 2003) uses an automated-numerical approach that employs a constrained least-squares fit of the theoretical and experimental dispersion curves. A second inversion algorithm, developed by Lai and Rix (1998) was used to compare with profiles generated using the OYO software. For the Cascia, Umbria site, noted above in Figure 3, we invert a shear wave velocity structure that climbs in from less than 300 m/s at the surface to in excess of 1900 m/s at 40 meters. The averaged $V_{s,30}$ value for this site is 540 m/s.

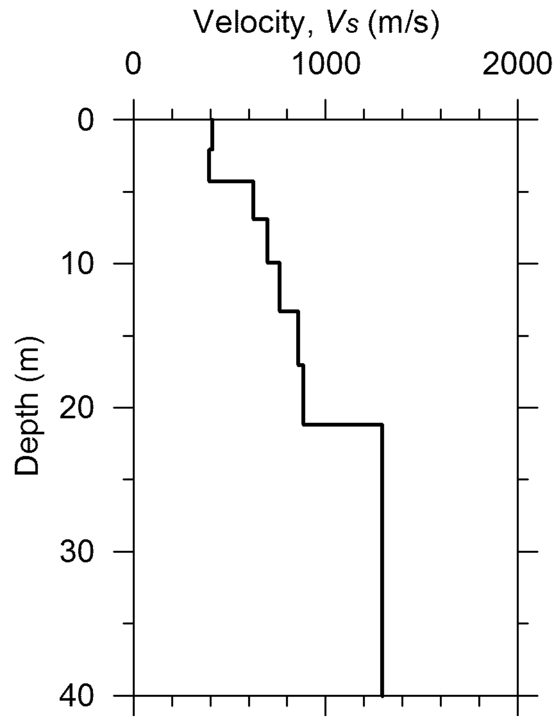

Figure 4. Shear wave velocity profile for Cascia, Umbria site 267CSC.

The testing program investigated seventeen sites in Umbria and Marche. These sites are listed in the order they were tested in Table 1. Typically, the strong motion recording (SMR) stations are located in residential or light industrial sites outside the town center, parks, or on private farm land. We located the testing system next to the SMR stations, or the GPS location of the site if we could not observe the SMR station.

SITE	SITE NAME	TOWN	REGION	LAT	LON	NEHRP	Vs_30 (m/s)	NEHRP(SUB)
254BEV	BEVAGNA	BEVAGNA	UMBRIA	42.932	12.611	D	182	D-
255FSMI	CHURCH ST MARIA	FOLIGNO	UMBRIA	42.954	12.699	C	380	C-
256CSA	CASTEL NUOVO ASSISI	ASSISI	UMBRIA	43.008	12.591	D	293	D+
257CLF	COLFIORITO	COLFIORITO	UMBRIA	43.037	12.921	E	168	E
258CLC	COLFIORITO-CASERMETTE	COLFIORITO	UMBRIA	43.029	12.890	D	296	D+
259NCR	NOCERA	NOCERA	UMBRIA	43.111	12.785	C	477	C-
260NCB	STATION-B BISCONTIN	NOCERA UMBRA - B	UMBRIA	43.104	12.805	C	393	C-
261NCS	STATION-C GRAVEL ROAD	NOCERA UMBRA - C	UMBRIA	43.148	12.791	C	585	C+
262GBP	GUBBIO SOIL SITE PIANA	GUBBIO	UMBRIA	43.314	12.590	D	281	D+
263GBB	GUBBIO - PARK COLLO	GUBBIO	UMBRIA	43.358	12.595	B	790	B-
264NCI (NRZI)	NORCIA INDUSTRIAL PARK	NORCIA	UMBRIA	42.780	13.097	C	525	C+
265NRC	NORCIA SITE C	NORCIA SITE C	UMBRIA	42.792	13.097	C	568	C+
266NRA	NORCIA TEMP. STA. A	NORCIA	UMBRIA	42.796	13.081	D	218	D-
267CSC	CASCIA	CASCIA	UMBRIA	42.719	13.012	C	540	C+
268CSR	CASCIA PETRUCCI APTMTS	CASCIA	UMBRIA	42.718	13.018	C	430	C-
269SELW	SELLANO WEST	SELLANO	UMBRIA	42.886	12.922	C	503	C-
270MTL	MATELICA	MATELICA	MARCHE	43.248	13.008	C	491	C-

Table 1. Italian station locations and their corresponding SASW and SMR site identifier, along with the computed 30-meter average shear wave velocity and NEHRP site code.

The inversion of a theoretical velocity profile was performed using the two algorithms noted above. The use of two independent algorithms is intended to provide quality control and quality assurance checks on the inverted velocity profile. For the Italian sites, the two algorithms computed similar velocity profiles when applied to the average dispersion curve. Typically, an approximately ten layer model was used for the inversion, with layer thicknesses geometrically expanding with depth. The increasing layer thicknesses correspond with decreasing dispersion information in the longer wavelength (deeper) portion of the dispersion curve. The profiles generally increase in stiffness with depth, though low velocity layers are present in several of the profiles.

The simplest way of characterizing the overall site condition is to use the average shear wave velocity in the uppermost 30 meters of the subsurface (V_{s30} from the IBC, 2002). Equation 3 is used to compute this average velocity based on the unit layer thickness (d_i) and the corresponding interval-velocity (V_{Si}).

$$V_{\substack{S-depth-\\averaged}} = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{V_{Si}}} \tag{3}$$

The Italian SMR averaged velocities for the upper 30 meters ranged from 168 to 790 m/s. The velocities fall within NEHRP categories “E”-through- “B”.

Data reprocessing of slow sites

To perform the SASW tests, we used two electromechanical shakers that work in parallel-phase to load the ground with 200-kg of dynamic force. With a frequency controlled source, the test starts from a high frequency and progresses in a stepped ('swept') sine mode to the lowest frequency setting. At four sites (Colfiorito sites 257CLF and 258CLF, Gubbio Piana site 262GBP, and Norcia temporary site 266NRA) there are very low velocity lake or marsh deposits. At these sites, the field data collection was performed incorrectly with a lowest frequency setting that was too high to capture the first phase jump (first 180° of data). For these cases, a given seismometer separation was tested with a frequency sweep range designed in order to capture data from below 180 degrees, to 720 degrees, but actually captured data above 180 degrees, so that the first phase jump was at 540 degrees. For these sites, a simple reprocessing was done to the data to add the required one phase jump (360°) to correct the dispersion curves to the proper wrapped phase number. This adjustment of exactly one phase jump of 360° properly positions the dispersion curves to their true phase. The two effects of the correction of the phase is the decrease in the computed wavelengths and velocities. The wavelength is decreased by:

$$\lambda_{(corrected)}=2\pi d/(\theta+2\pi) \tag{4}$$

.

The velocities decrease by

$$V_r = f \bullet 2\pi d/(\theta+2\pi) \tag{5}$$

The effect of correcting the phase wrap and reducing the calculated wavelength, is to ultimately reduce the depth of the sub-surface velocity profile.

Besides the reprocessing of four sites, we used the opportunity to reevaluate the other thirteen sites using the OYO code and an alternate inversion code developed by Georgia Tech University (Lai and Rix, 1998). The velocity characteristics for these sites are, either, the same or similar to the 2008 open-file report results.

Field sites

Seventeen field sites were investigated in Umbria and Marche States between November 11, 2006 and November 21, 2006. At each of these sites, we deployed SASW and micro tremor equipment to capture surface waves either actively generated by our shaker or ambient vibrations.

Site 254BVG Located in Bevagna, Umbria State, Italy. This site data was collected on November 11, 2006 at latitude N42.932, longitude E12.611. The site is located in an agricultural field several blocks from the walled town of Bevagna. This site is listed in the INGV catalog as a ITDPC network seismometer, located at the boundary of fluvial sedimentary deposits and argillaceous lacustrian deposits. The SASW test was measured on a dirt road immediately adjacent to the accelerometer structure, a masonry building. The soil profile and microtremor recording are available for the site from the INGV website. Generally, the soil profile at BVG consists of organic and inorganic fine-grained deposits to a maximum depth of 51 m, and a clean sand layer between 1.5 and 5.2 m. The location and seismometer information for the site, as well as the soil log, can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code BVG.

Site 255FSMI, located in Foligno city, Umbria State, Italy. This site data was collected on November 12, 2006 at latitude N42.95417, longitude E12.6989. The site is located in the urban center of the city of Foligno near the church of Santa Maria. This site is listed in the INGV catalog as the ENEA seismometer station FSMI and is located at the boundary of fluvial sedimentary deposits and argillaceous lacustrian deposits. The SASW test was measured in a parking lot adjacent to tennis courts, approximately one block (100 m) northwest the recording station. A station Monograph can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code FSMI, and includes a map showing the location of the station, and seismometer information for the site, as well as the surface geology and microtremor recording.

Site 256CSA is located in the Castelnuovo Assisi industrial park of Cannara, near Assisi. In Umbria State. Data for this site were collected on November 12, 2006 at latitude N43.00806°, E12.59052°. This industrial park is a light industry neighborhood approximately 1 km in area, converted from agricultural fields. The test site is 7 km southwest of the two top castle town of Assisi. The SASW test was located immediately adjacent to the CSA seismometer site, administered under the seismic network ITDPC, on recent fluvial and lake sediments of Pleistocene - Holocene age. On the INGV site CSA has a shear-wave velocity profile, surface geology map, and microtremor data. The INGV velocity profile and soil boring indicate that the upper 10 m of the site is an argillaceous lacustrian deposit, with an average velocity of 200 m/s.

In the zone from 10-50 m, there are unconsolidated sand and gravel with an average velocity of published 600 m/s. Below 50 m, the sand and gravel deposits increase in velocity to as much as 1000 m/s. A station Monograph can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code CSAD, a new station placed near the location of the original station CSA, and includes a map showing the location of the station, seismometer information for the site, surface geology, borehole data, a shear-wave velocity profile, a geologic cross-section of the site, and a micro tremor recording.

Site 257CLF is located in an agricultural area near the city of Colfiorito, in Umbria State. The sasw test was performed at latitude 43.03737° north, and Longitude 12.92118° east, approximately 90 m north east of the ENEL Seismometer station. Several detailed geologic maps are available for this site on the plane of Colfiorito, a Pleistocene and Holocene lakebed and low-lying marshy area that receives the title input from the adjacent hills. A station Monograph can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code CLF and includes a map showing the location of the station, photographs, seismometer information for the site, surface geology, a shear-wave velocity profile, and a micro tremor recording. The velocity log from the INGV site indicates a very low velocity deposit from the surface to 54 m depth that ranges between 126 and 200 m per second. Beneath the 54 m, the site enters the underlying bedrock with the published velocity of approximately 1500 m/s.

Site 258CLC is located in the town center of Colfiorito-Casermette, in a state of Umbria State. The test site was located at latitude 43.02865° north, and longitude 12.89037° East, approximately 2.5 Kilometers west southwest of site 257CLF. The data set was recorded on November 13, 2006. A station Monograph for the ITDPC station can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code CLC and includes a map showing the location of the seismometer station, photographs, surface geology, and a micro tremor recording.

Site 259NCR is located in Nocera Umbra, in Umbria State, at latitude 43.11134° north, and longitude 12.78467° East, is a residential area approximately 300 m west of the town center, on a sloped hillside. Data this site was recorded on November 14, 2006. The INGV website has information for Site NCR and a second Seismometer at the same location coded NCR two, both ENEL administered stations. The Seismometer site is founded on colluvium composed of clay silt and sand lenses to a depth of 4 m, with a velocity of approximately 200 m per sec. Beneath the surface soil deposit, is a layered clayey silty marl to a depth of approximately 8 m, with a published velocity ranging from 400- 500 m/s. Below 8m is calcareous marl with the published shear-wave velocity of between 700-950 m/s. A station Monograph can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code NCR and includes a map showing the location of the station, photographs, seismometer information for the site, surface geology, a shear-wave glossary log, and microtremor recording. No Monograph has been provided for station NCR2.

Site 260NCB is located in Nocera Umbra and is designated station “B” Biscontini. Data for this site was collected on November 14, 2006, and was located at latitude 43.10358° north, and Longitude 12.80518° East, approximately 1.5 km southeast of the town. This site is located in a alluvium-filled Valley. At the time of this writing no stratigraphic information was available for this ITDPC site at the INGV website. Basic information about the location and Operational time-window of site NCB can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*.

Site 261NCS is located at Nocera Umbra station “S”. Data for the site was collected on November 15, 2006 at location latitude 43.14835° north, and Longitude 12.79134° east, approximately 4 km north of the town. This site is at the end of a country road in a sloping stream drainage carrying alluvium from the adjacent hill slopes to the east. At the time of this writing no information was available for this site at the INGV website.

Site 262GBP is located in an agricultural site 4 km south of the town of Gubbio. The SASW test was located at latitude 43.311° north, and Longitude 12.5906° East, and collected on November 17, 2006. The local designation for this site is Gubbio Piana soil site. A published shear-wave profile for the ITDPC site is available on the INGV website and indicates a thin veneer of soil with high velocity in the range of 500 m/s, rests upon high velocity bedrock between 1500 m/s and 2000 m/s.

Site 263GBB is a steep sloping rock site above an east of the town of Gubbio at an location called Park Collo. Data for this site was collected on November 17, 2006 and is located at latitude 43.35786° north, and longitude 12.59470° East. This site is situated on limestone and marl deposits, with no soil cover. The INGV website has photographs, and a surface geology map for this site in a station Monograph at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code GBB. The monograph includes a map showing the location of the station, photographs, seismometer information, and surface geology.

Site 264NCI(NRZI) is located in Norcia industrial park, on Via Del Lavoro, in Norcia in Umbria State. Data for the site was collected on November 18, 2006 and is located at latitude 42.77974° North, and Longitude 13.09729° East. At the time of this writing no stratigraphy information was available for this site at the INGV website. Basic seismometer location information can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver* under station code NRZI.

Site 265NRC is located one block south of the walled town of Norcia. The data was collected on November 18, 2006 on Vaile Enrico Lonbrici at latitude 42.79223° north, and longitude 13.09700° East, approximately 220 m from ITDPC seismometer station NRC. A station Monograph can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code NRC and includes a map showing the location of the station, photographs, seismometer information for the site, surface geology, a shear-wave velocity profile, a standard penetration test log, and a micro tremor recording. The webpage for the site also has downloadable geotechnical data. The surface geology of the SASW test is sandy gravel fluvial and lake deposits. The shear-wave velocity profile from the ITACA web site has surface velocities of approximately 200 m/s at the surface to 665 m/s at 2 m. From 2 m to 47 m, the velocity varies between 665 m/s and 850 m/s, with the exception of a low velocity layer between 30 and 32 m. Most of this layer is composed a calcareous sand and gravel. Deeper than 48 m, the velocity drops significantly to between 240 m/s and 480 m/s in an organic rich fine-grained deposit.

Site 266NRA is located at an ENEA seismometer station site in Norcia-Altavilla, located at latitude 42.79556° north, and Longitude 13.08096° East. This site is located approximately 700 m west of the Western wall of the city of Norcia, along a roadside pullout off Vaile Umbria Road. At the time of this writing no stratigraphic information was available for this site at the INGV website. Basic seismometer location information can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver* under station code NRA.

Site 267CSC is located in the town of Cascia, in Umbria State, located at 42.71875° north, and 13.012° East behind the Hotel Delle Rose, approximately 170 m from the Monastery of Santa Rita. The data was collected on November 20, 2006. The SASW site is located on a steep hill slope is on the western side of the town. The location and seismometer information for the ITDPC site can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code CSC, as well as a map of the surface geology.

Site 268CSR is located on the hill slope east of the central town of Cascia. The SASW test was performed at latitude 42.7178 80° north, Longitude 13.01840° East, on November 20, 2006. The ITDPC seismometer site is located at the ground floor level of the Petrucci Apartments, whereas the SASW test was performed on a 100 m straight stretch of road named Via Filippo Tagliolini, off the main road Viale Cavour. At the time of this writing no stratigraphic information was available for Casca-Petrucci site at the INGV website. The location and seismometer information for the site can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code CSR.

Site 269SELW is located on the hilltop ridge in the western part of the Sellano in Umbria State. The SASW test was located at latitude 42.8860° north, longitude12.9220° East along Viale Guglielmo Marconi. A station Monograph for Sellano West can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver* under station code SELW, and includes a map showing the location of the station, photographs, seismometer information for the site, surface geology, a shear-wave velocity profile, a standard penetration test log, and a micro tremor recording. The webpage for the site also has downloadable geotechnical data. The published shear-wave velocity log for the site indicates that a low velocity surface layer (less than 200 m/s) in the upper 3 m rapidly gives away to an increasingly stiff deposit that climbs to 600 m/s or greater by 10 m. This ridge top profile probably represents surface soil over a weathered bedrock surface.

Site 270MTL in the city of Matellica in the state of Marche. The site is located at latitude 43.24841° north, Longitude 13.0079° East, and was collected on November 21, 2006. site 270 MTL has stratigraphic information on the INGV website. A 30 m borehole indicates that beneath a 1 m layer of man made-fill, is a silty sandy gravel deposit to a depth of G-8 leaders with it with thin inter-beds a finer grain inorganic silts and clays. Weathered bedrock was identified at 28 m. The location and seismometer information for the site can be found at *http://itaca.mi.ingv.it/ItacaNet/CadmoDriver*, under station code MTL.

Acknowledgments

The authors would like to thank is the Pacific Earthquake Engineering Research (PEER) Center for support of work to better characterize strong-motion recording sites shaken by significant recent events. The reprocessing of several sites are the result of improved site information available from the website of DPC-INGV, from comments and discussions with Sebastiano Foti whose interactions with the authors is supported within the framework of the S4 Project 2007-2009 grant of DPC-INGV.

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Appendix 1: Seismic s-wave velocity profile and dispersion data for seventeen Italian stations in Umbria and Marche states.

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**254BEV**
NEHRP CLASS:	**D**
Vs30 (m/s)	**182**
SUB-CLASS	**D-**

Location

SMR Station	SMI
State	UMBRIA
Description	
POSITION	BEVAGNA
LAT (N)	42.9324
LON (E)	12.6111

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	11-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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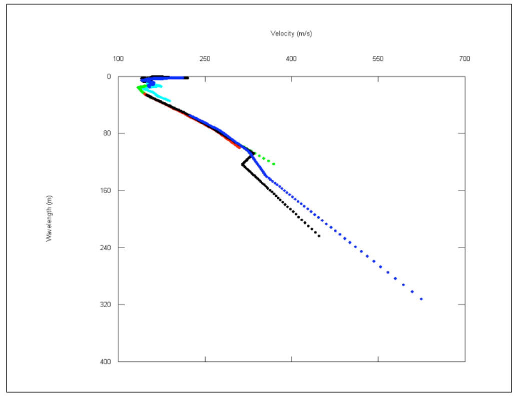
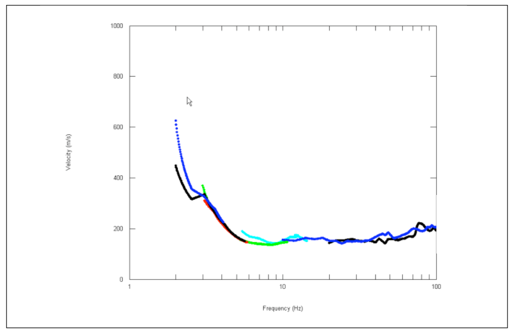
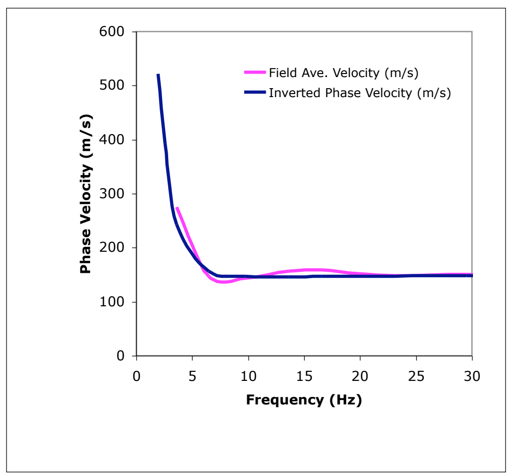


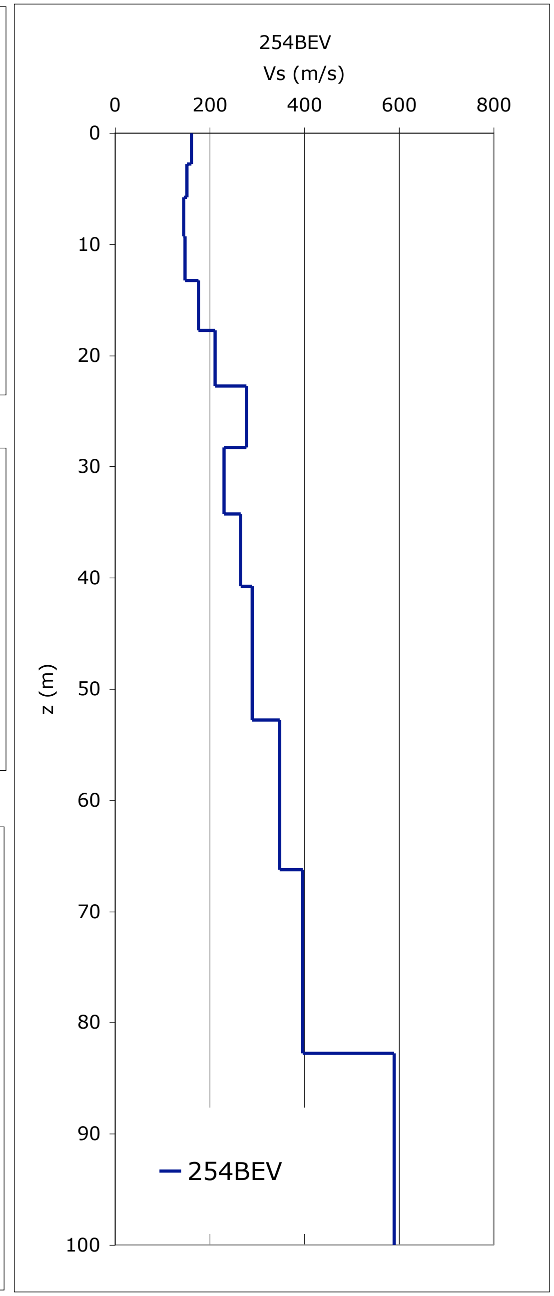
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

254BEV	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	**Theoretical Disp. Vr (m/s)**	**Frequency (Hz)**		**Inversion Vs (m/s)**	**Depth (m)**
				160.8	0.0
540.0	522.9	1.9		160.8	2.8
375.0	393.4	2.5		151.6	2.8
275.9	244.3	3.6		151.6	5.8
148.5	157.1	6.4		144.2	5.8
144.7	148.5	9.7		144.2	9.3
157.5	147.5	13.6		147.9	9.3
159.8	147.7	16.5		147.9	13.3
152.5	148.2	19.9		175.8	13.3
149.0	148.5	23.0		175.8	17.8
150.7	148.8	26.3		210.7	17.8
151.7	148.9	29.5		210.7	22.8
149.4	148.9	32.6		277.3	22.8
152.1	148.6	35.8		277.3	28.3
153.8	148.4	38.8		230.2	28.3
155.7	148.0	42.4		230.2	34.3
145.8	147.8	45.5		264.8	34.3
155.3	147.5	48.7		264.8	40.8
160.2	147.3	52.3		288.6	40.8
158.6	147.2	54.9		288.6	52.8
157.3	147.0	58.5		347.6	52.8
				347.6	66.3
				396.4	66.3
				396.4	82.8
				589.2	82.8
				589.2	100.8
				Vs30	181.8

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**255FSMI**
NEHRP CLASS:	**C**
Vs30 (m/s)	**380**
SUB-CLASS	**C-**

Location

SMR Station	FSMI
State	UMBRIA
Description	CHURCH ST MARIA
POSITION	FOLIGNO
LAT (N)	42.95417
LON (E)	12.69892

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	12-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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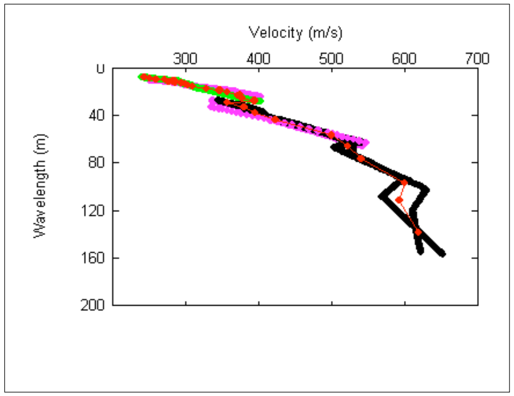
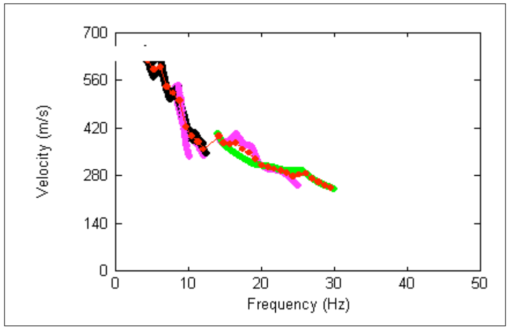
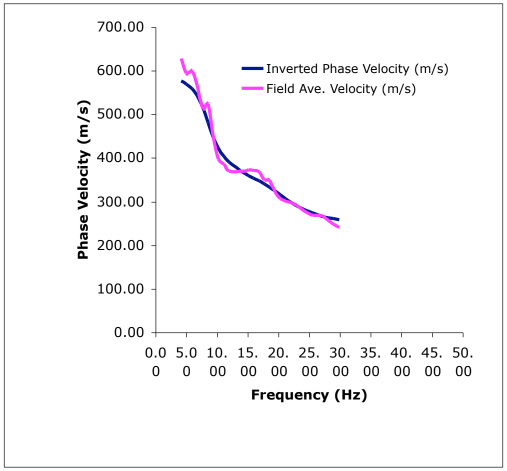


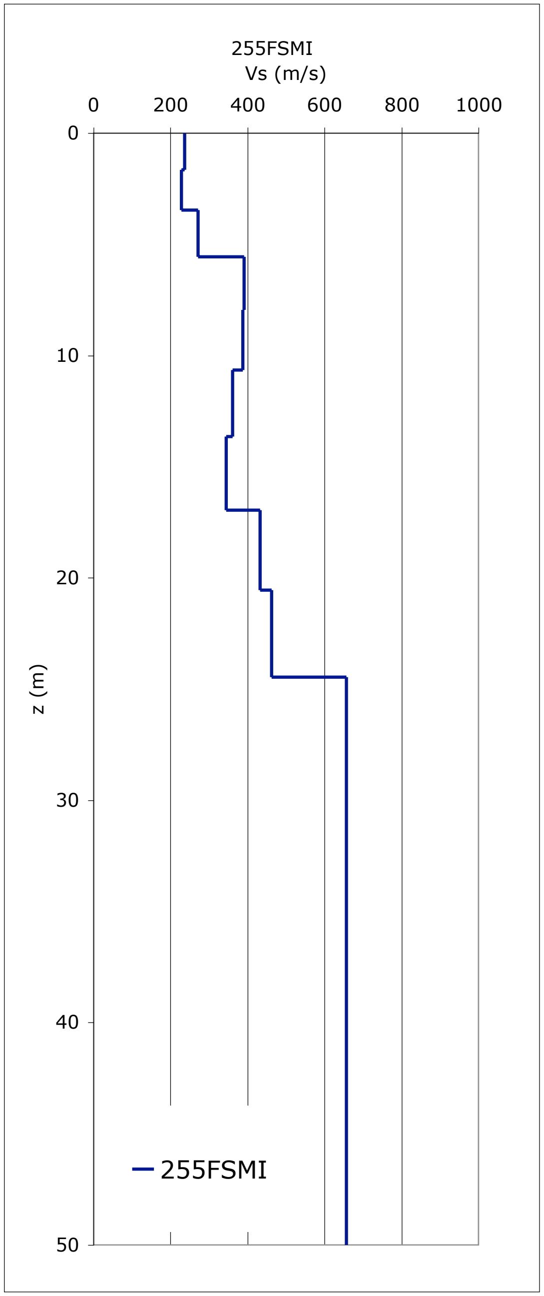
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

255FSMI	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	**Theoretical Disp. Vr (m/s)**	**Frequency (Hz)**		**Inversion Vs (m/s)**	**Depth (m)**
				236.4	0.0
629.4	578.0	4.1		236.4	1.7
596.1	570.8	4.9		227.4	1.7
600.2	560.7	5.8		227.4	3.5
567.8	544.6	6.7		270.9	3.5
513.4	518.0	7.6		270.9	5.6
524.7	483.1	8.4		390.6	5.6
451.7	449.6	9.3		390.6	8.0
399.6	423.6	10.2		387.4	8.0
388.0	404.8	11.0		387.4	10.7
370.8	391.1	11.9		360.2	10.7
370.8	368.0	14.1		360.2	13.7
374.0	361.4	15.0		344.3	13.7
372.8	355.0	15.9		344.3	17.0
369.3	348.6	16.8		431.9	17.0
350.0	341.8	17.6		431.9	20.6
350.9	334.3	18.5		461.4	20.6
323.0	325.9	19.3		461.4	24.5
308.0	317.4	20.2		656.7	24.5
302.0	308.5	21.1		656.7	40.0
299.1	300.0	21.9			
294.0	292.5	22.8			
284.1	285.8	23.7			
276.0	280.1	24.6			
270.7	275.3	25.4			
270.7	271.2	26.3			
268.9	267.6	27.1			
257.7	264.6	28.0			
249.4	262.0	28.9			
242.1	260.2	29.8			
				Vs30	380.2

UMBRIA-MARCHE, ITALY SMR Stations

Site ID 256CSA
NEHRP CLASS: D
Vs30 293 (m/s)
SUB-CLASS D+

Location

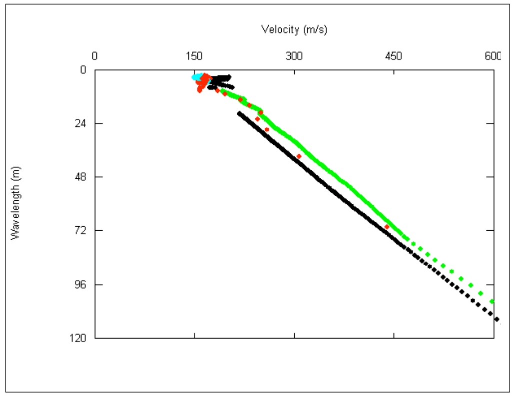
SMR Station CSAD
State UMBRIA
Description CASTEL NUOVO ASSISI
POSITION ASSISI
LAT (N) 43.0081
LON (E) 12.5905

Data Type SWEPT-SINE SASW
Investigators KAYEN, SCASSERRA
Date collected 12-Nov-2006

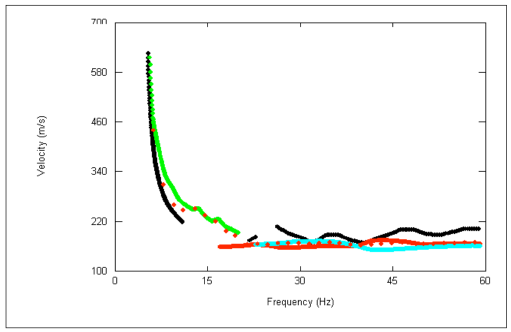
TEST METHODS PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS

PROJECT NAME UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR PEER, UNIV OF ROME

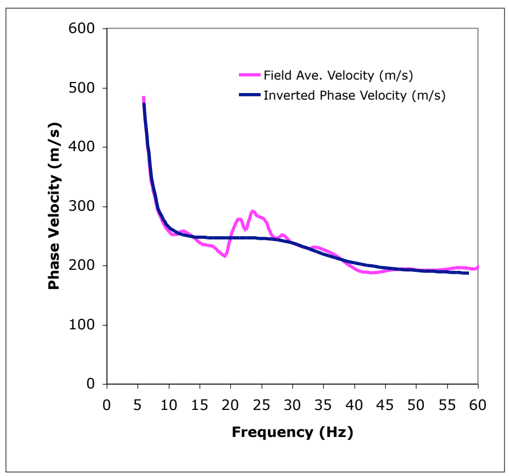
SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



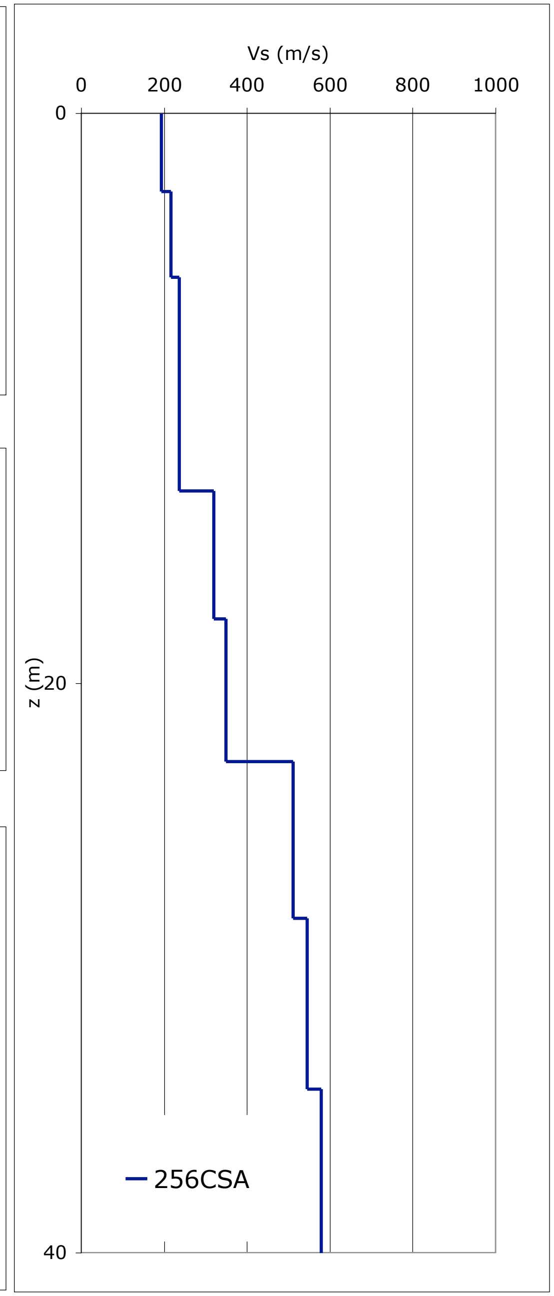
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

256CSA	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				192.7	0.0
486.1	475.3	5.9		192.7	2.8
360.5	367.6	6.9		215.4	2.8
303.5	306.9	8.0		215.4	5.8
273.0	279.2	9.0		236.1	5.8
257.8	265.3	10.0		236.1	9.3
252.1	258.2	10.9		236.6	9.3
257.8	253.1	12.1		236.6	13.3
253.7	250.5	13.1		319.3	13.3
246.1	249.0	14.1		319.3	17.8
246.1	248.1	15.2		349.3	17.8
246.1	247.7	16.2		349.3	22.8
246.1	247.5	17.2		510.1	22.8
246.1	247.5	18.3		510.1	28.3
232.7	247.5	19.3		545.3	28.3
255.7	247.5	20.2		545.3	34.3
251.4	247.5	21.4		578.2	34.3
251.4	247.5	22.4		578.2	40.8
251.4	247.3	23.4		565.8	40.8
251.4	246.9	24.4			
251.4	246.2	25.5			
251.4	245.3	26.6			
246.9	243.9	27.6			
252.1	242.1	28.6			
240.1	239.6	29.6			
235.4	236.5	30.6			
231.1	232.9	31.6			
229.5	228.9	32.6			
231.8	224.7	33.7			
228.4	220.6	34.8			
224.0	217.0	35.8			
218.1	213.7	36.8			
211.3	210.5	37.8		Vs30	293.2

UMBRIA-MARCHE, ITALY SMR Stations

Site ID **257CLF**
NEHRP CLASS: **E**
Vs30 (m/s) **168**
SUB-CLASS **E**
Reanalysis 8_2008
Location

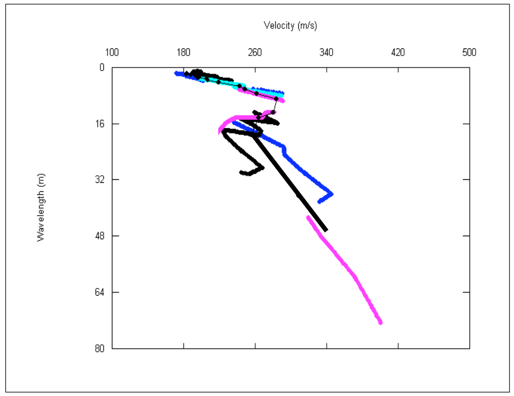
SMR Station CLF
State UMBRIA
Description COLFIORITO-NR.MARCHE BRDR
POSITION COLFIORITO
LAT (N) 43.03737
LON (E) 12.92118

Data Type SWEPT-SINE SASW
Investigators KAYEN, SCASSERRA
Date collected 11/13/200

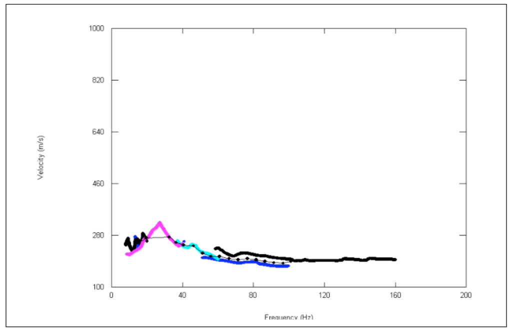
TEST METHODS PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS

PROJECT NAME UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR PEER, UNIV OF ROME

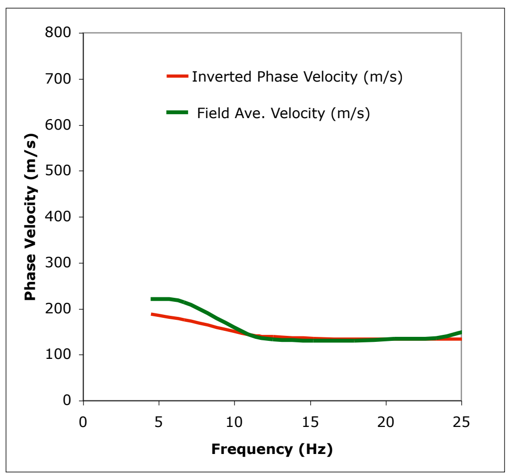
SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



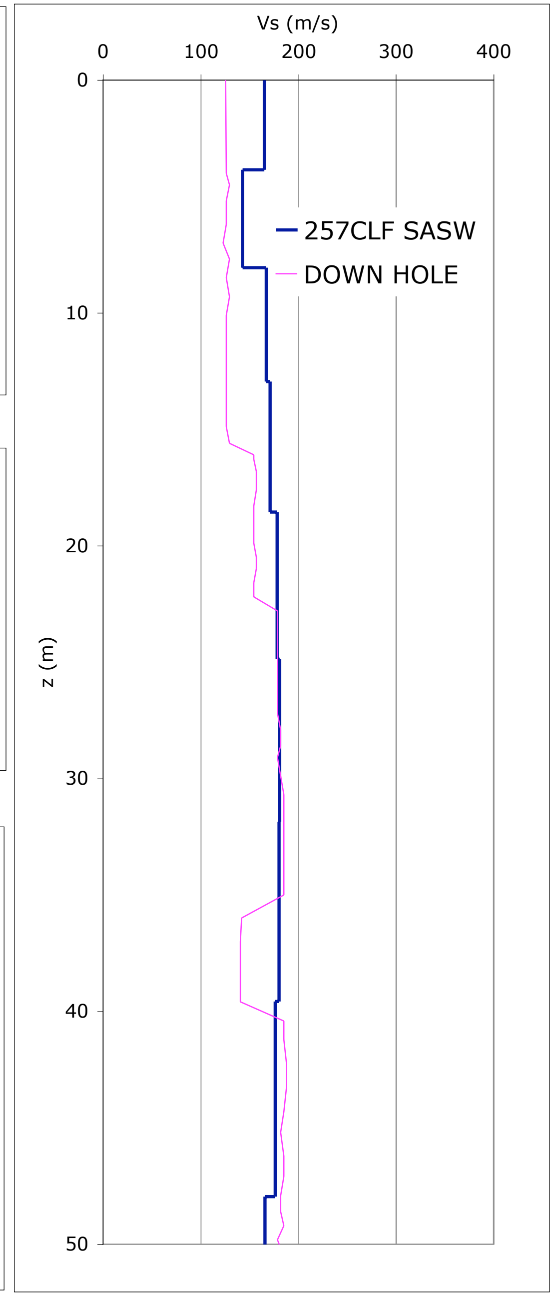
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

257CLF	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				164.8	0.0
221.6	190.0	4.5		164.8	3.9
214.7	176.5	6.6		142.9	3.9
145.3	144.7	10.9		142.9	8.1
134.2	140.1	12.5		167.2	8.1
131.6	136.7	15.2		167.2	13.0
131.2	135.5	17.9		171.1	13.0
135.6	135.3	20.6		171.1	18.6
136.4	135.5	23.3		178.4	18.6
159.0	135.8	26.2		178.4	24.9
166.7	136.2	28.7		180.6	24.9
167.5	136.6	31.4		180.6	31.9
164.9	136.9	34.1		180.1	31.9
161.1	137.1	36.8		180.1	39.6
157.4	137.2	39.3		176.3	39.6
139.4	137.2	42.1		176.3	48.0
145.2	137.1	44.8		165.4	48.0
147.6	136.8	47.5		165.4	57.1
144.0	136.5	50.2		161.7	57.1
161.5	136.1	53.0			
163.8	135.6	55.6			
161.9	135.2	58.3			
180.5	134.8	60.7			
191.6	134.3	63.7			
188.7	133.8	66.4			
185.7	133.4	69.1			
183.8	133.0	71.8			
185.1	132.7	74.5			
186.4	132.3	77.2			
187.2	132.0	79.9			
184.1	131.7	82.6			
179.1	131.4	85.3			
176.6	131.2	88.0		Vs30	168.0

UMBRIA-MARCHE, ITALY SMR Stations

Site ID **258CLC**
Site Class **D**
Vs30 (m/s) **296**
SUB-CLASS **D+**
Reanalysis Fall_2008
Location

SMR Station	CLF
State	UMBRIA
Description	COLFIORITO-CASERMETTE
POSITION	COLFIORITO
LAT (N)	43.02865
LON (E)	12.89037

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	13-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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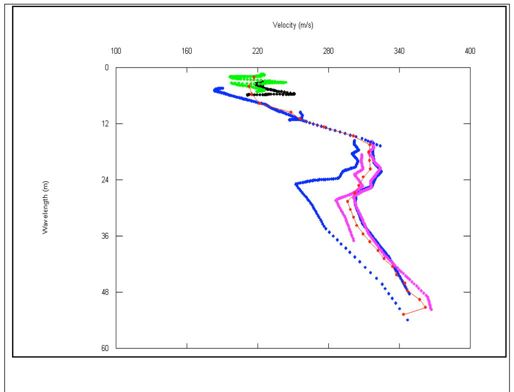
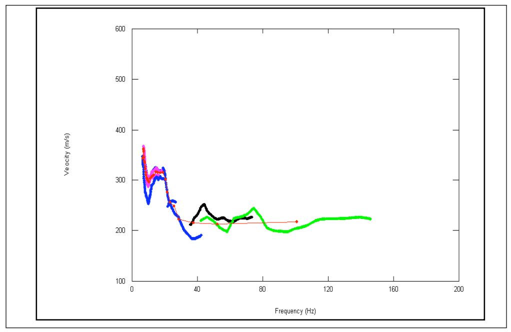
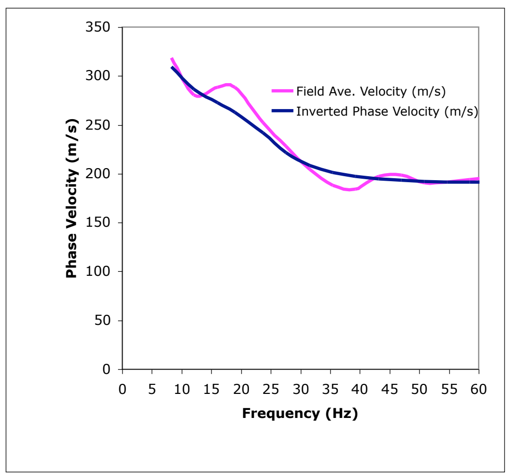


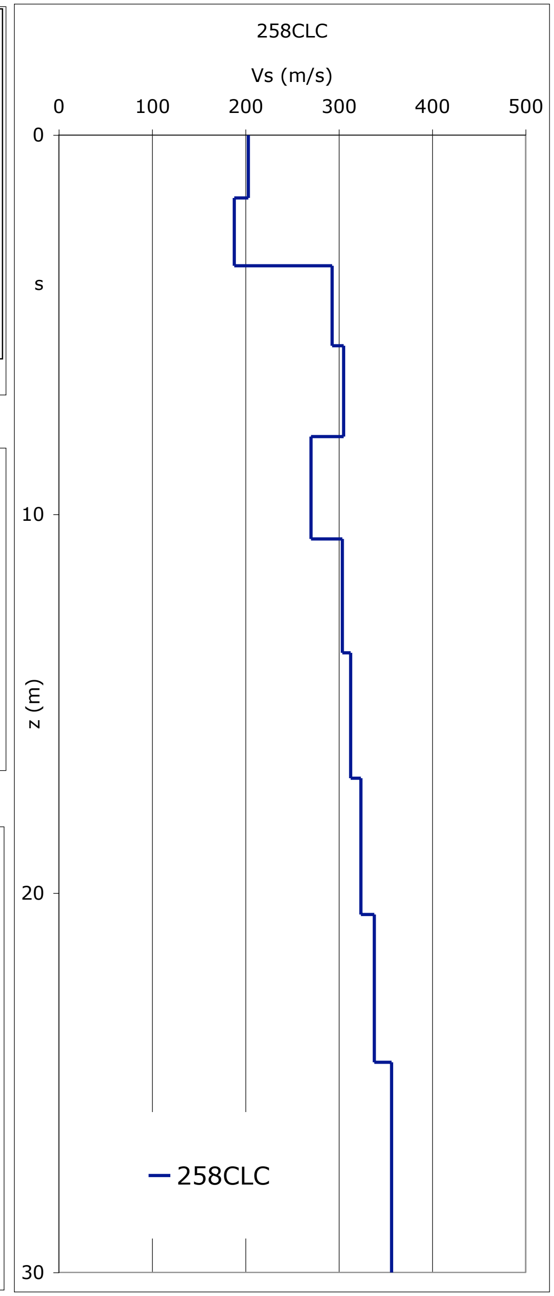
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

258CLC	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				202.8	0.0
319.3	310.3	8.1		202.8	1.7
281.4	287.0	12.0		188.0	1.7
278.8	273.3	15.9		188.0	3.5
258.7	263.7	18.9		292.7	3.5
253.0	242.2	23.6		292.7	5.6
228.9	222.0	27.5		304.8	5.6
205.2	209.0	31.4		304.8	8.0
188.7	201.9	35.3		269.6	8.0
184.8	197.7	39.1		269.6	10.7
198.1	195.2	43.1		303.5	10.7
199.4	193.8	46.8		303.5	13.7
191.7	192.8	50.7		312.6	13.7
191.8	192.3	54.6		312.6	17.0
194.8	191.9	58.4		323.6	17.0
199.5	191.9	62.3		323.6	20.6
				338.0	20.6
				338.0	24.5
				356.5	24.5
				356.5	30.0
				Vs30	295.7

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**259NCR**
NEHRP CLASS:	**C**
Vs30 (m/s)	**477**
SUB-CLASS	**C-**

Location

SMR Station	NCR
State	UMBRIA
Description	NOCERA
POSITION	NOCERA
LAT (N)	43.11134
LON (E)	12.78467

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	14-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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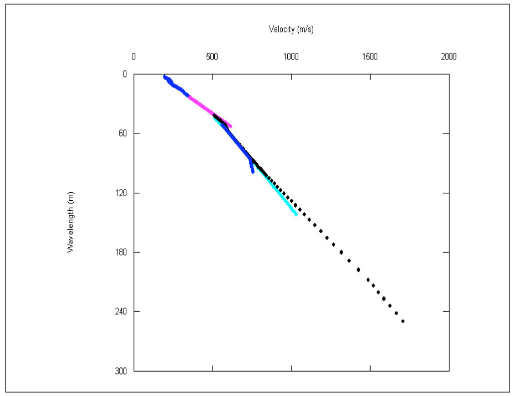
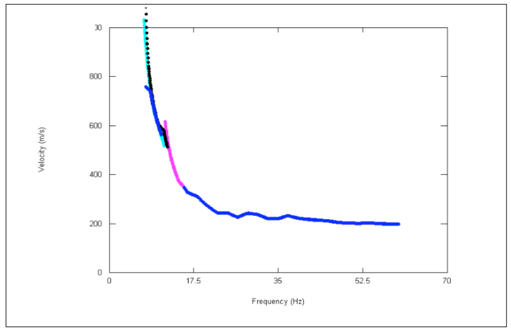
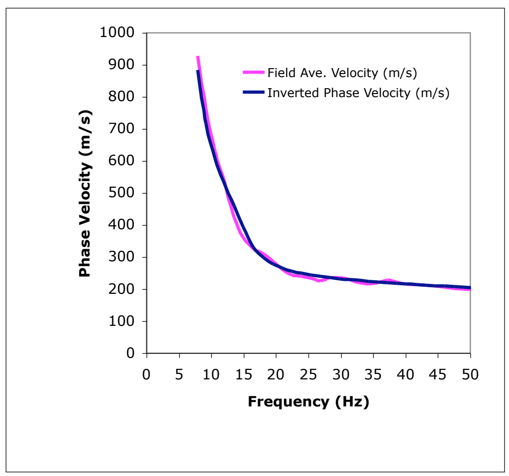


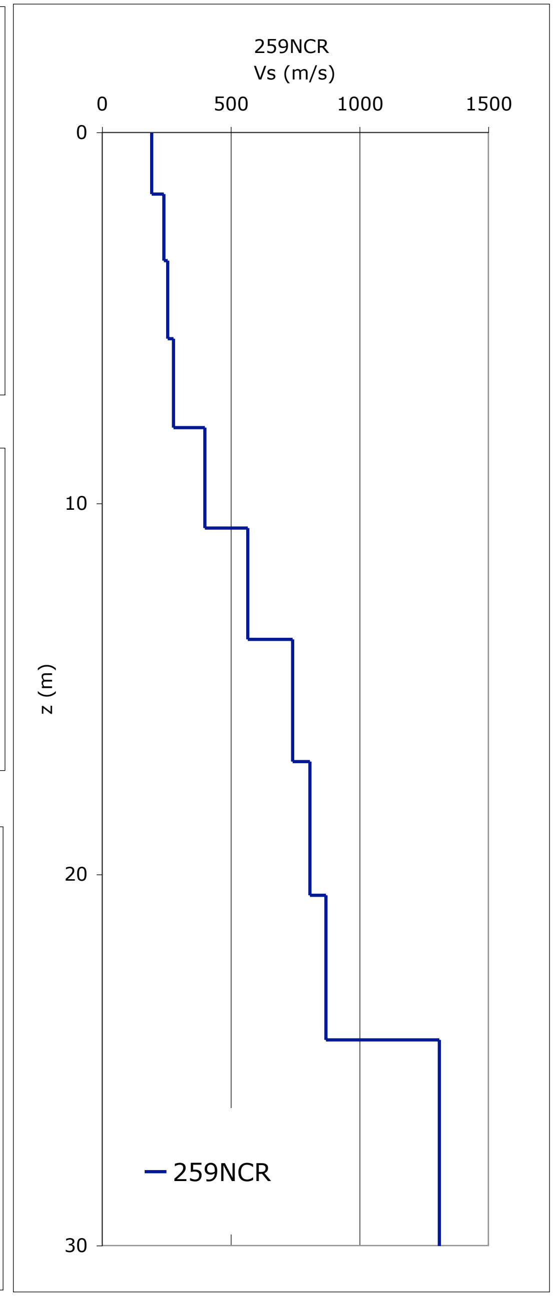
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

259NCR	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				192.4	0.0
929.0	885.2	7.8		192.4	1.7
764.1	717.3	9.1		239.1	1.7
632.7	609.3	10.5		239.1	3.5
550.7	539.5	11.8		253.6	3.5
425.8	462.0	13.5		253.6	5.6
364.5	396.7	14.8		275.9	5.6
327.3	332.8	16.4		275.9	8.0
311.8	299.5	17.9		398.8	8.0
287.2	279.6	19.4		398.8	10.7
264.2	267.1	20.9		564.7	10.7
246.6	258.1	22.3		564.7	13.7
242.8	251.2	23.8		738.1	13.7
235.9	245.7	25.3		738.1	17.0
228.0	241.3	26.8		805.3	17.0
237.4	237.7	28.3		805.3	20.6
238.8	234.6	29.7		868.1	20.6
232.3	231.7	31.2		868.1	24.5
221.2	229.1	32.7		1309.1	24.5
218.8	226.6	34.2		1309.1	30.0
222.6	224.5	35.6			
229.5	222.4	37.1			
223.9	220.3	38.6			
218.8	218.3	40.1			
215.8	216.4	41.6			
213.4	214.5	43.1			
211.3	212.8	44.5			
208.2	211.2	45.9			
203.7	209.5	47.4			
202.1	207.9	48.9			
200.9	206.4	50.4			
200.3	205.0	51.9			
201.4	203.7	53.3		Vs30	477.4

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**260NCB**
NEHRP CLASS:	**C**
Vs30 (m/s)	**393**
SUB-CLASS	**C-**

Location

SMR Station	NCB
State	UMBRIA
Description	STATION-B BISCONTIN
POSITION	NOCERA UMBRA - B
LAT (N)	43.10358
LON (E)	12.80518

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	14-Nov-2006

TEST METHODS PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS

PROJECT NAME UMBRIA-MARCHE SMR CHARACTERIZATION

SPONSOR PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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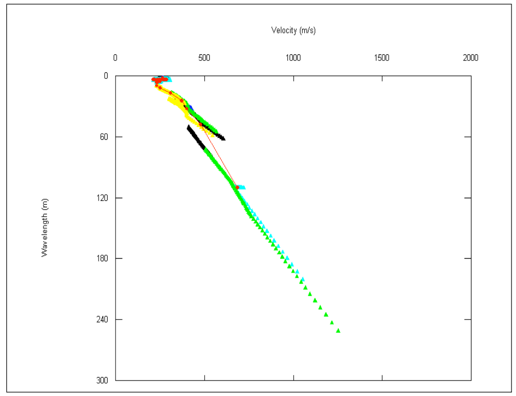
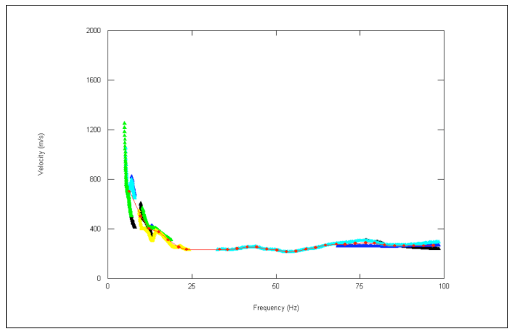
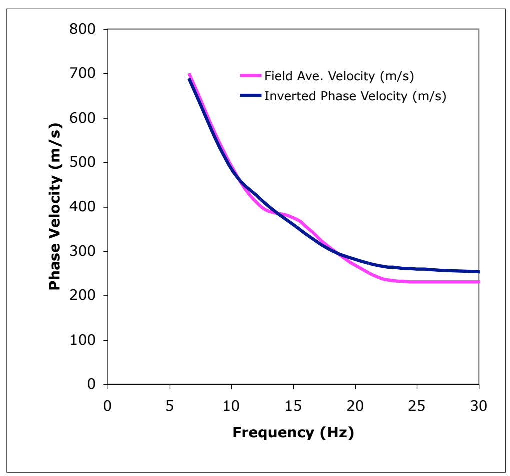


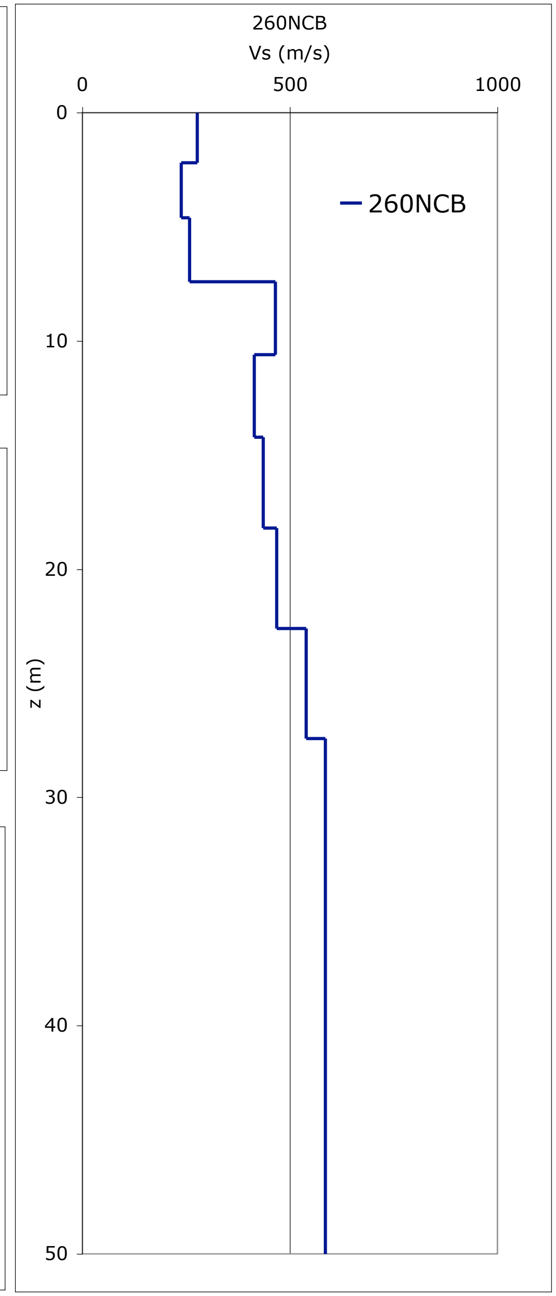
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

260NCB	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				276.1	0.0
701.9	690.3	6.5		276.1	2.2
501.5	494.0	9.8		238.3	2.2
402.6	418.2	12.3		238.3	4.6
373.7	356.2	15.2		258.5	4.6
309.1	303.6	18.0		258.5	7.4
252.5	274.3	21.1		464.2	7.4
234.1	263.7	23.4		464.2	10.6
234.2	250.7	33.3		414.0	10.6
232.6	250.1	35.6		414.0	14.2
239.2	249.7	38.5		435.6	14.2
251.3	249.7	41.5		435.6	18.2
251.9	249.8	44.3		467.6	18.2
236.0	250.1	47.3		467.6	22.6
228.8	250.4	50.3		538.3	22.6
214.5	250.7	53.1		538.3	27.4
220.6	251.1	56.0		584.7	27.4
235.1	251.4	59.0		584.7	32.6
247.1	251.7	61.8		584.7	50.0
267.1	252.0	64.8			
275.7	252.2	68.0			
275.0	252.4	70.6			
281.0	252.5	73.6			
288.4	252.6	76.7			
284.3	252.7	79.3			
269.8	252.7	82.3			
264.1	252.6	85.3			
263.2	252.5	88.1			
263.4	252.3	91.1			
264.7	252.1	94.0			
266.9	252.1	96.8			
				Vs30	392.6

UMBRIA-MARCHE, ITALY SMR Stations

Site ID **261NCS**
NEHRP CLASS: **C**
Vs30 (m/s) **585**
SUB-CLASS **C+**
RE-ANALYSIS 2008
Location

SMR Station	NCS
State	UMBRIA
Description	STATION-C GRAVEL ROAD
POSITION	NOCERA UMBRA - C GRAVEL RD
LAT (N)	43.14835
LON (E)	12.79134

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	15-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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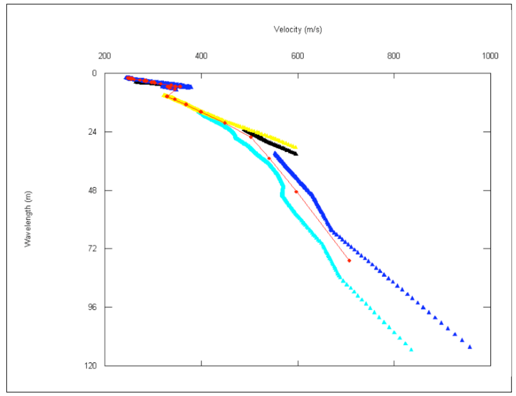
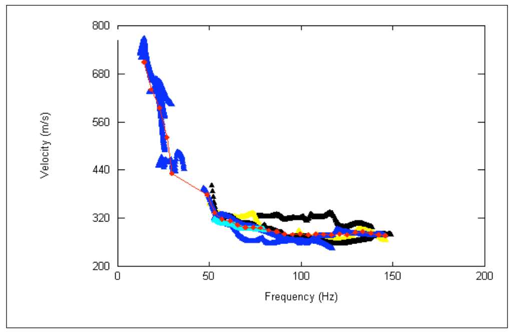
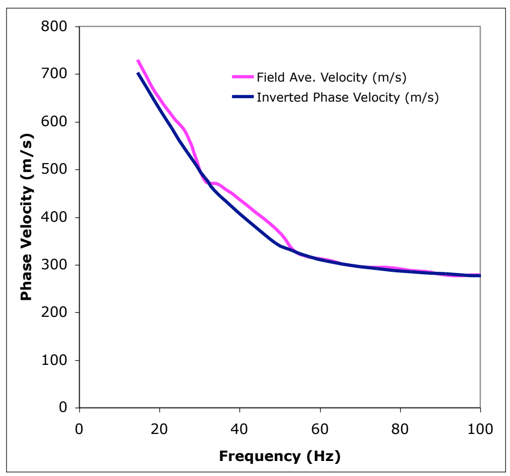


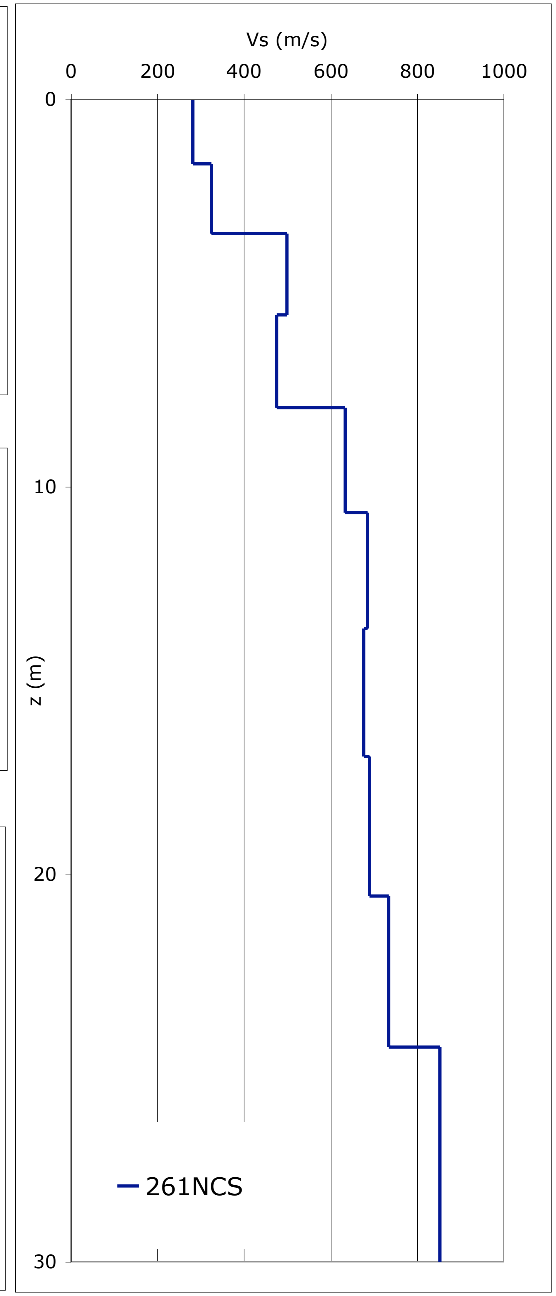
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

261NCS	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				280.9	0.0
731.3	704.3	14.4		280.9	1.7
664.6	643.7	18.7		324.4	1.7
615.7	588.7	22.9		324.4	3.5
571.8	537.0	26.8		497.9	3.5
477.8	483.5	31.2		497.9	5.6
468.2	444.6	34.9		474.1	5.6
377.7	347.4	48.8		474.1	8.0
333.1	330.4	53.1		633.3	8.0
316.9	319.1	57.0		633.3	10.7
312.1	309.7	61.3		684.5	10.7
302.7	302.7	65.6		684.5	13.7
296.6	297.2	69.8		675.3	13.7
295.4	292.8	74.1		675.3	17.0
294.6	289.3	78.2		689.2	17.0
288.6	286.4	82.5		689.2	20.6
285.7	283.9	86.9		733.6	20.6
280.0	281.8	91.2		733.6	24.5
278.5	280.0	95.4		851.8	24.5
279.9	278.5	99.6		851.8	30.0
277.4	277.2	103.9			
280.5	276.1	108.2			
278.5	275.1	112.5			
278.2	274.3	116.6			
279.3	273.5	121.0			
278.3	272.9	125.3			
284.3	272.3	129.6			
285.1	271.8	133.9			
281.5	271.3	138.0			
277.1	270.9	142.3			
275.3	270.9	145.9			
				Vs30	584.9

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**262GBP**
NEHRP CLASS:	**D**
Vs30 (m/s)	**281**
SUB-CLASS	**D+**

Location

SMR Station	GBP
State	UMBRIA
Description	GUBBIO SOIL SITE PIANA
POSITION	GUBBIO
LAT (N)	43.314
LON (E)	12.59

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	17-Nov-2005
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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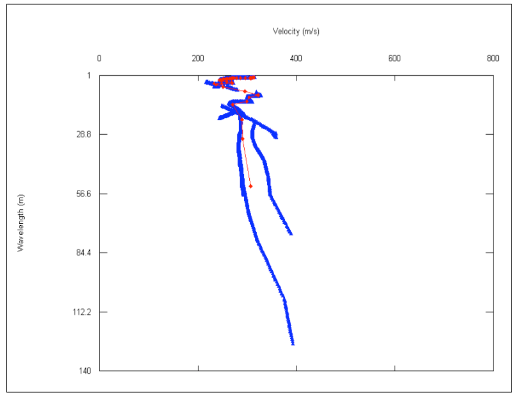
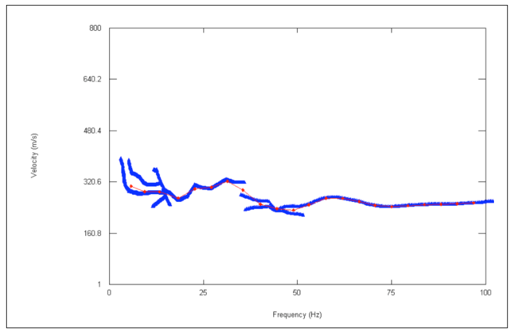
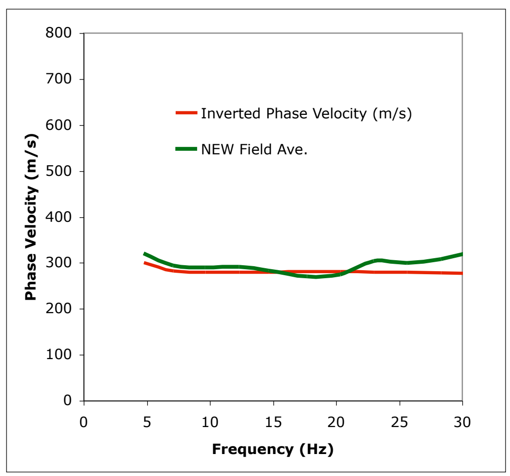


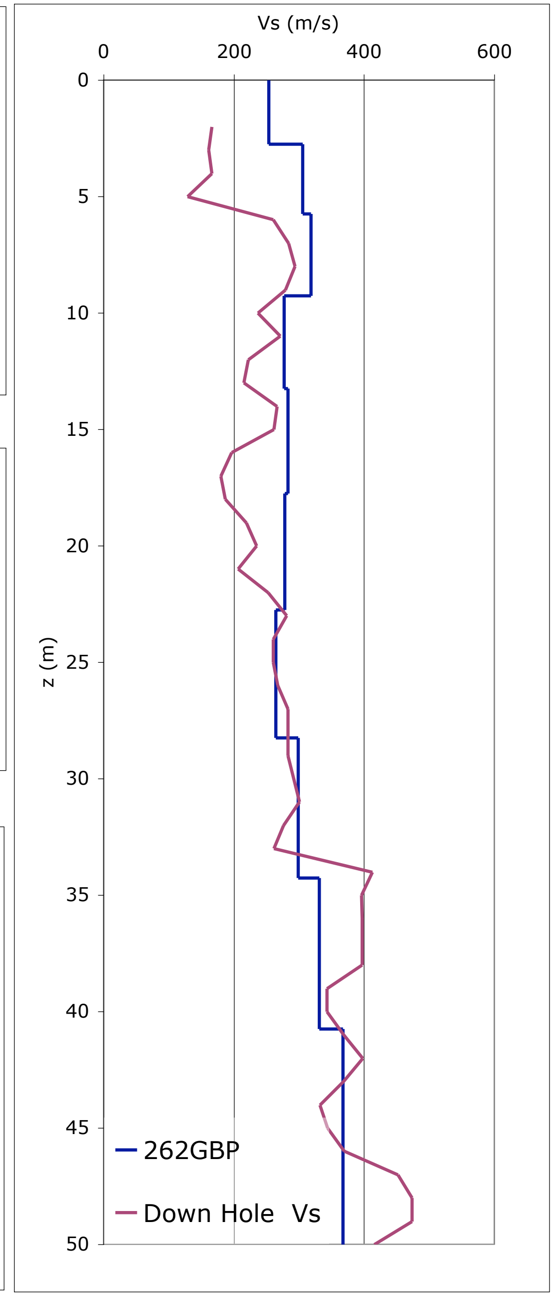
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

262GBP	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
321.6	301.7	4.7		253.7	0.0
294.8	283.6	7.1		253.7	2.8
290.2	280.5	9.6		304.9	2.8
292.1	280.6	12.3		304.9	5.8
283.3	281.3	14.6		317.8	5.8
270.8	281.8	17.7		317.8	9.3
275.3	281.9	20.3		277.1	9.3
304.9	281.5	23.0		277.1	13.3
300.6	280.9	25.6		282.5	13.3
308.8	279.9	28.3		282.5	17.8
323.9	278.1	30.9		277.8	17.8
319.2	275.1	33.5		277.8	22.8
252.0	268.0	38.9		263.8	22.8
250.3	264.8	41.5		263.8	28.3
235.1	261.8	44.2		298.2	28.3
234.4	259.2	46.8		298.2	34.3
231.9	256.8	49.4		331.0	34.3
239.6	255.0	51.8		331.0	40.8
259.5	253.1	54.7		367.0	40.8
269.5	251.6	57.3			
271.4	250.2	60.1			
267.9	249.1	62.7			
261.8	248.1	65.3			
253.9	247.3	67.9			
246.8	246.6	70.6			
243.5	246.0	73.2			
243.5	245.5	75.8			
246.0	245.0	78.6			
247.8	244.7	81.3			
249.3	244.3	83.9			
250.7	244.0	86.5			
250.3	243.8	89.1			
251.4	243.6	91.8		Vs30	281.0

UMBRIA-MARCHE, ITALY SMR Stations

Site ID **263GBB**
NEHRP CLASS: **B**
Vs30 **790 (m/s)**
SUB-CLASS **B+**

Location

SMR Station GBB
State UMBRIA
Description GUBBIO - PARK COLLO
POSITION GUBBIO
LAT (N) 43.35786
LON (E) 12.5947

Data Type SWEPT-SINE SASW
Investigators KAYEN, SCASSERRA
Date collected 17-Nov-2005

TEST METHODS PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS

PROJECT NAME UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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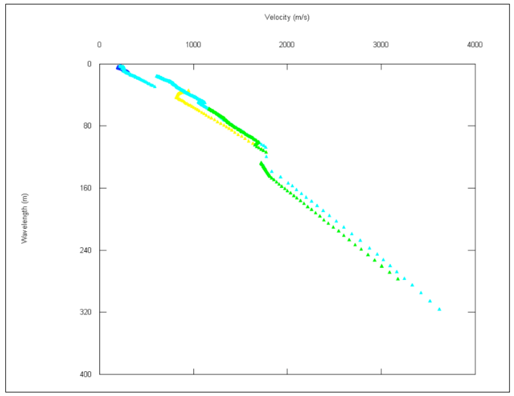
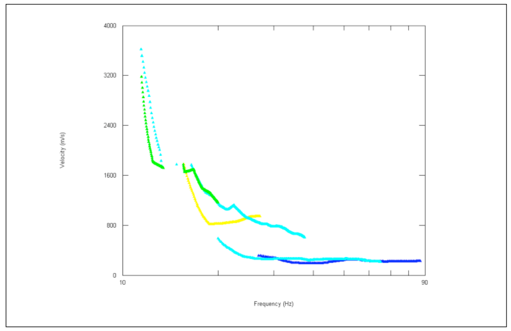
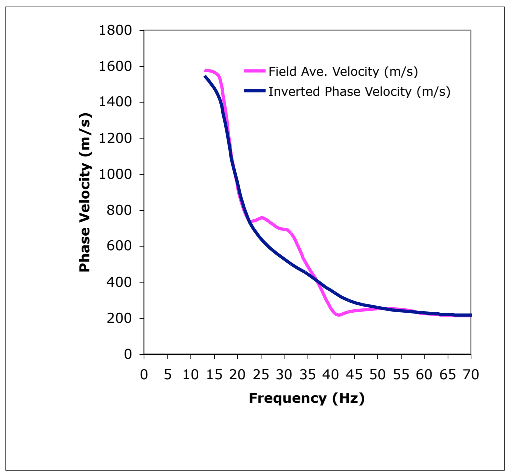


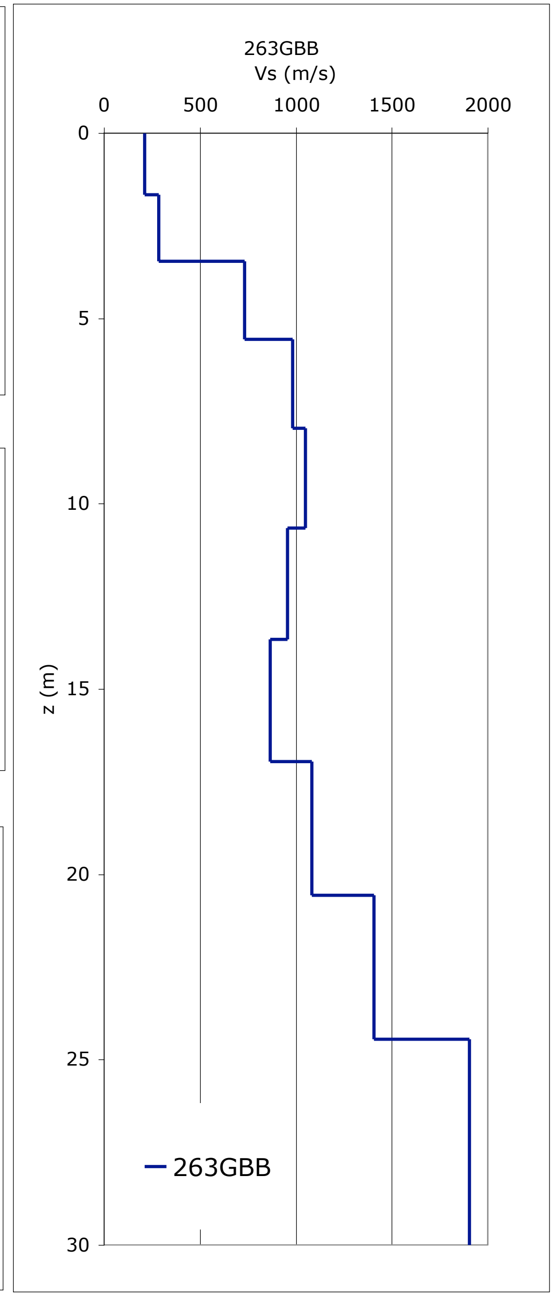
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

263GBB	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				211.3	0.0
1584.1	1551.9	12.8		211.3	1.7
1536.5	1419.2	16.2		284.6	1.7
1044.5	1046.9	19.0		284.6	3.5
753.5	756.7	22.2		730.0	3.5
761.2	633.5	25.4		730.0	5.6
707.3	563.5	28.3		981.4	5.6
675.6	506.9	31.4		981.4	8.0
520.8	458.4	34.3		1049.4	8.0
394.7	406.2	37.3		1049.4	10.7
230.2	344.6	40.6		956.4	10.7
239.2	304.0	43.7		956.4	13.7
248.3	278.4	46.8		864.6	13.7
256.5	261.6	49.9		864.6	17.0
257.9	249.9	52.9		1081.0	17.0
250.3	241.2	56.0		1081.0	20.6
232.4	234.6	59.1		1406.0	20.6
223.1	229.3	62.2		1406.0	24.5
218.9	225.7	64.8		1904.8	24.5
218.2	221.7	68.3		1904.8	30.0
220.4	218.9	71.3			
222.2	216.5	74.4			
223.5	214.5	77.5			
224.6	212.8	80.6			
225.7	211.3	83.7			
227.5	210.3	86.1			
242.6	202.5	149.1			
216.6	202.4	151.4			
200.6	202.3	154.6			
194.8	202.3	157.4			
191.5	202.2	160.6			
190.6	202.1	163.8			
190.4	202.1	166.6		Vs30	789.5

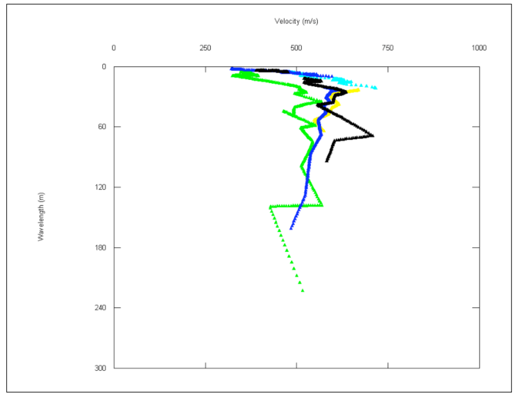
UMBRIA-MARCHE, ITALY SMR Stations

Site ID **264NCI (NRZI)**
NEHRP CLASS: **C**
Vs30 (m/s) **525**
SUB-CLASS **C-**

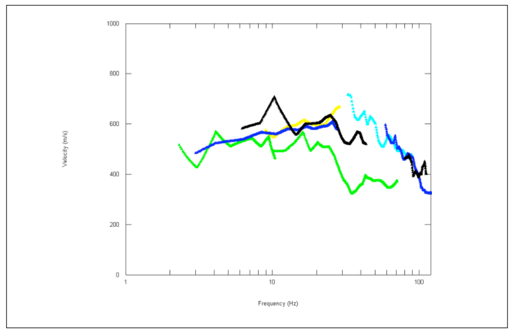
Location	
SMR Station	NCI (NRZI)
State	UMBRIA
Description	NORCIA INDUSTRIAL PARK
POSITION	NORCIA
LAT (N)	42.77974
LON (E)	13.09729

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	18-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

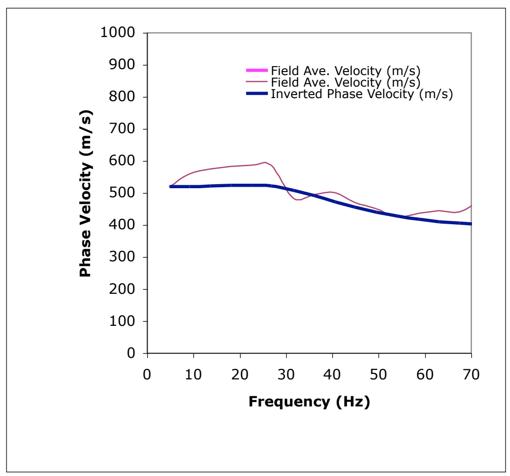
SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



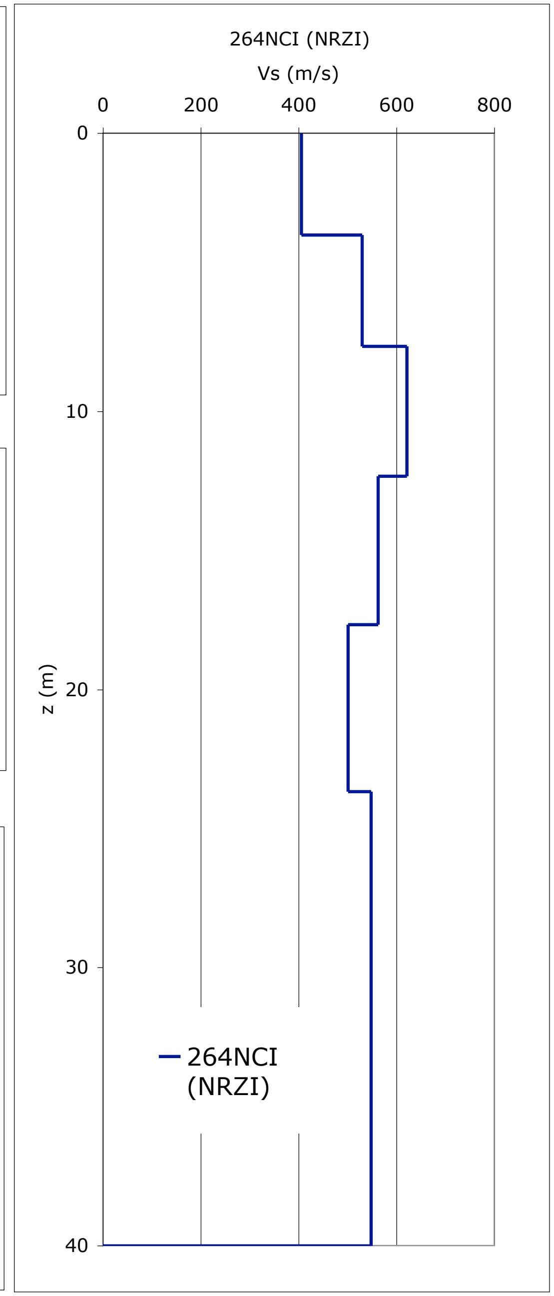
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

264NCI (NRZI)	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				405.8	0.0
519.3	522.1	4.7		405.8	3.7
559.9	522.3	9.1		529.3	3.7
575.3	524.3	13.5		529.3	7.7
583.4	526.6	18.0		621.3	7.7
588.7	526.8	22.5		621.3	12.3
587.4	523.1	26.7		561.5	12.3
483.4	511.0	31.6		561.5	17.7
495.2	493.2	36.0		501.1	17.7
501.4	473.6	40.5		501.1	23.7
472.2	457.1	44.6		548.1	23.7
451.7	441.2	49.4		548.1	30.0
425.9	429.3	53.9		548.1	40.0
437.0	419.8	58.6			
446.2	412.8	63.0			
442.7	407.4	67.4			
473.9	403.4	71.5			
487.1	399.8	76.3			
470.5	397.0	81.0			
471.9	395.0	85.4			
447.8	393.4	89.8			
417.0	392.1	94.4			
397.0	391.1	98.8			
382.7	390.2	103.3			
387.8	389.5	107.8			
350.1	389.0	112.0			
324.7	388.5	116.9			
324.9	388.1	121.3			
323.9	387.8	125.7			
322.2	387.8	130.3			
				Vs30	525.1

UMBRIA-MARCHE, ITALY SMR Stations

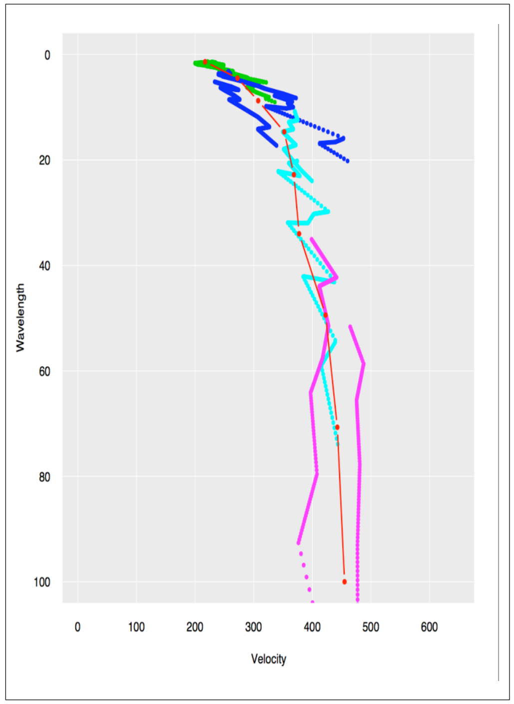
Site ID **265NRC**
NEHRP CLASS: **C**
Vs30 (m/s) **568**
SUB-CLASS **C+**

Location

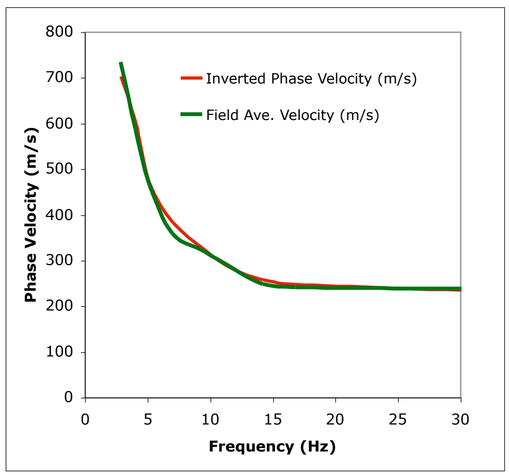
SMR Station	NRC
State	UMBRIA
Description	NORCIA SITE C-CENTRAL DIST.
POSITION	NORCIA SITE C-CENTRAL DIST.
LAT (N)	42.79223
LON (E)	13.097

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	18-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

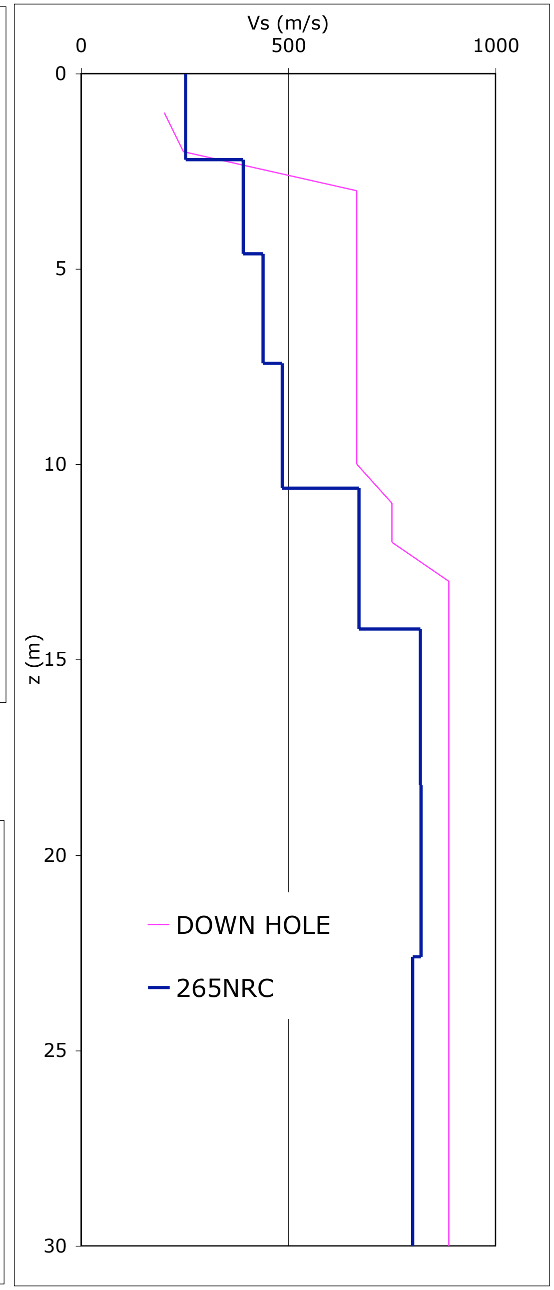
SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



(A) Merged Field-LAMBDA Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

265NRC	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	**Theoretical Disp. Vr (m/s)**	**Frequency (Hz)**		**Inversion Vs (m/s)**	**Depth (m)**
				251.5	0.0
735.0	704.6	2.8		251.5	2.2
590.0	605.4	4.0		390.2	2.2
471.4	473.3	5.0		390.2	4.6
360.5	385.2	7.0		437.8	4.6
321.2	324.7	9.5		437.8	7.4
283.7	282.5	11.7		483.9	7.4
248.9	258.6	14.2		483.9	10.6
243.0	249.9	16.8		669.8	10.6
233.8	213.0	55.3		669.8	14.2
233.3	210.3	57.8		817.9	14.2
233.7	208.3	60.1		817.9	18.2
226.6	206.7	62.3		819.5	18.2
216.2	205.2	64.8		819.5	22.6
209.8	204.0	67.3		800.1	22.6
209.0	203.0	69.7		800.1	27.4
215.1	202.1	72.2		799.9	27.4
218.1	201.4	74.6		799.9	32.6
216.9	200.8	77.1		799.9	32.6
213.6	200.3	79.5			
210.7	199.9	81.8			
208.5	199.6	84.1			
207.7	199.2	86.5			
204.9	199.0	88.9			
202.4	198.7	91.4			
200.5	257.4	93.8			
198.9	198.0	96.3			
197.5	197.2	98.8			
196.4	196.5	101.0			
191.2	195.9	103.3			
191.3	195.2	105.8			
192.9	194.7	108.2			
192.5	194.1	110.7		Vs30	568.3

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**266NRA**
NEHRP CLASS:	**D**
Vs30 (m/s)	**218**
SUB-CLASS	**D-**

Location

SMR Station	NRA
State	UMBRIA
Description	NORCIA TEMPORARY STATION A
POSITION	NORCIA
LAT (N)	42.79556
LON (E)	13.08096

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	19-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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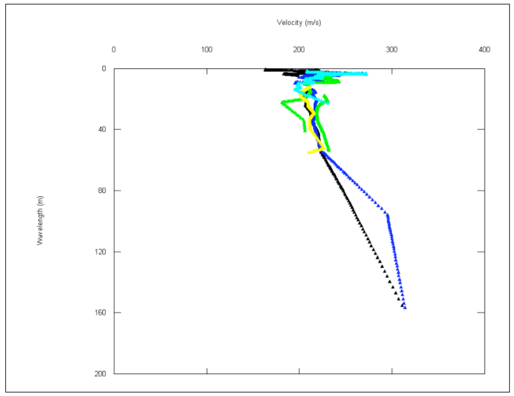
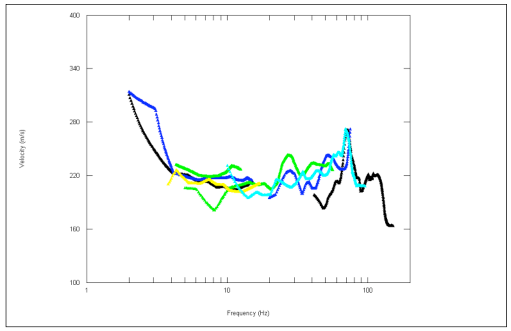
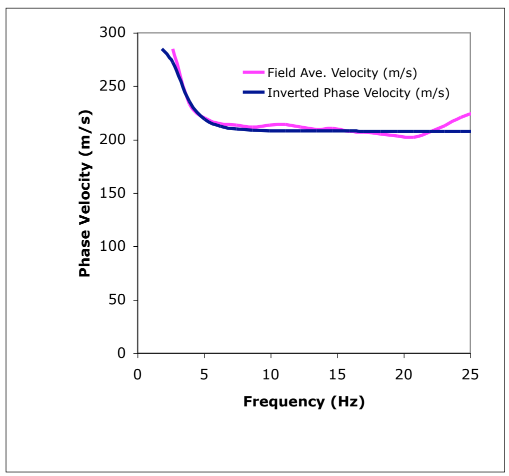


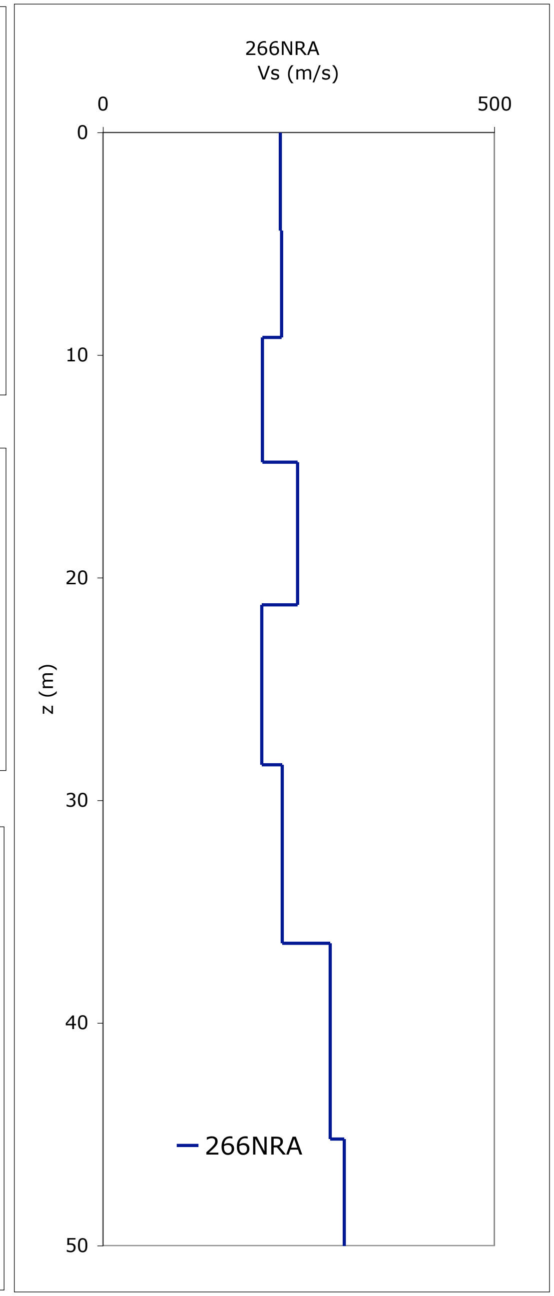
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

266NRA	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				226.2	0.0
310.0	285.5	1.8		226.2	4.4
285.6	273.1	2.6		227.8	4.4
233.8	236.2	3.9		227.8	9.2
221.1	219.7	5.0		203.3	9.2
215.2	213.1	6.2		203.3	14.8
214.1	210.5	7.4		248.0	14.8
212.4	209.3	8.6		248.0	21.2
214.4	208.9	9.8		202.3	21.2
214.7	208.8	11.0		202.3	28.4
212.4	208.7	12.2		228.8	28.4
210.0	208.7	13.4		228.8	36.4
211.1	208.7	14.6		289.9	36.4
207.9	208.6	15.9		289.9	45.2
207.8	208.5	16.9		307.7	45.2
205.5	208.4	18.2		307.7	54.8
203.8	208.4	19.5		325.5	54.8
203.0	208.3	20.7		325.5	65.2
207.7	208.3	21.9		337.4	65.2
213.8	208.3	23.0		337.4	80.0
221.2	208.3	24.3			
226.2	208.3	25.5			
229.1	208.3	26.7			
226.8	208.3	27.9			
227.8	207.5	29.1			
224.2	207.5	30.3			
220.6	206.7	31.5			
218.2	205.9	32.7			
217.0	205.2	33.9			
219.2	204.4	35.1			
219.9	203.7	36.3			
221.8	203.0	37.5			
222.6	202.3	38.7		Vs30	218.4

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**267CSC**
NEHRP CLASS:	**C**
Vs30 (m/s)	**540**
SUB-CLASS	**C+**

Location

SMR Station	CSC
State	UMBRIA
Description	CASCIA
POSITION	CASCIA
LAT (N)	42.71875
LON (E)	13.012

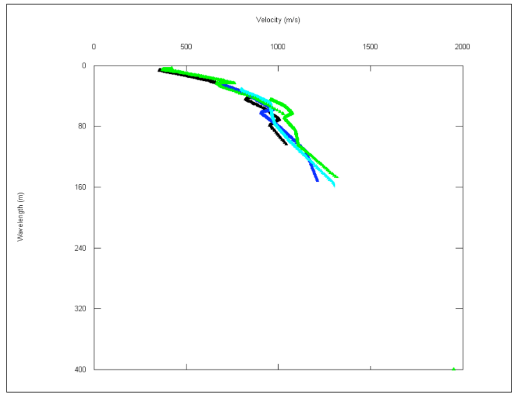
Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	20-Nov-2006

TEST METHODS PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS

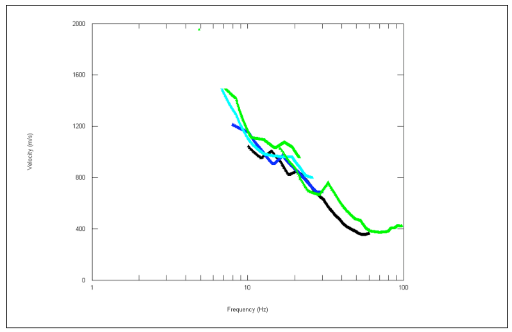
PROJECT NAME UMBRIA-MARCHE SMR CHARACTERIZATION

SPONSOR PEER, UNIV OF ROME

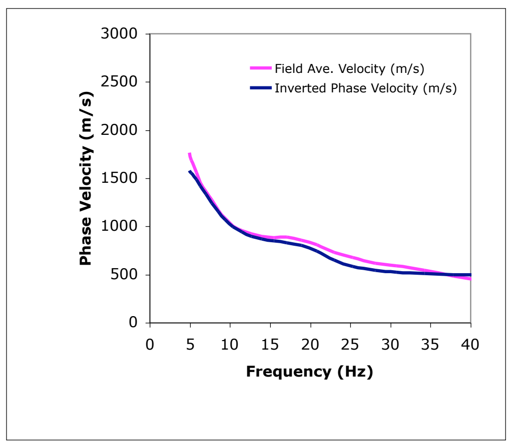
SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.



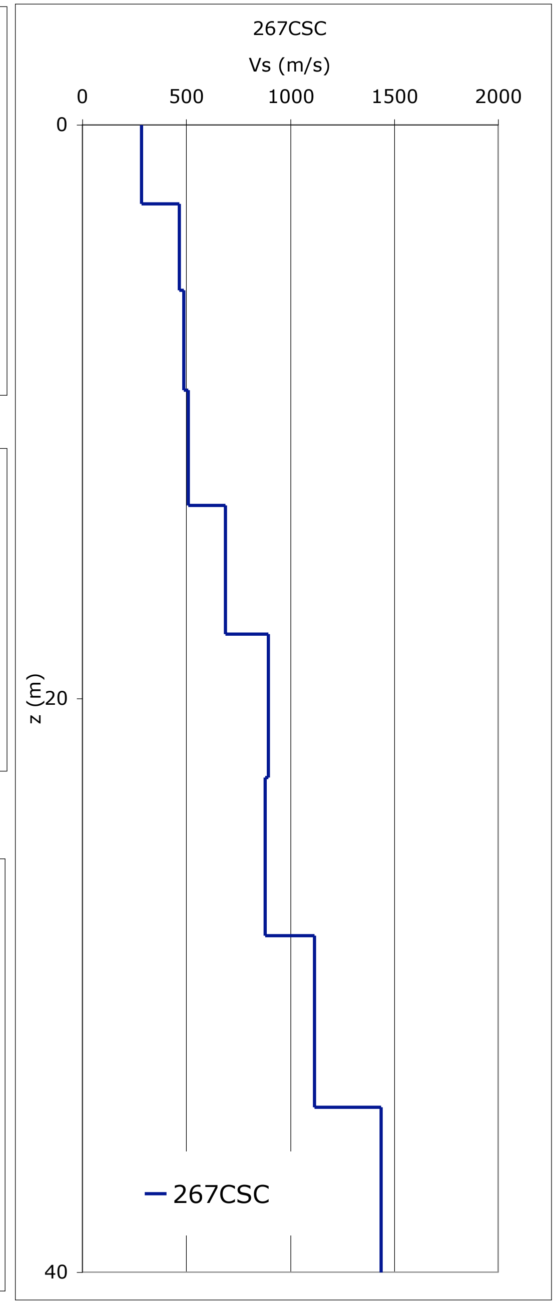
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

267CSC	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				284.2	0.0
1774.5	1583.4	4.9		284.2	2.8
1691.7	1560.5	5.1		466.0	2.8
1564.0	1495.7	5.7		466.0	5.8
1459.2	1428.3	6.3		487.6	5.8
1364.4	1340.8	6.9		487.6	9.3
1283.4	1246.3	7.7		508.6	9.3
1172.8	1158.5	8.5		508.6	13.3
1091.5	1075.9	9.3		686.3	13.3
1011.1	1003.4	10.3		686.3	17.8
959.5	946.9	11.4		894.5	17.8
926.1	905.9	12.6		894.5	22.8
899.6	877.0	13.9		878.3	22.8
888.4	855.2	15.4		878.3	28.3
893.2	835.8	17.0		1116.4	28.3
863.4	807.7	18.8		1116.4	34.3
818.3	748.4	20.7		1436.5	34.3
736.3	655.9	23.0		1436.5	40.8
686.5	591.7	25.3			
621.7	551.9	28.0			
599.1	531.4	30.6			
552.7	515.8	34.2			
489.0	507.0	37.8			
435.4	501.3	41.7			
				Vs30	540.0

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**268CSP**
NEHRP CLASS:	**C**
Vs30	**430**
SUB-CLASS	**C-**

Location

SMR Station	CSP
State	UMBRIA
Description	CASCIA PETRUCCI APARTMENTS
POSITION	CASCIA
LAT (N)	42.71788
LON (E)	13.0184

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	20-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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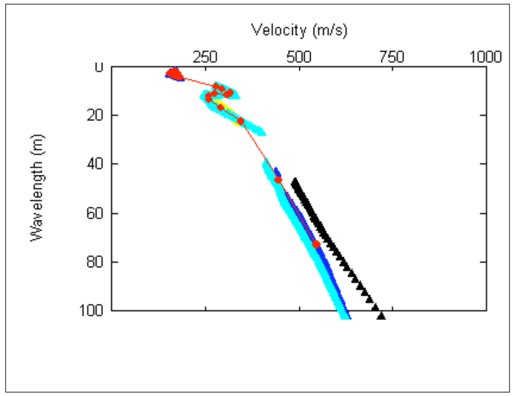
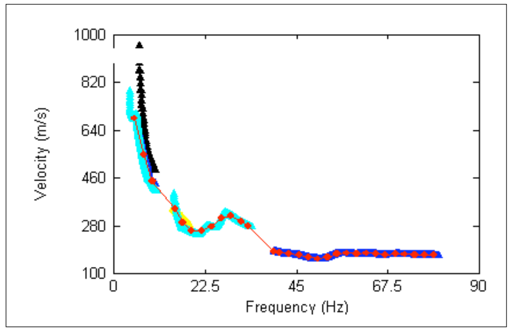
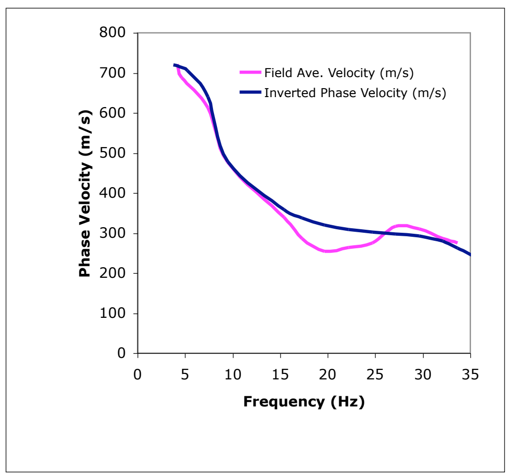


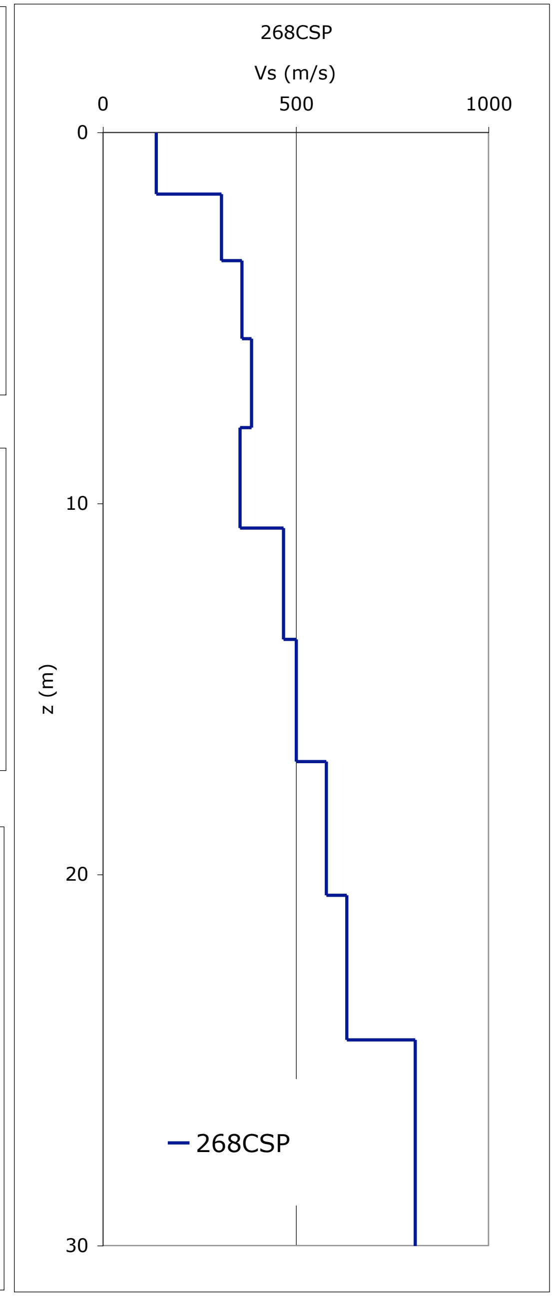
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

268CSP	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				138.2	0.0
791.0	721.2	3.7		138.2	1.7
685.2	707.3	5.2		307.0	1.7
614.6	641.9	7.3		307.0	3.5
478.4	479.6	9.4		360.6	3.5
341.0	360.6	15.3		360.6	5.6
337.8	340.0	17.2		384.1	5.6
326.6	321.8	19.6		384.1	8.0
316.3	310.1	22.2		354.5	8.0
306.9	303.6	24.6		354.5	10.7
310.0	299.3	27.1		468.4	10.7
311.4	294.8	29.5		468.4	13.7
288.8	281.0	32.0		500.9	13.7
277.0	264.7	33.6		500.9	17.0
181.3	192.5	39.9		579.3	17.0
176.4	177.7	41.9		579.3	20.6
172.1	165.2	44.3		632.1	20.6
164.8	157.1	46.7		632.1	24.5
157.0	157.1	49.2		808.6	24.5
				808.6	30.0
				Vs30	430.2

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**269SELW**
NEHRP CLASS:	**C**
Vs30 (m/s)	**503**
SUB-CLASS	**C-**

Location

SMR Station	SELW
State	UMBRIA
Description	
POSITION	SELLANO WEST
LAT (N)	42.886
LON (E)	12.922

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	21-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS

PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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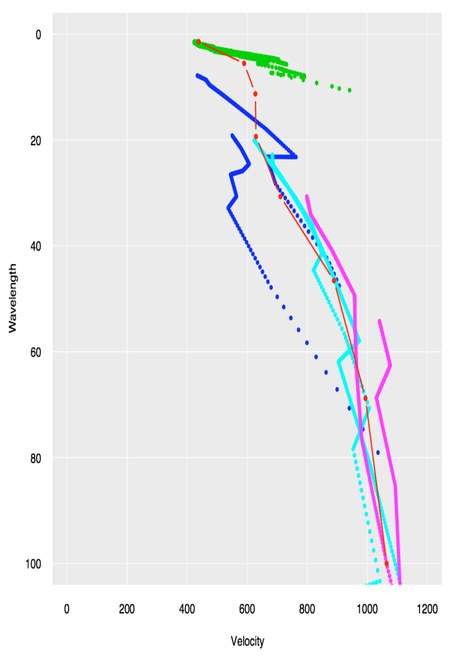
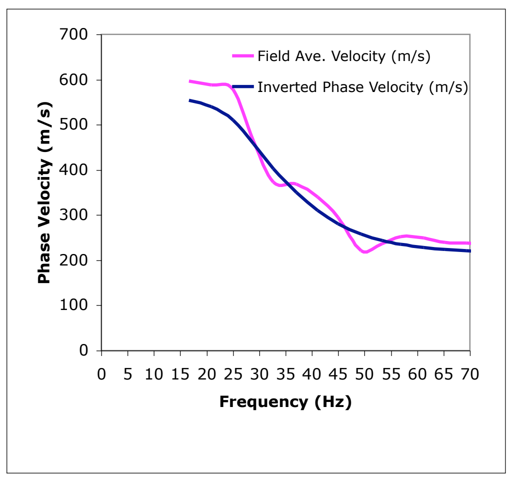
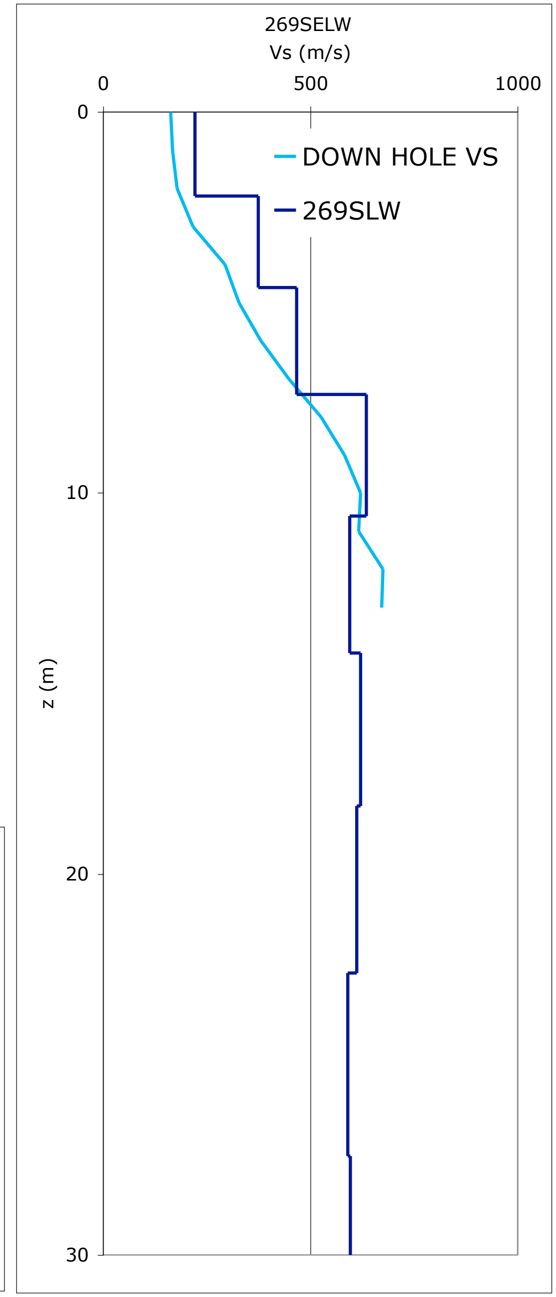


(A) Merged Field-LAMBDA Dispersion Curves



(B) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(C) Shear Wave Velocity SASW

269SELW	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	**Theoretical Disp. Vr (m/s)**	**Frequency (Hz)**		**Inversion Vs (m/s)**	**Depth (m)**
				220.7	0.0
598.0	554.8	16.5		220.7	2.2
590.1	540.9	20.7		373.7	2.2
579.2	511.7	25.0		373.7	4.6
465.1	459.1	28.8		466.6	4.6
374.4	404.3	32.6		466.6	7.4
370.5	351.0	37.0		634.3	7.4
341.3	311.9	41.0		634.3	10.6
296.3	282.7	44.9		593.7	10.6
222.7	259.7	49.2		593.7	14.2
237.6	245.8	53.2		620.2	14.2
254.3	237.3	56.8		620.2	18.2
250.8	230.2	61.1		611.5	18.2
241.2	225.5	65.2		611.5	22.6
239.2	222.2	69.2		589.8	22.6
235.6	219.7	73.2		589.8	27.4
230.8	217.8	77.2		595.8	27.4
227.4	216.4	81.3		595.8	32.6
229.2	215.3	85.3		595.9	32.6
226.5	214.4	89.3			
226.5	213.7	93.3			
229.3	213.1	97.5			
221.5	212.6	101.6			
223.2	212.3	105.6			
223.1	212.0	109.6			
216.8	211.7	113.6			
212.9	211.5	117.7			
211.9	211.4	121.7			
210.0	211.2	125.7			
206.0	211.1	129.7			
206.1	211.0	133.8			
202.4	211.0	137.6			
187.2	210.9	141.8		Vs30	502.9

UMBRIA-MARCHE, ITALY SMR Stations

Site ID	**270MTL**
NEHRP CLASS:	**C**
Vs30 (m/s)	**491**
SUB-CLASS	**C-**

Location

SMR Station	MTL
State	MARCHE'
Description	MATELICA
POSITION	
LAT (N)	43.24841
LON (E)	13.0079

Data Type	SWEPT-SINE SASW
Investigators	KAYEN, SCASSERRA
Date collected	21-Nov-2006
TEST METHODS	PARALLEL-ARRAY SOURCES; CONTINUOUS HARMONIC WAVE-SASW; 3D AMBIENT MICROTREMOR ANALYSIS
PROJECT NAME	UMBRIA-MARCHE SMR CHARACTERIZATION
SPONSOR	PEER, UNIV OF ROME

SITE SUB CLASS:	**Vs30 (m/s)**
A	>1500 m/s
B+	1080 < Vs30 ≤ 1500 m/s
B-	720 < Vs30 ≤ 1080 m/s
C+	540 < Vs30 ≤ 720 m/s
C-	360 < Vs30 ≤ 540 m/s
D+	270 < Vs30 ≤ 360 m/s
D-	180 < Vs30 ≤ 270 m/s
E	<180 m/s
F	Special Soil Conditions: Liquefiable soils; quick and high sensitivity clays; collapsible cemented soils; peats>3m; high (>75) PI soils thicker than 8m; soft/medium stiff clays thicker than 36m.

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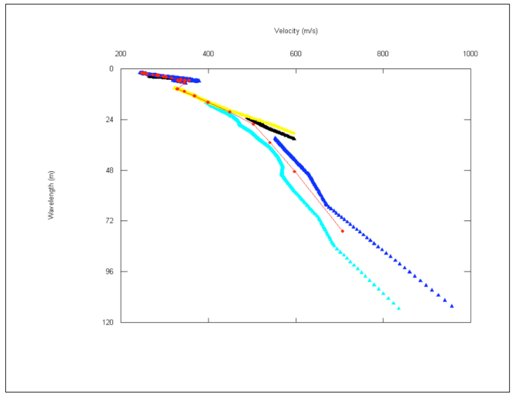
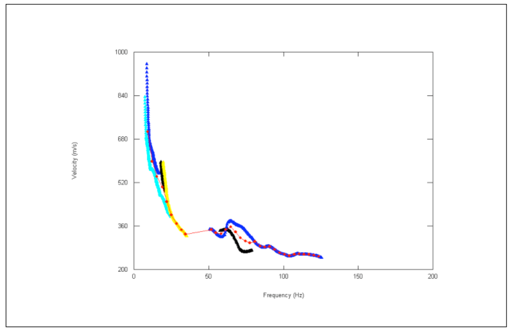
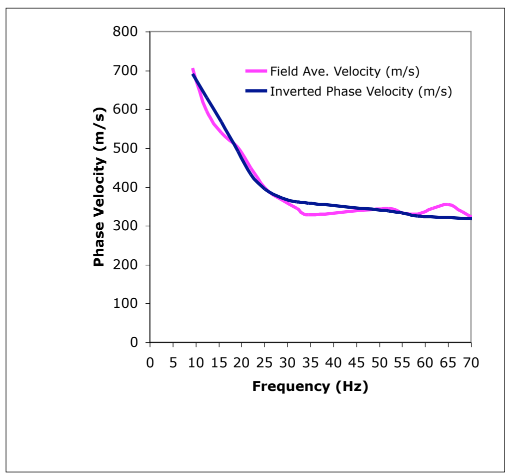


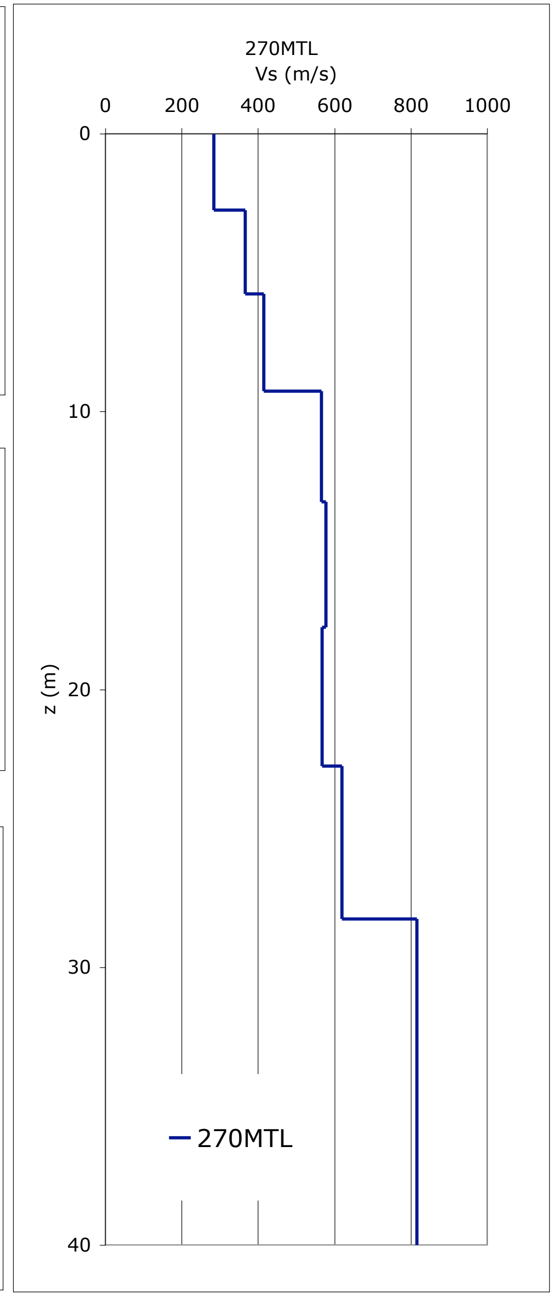
(A) Merged Field-LAMBDA Dispersion Curves



(B) Merged Field-Frequency Dispersion Curves



(C) Inversion-theoretical dispersion curve versus averaged field dispersion curve,



(D) Shear Wave Velocity SASW

270MTL	DISPERSION DATA			INVERSION PROFILE	
Site Disp. Vr (m/s)	Theoretical Disp. Vr (m/s)	Frequency (Hz)		Inversion Vs (m/s)	Depth (m)
				282.8	0.0
707.6	693.2	9.2		282.8	2.8
597.7	632.1	12.3		365.1	2.8
541.5	568.9	15.5		365.1	5.8
503.0	493.2	19.1		415.2	5.8
449.6	433.7	22.0		415.2	9.3
399.7	396.1	25.0		565.6	9.3
368.7	373.5	28.7		565.6	13.3
345.6	363.7	32.0		576.4	13.3
329.9	359.0	34.5		576.4	17.8
346.6	340.0	51.8		567.5	17.8
334.8	334.4	54.8		567.5	22.8
331.5	326.5	58.3		618.5	22.8
316.9	318.7	71.3		618.5	28.3
304.5	310.8	74.6		815.9	28.3
297.6	304.2	77.7		815.9	30.0
302.2	298.3	81.1			
286.0	293.5	84.4			
282.2	289.7	87.6			
283.9	286.3	90.9			
273.6	283.6	94.2			
261.7	281.4	97.5			
255.3	279.5	100.8			
250.0	277.9	104.0			
255.0	276.5	107.3			
257.2	275.4	110.7			
256.3	274.4	113.8			
254.9	273.6	117.1			
251.8	272.9	120.4			
247.7	272.3	123.6			
				Vs30	491.0