Task 5: Classificazione sismica dei siti ITACA

Responsabili task:
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Aims of the task

- Revise the classification of the sites of the Italian strong-motion stations according to the classes of the Eurocode 8 and the Italian seismic codes
- Provide the database end-user parameters also obtained with low cost methods, suitable for alternative site classification techniques
- Classification of rock sites

Working steps

1. Carry out the state of the art on soil classification
2. Collect a set of well documented recording station
3. Establish classification schemes alternative to the proposed standard
4. Test soil classification through error distribution in GMPE

State of the work

1. Revised classification of the sites of the Italian strong motion stations, based on the information coming from Task 2, according to the Italian and EC8 seismic norms (NEEDS TASK2 RESULTS);
2. Critical review of the methods proposed in the literature for improve site classification, and check of their applicability using the Italian data set (ONGOING)
3. Selection of a set of parameters suitable for site response characterization, obtainable either by low cost geophysical investigations or by spectral techniques (ONGOING)
4. Examples of classification of well characterized recording sites according to the previous criteria and parameters, and possible introduction of a new classification scheme (ONGOING)

State of the work (2)

5. Test of the site classification schemes through the estimation of the standard deviation of empirical ground motion models (ONGOING)
6. Interaction with Task 3 to identify the experimental procedures suitable to calibrate the previous parameters with low cost procedures (FUTURE)
7. Investigation of rock or very stiff soil sites, to enlarge the set of Class A velocity profiles, and to propose possible sub-divisions of Class A sites into sub-classes (ONGOING)
8. Identification in the database, of outcropping bedrock sites suitable as reference sites for seismic hazard studies (NEEDS TASK4 RESULTS)
9. Verification of simplified classification criteria based on the information available from geology maps (FUTURE)

1. State of the art

- Collect published papers on site classification and International and Italian seismic codes (DONE 80%)
- Carry out the state-of-the-art in site classification with special emphasis on the parameters used to discriminate among soil classes (ONGOING)

State of the art (about 30 papers collected)

Anderson J. G., Lee Y, Zeng Y., Day S. (1996). Control of strong motion by the upper 30 meters. . Bull. Seism. Soc. Am., 86, n. 6, 1749-1759
Barani S., De Ferrari R., Ferretti G., Eva C. (2008) Assessing the Effectiveness of Soil Parameters for Ground Response Characterization and Soil Classification. Earthquake Spectra, 24, No. 3, 565–597.

Borcherdt R. D. (1994). Estimates of site-dependent response spectra for design (methodology and justification). Earthquake Spectra, 10, 617-653.

Borcherdt R. D. (2002) Empirical Evidence for Site Coefficients in Building Code Provisions. Earthquake Spectra, 18, No. 2, 189–217.

Borcherdt R. D. Glassmoyer G. (1992) On the characteristics of local geology and their influence on ground motions generated by the Loma Prieta earthquake in th San Francisco Bay region, California. Bull. Seism. Soc. Am., 82, n.2, 603-641

Choi Y., Stewart J.P. (2005) Nonlinear Site Amplification as Function of 30 m Shear Wave Velocity. Earthquake Spectra, 21, No. 1, 1–30

Dobry R., Borcherdt R. D., Crouse C. B., Idriss I. M., Joyner W. B., Martin G. R., Power M. S., Rinne E. E., Seed R. B. (2000) New site coefficients and site classification system used in recent building seismic code provisions. Earthquake Spectra, 16, n. 1, 41-67.

Field E. H. (2000) A Modified Ground-Motion Attenuation Relationship for Southern California that Accounts for Detailed Site Classification and a Basin-Depth Effect. Bull. Seism. Soc. Am. 90, 6B, S209–S221

Fukushima Y., Bonilla L. B.; Scotti O.; Douglas J. Site Classification Using Horizontal-to-vertical Response Spectral Ratios and its Impact when Deriving Empirical Ground-motion Prediction Equations. Journal of Earthquake Engineering, 11:5, 712 - 724

Ghasemi H., Zare M., Fukushima Y, Sinaeian F. (2008) Applying empirical methods in site classification, using response spectral ratio (H/V): A case study on Iranian strong motion network (ISMN). Soil Dynamics and Earthquake Engineering

Lee C.T., Cheng C.T., Liao C.W., Tsai Y.B. (2001). Site Classification of Taiwan Free-Field Strong-Motion Stations. Bull. Seism. Soc. Am., 91, 5, 1283–1297

Lee Y., Anderson J. G. (2000). Potential for Improving Ground-Motion Relations in Southern California by Incorporating Various Site Parameters. Bull. Seism. Soc. Am. 90, 6B, S170–S186.

Mucciarelli M., Gallipoli M.R. (2006) Comparison between vs30 and other estimates of site amplification in italy. Proceeding of the First European Conference on Earthquake Engineering and Seismology (a joint event of the 13th ECEE & 30th General Assembly of the ESC) Geneva, Switzerland, 3-8 September 2006

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1997 NEHRP provisions and 1997 UBC

Soil profile type	Description	Shear wave velocity top 30 m (m/s)	Standard Pen. Resistance N (blows/ft)	Undrained shear strength (kPa)
A	Hard rock	> 1500	-	-
B	Rock	760-1500	-	-
C	Very dense soil/ soft rock	360-760	> 50	> 100
D	Stiff soil	180-360	15 – 50	50 – 100
E	Soft soil	< 180	< 15	< 50
F	Special soils requiring site-specific evaluation	-	-	-

This classification is based on Borcherdt (1994) site amplification factors evaluated primarily on observations from the 1989 Loma Prieta earthquake, which showed significant nonlinear site response effects

EC8

Subsoil class	Description of stratigraphic profile	Parameters		
		$V_{s,30}$ (m/s)	N_{SPT} (bl/30cm)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5m of weaker material at the surface	> 800	_	_
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of m in thickness, characterised by a gradual increase of mechanical properties with depth	360 – 800	> 50	> 250
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of m	180 – 360	15 - 50	70 – 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil	< 180	< 15	< 70
E	A soil profile consisting of a surface alluvium layer with $V_{s,30}$ values of class C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with $V_{s,30}$ > 800 m/s			
S_1	Deposits consisting – or containing a layer at least 10 m thick – of soft clays/silts with high plasticity index (PI > 40) and high water content	< 100 (indicative)	_	10 – 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in classes A –E or S_1			

Japan Road Association (1980, 1990)

Subsoil class	**Description of stratigraphic profile**	**Parameters**	
		$V_{s,30}$ (m/s)	T_0 (s)
SC I	Rock or stiff soil	> 600	< 0.2
SC II	Hard soil	300 – 600	0.2 – 0.4
SC III	Medium soil	200 - 300	0.4 – 0.6
SC IV	Soft soil	< 200	> 0.6

Bray and Rodriguez Marek (1997)

Site	Description	Site Period	Comments
A	Hard Rock	≤ 0.1 s	Hard, strong, intact rock; $V_s \geq 1500$ m/s
B	Rock	≤ 0.2 s	Most "unweathered" California rock cases ($V_s \geq 760$ m/s or < 6 m of soil).
C-1	Weathered/Soft Rock	≤ 0.4 s	Weathered zone > 6 m and < 30 m (V_s > 360 m/s increasing to > 700 m/s).
-2	Shallow Stiff Soil	≤ 0.5 s	Soil depth > 6 m and < 30 m
-3	Intermediate Depth Stiff Soil	≤ 0.8 s	Soil depth > 30 m and < 60 m
D-1	Deep Stiff Holocene Soil, either **S** (Sand) or **C** (Clay)	≤ 1.4 s	Soil depth > 60 m and < 200 m. Sand has low fines content (< 15%) or nonplastic fines (PI < 5). Clay has high fines content (> 15%) and plastic fines (PI > 5).
-2	Deep Stiff Pleistocene Soil, **S** (Sand) or **C** (Clay)	≤ 1.4 s	Soil depth > 60 m and < 200 m. See D_1 for S or C sub-categorization.
-3	Very Deep Stiff Soil	≤ 2 s	Soil depth > 200 m.
E-1	Medium Depth Soft Clay	≤ 0.7 s	Thickness of soft clay layer 3 m to 12 m
-2	Deep Soft Clay Layer	≤ 1.4 s	Thickness of soft clay layer > 12 m.
F	Special, e.g., Potentially Liquefiable Sand or Peat	≈ 1 s	Holocene loose sand with high water table ($z_w \leq 6$ m) or organic peat.

An Empirical Site-Classification Method for Strong-Motion Stations in Japan Using H/V Response Spectral Ratio by Zhao, Irikura, Zhang, Fukushima, Somerville, Asano, Ohno, Oouchi etc..2006 BSSA Vol 96/3 (914 - 925)

ZHAO et al. (2006)

JAPAN ROAD ASSOCIATION

CAT.	PERIOD T (sec)
SCI	T < 0.2
SCII	0.2 <= T < 0.4
SCIII	0.4 <= T < 0.6
SCIV	T >= 0.6

Four site classes defined by dominant site period, obtained from the average response spectral ratios of the horizontal and vertical components (H/V)

Site Classification using horizontal-to-vertical Response Spectral Ratios and its impact when deriving empirical ground-motion prediction equations by Fukushima, Bonilla, Scotti, Douglas 2007 JEE Vol 11 (712-724)

Sites are classified based on their predominant period computed using average horizontal-to-vertical (H/V) response spectral ratios

FUKUSHIMA et al. (2007)

CAT.	PERIOD T (sec)
SC1	T < 0.2
SC2	0.2 <= T < 0.6
SC3	T >= 0.6
SC4	Generic Rock
SC5	Generic Soil

→ SCII + SCIII

Pitilakis, K. et al. (2003) Experimental and theoretical analyses of site effects toward the improvement of soil classification and design spectra in EC8 and Greek Seismic Code. Final Report Organization of Seismic Planning and Protection

SOIL CATEG.		DESCRIPTION	To (sec)	REMARKS
A	A_1	Healthy rock formations	≤0.2	Vs ≥1500 m/s
	A_2	Slightly weathered/segmented rock formations,(thickness of weathered layer < 5.0m)		Weak layer: $V_s \geq 300$ m/s Rock form.: $V_s \geq 800$ m/s
		Geologic formations which resemble to rock formations in their mechanical properties and their composition (e.g. conglomerates)		$V_s \geq 800$ m/sec
B	B_1	Highly weathered rock formations whose weathered layer has a considerable thickness of 5.0 - 30.0m	≤ 0.4	Weathered layer: $V_{s(1)} \geq 300$ m/s
		Soft rock formations of great thickness or formations of similar stiffness and mechanical properties (e.g. stiff marls)		V_s = 400 - 800 m/s $N_{SPT(2)} > 50$ $S_{u(3)} > 200$KPa
		Homogeneous soil formations of very dense sand – sand gravel and/or very stiff clay, and small thickness (less than 30.0m)		V_s = 400 - 800 m/s $N_{SPT} > 50$ $S_u > 200$Kpa
	B_2	Homogeneous soil formations of very dense sand – sand gravel and/or very stiff clay, and medium thickness (30.0 - 60.0m), whose mechanical properties and stiffness increase with depth	≤0.8	V_s = 400 - 800 m/s $N_{SPT} > 50$ $S_u > 200$Kpa
C	C_1	Soil formations of dense to very dense sand–sand gravel and/or stiff to very stiff clay, of great thickness (>60.0m), whose mechanical properties and strength are constant and/or increasing with depth	≤1.2	V_s = 400 - 800 m/s $N_{SPT} > 50$ $S_u > 200$KPa
	C_2	Soil formations of medium dense sand – sand gravel and/or medium stiffness clay (PI > 15, fines percentage > 30%) of medium thickness (20.0m – 60.0m)	≤1.2	V_s = 200 - 400 m/s $N_{SPT} > 20$ $S_u > 70$KPa
	C_3	Category C2 soil formations of great thickness (>60.0 m), homogenous or stratified that are not interrupted by any other soil formation with a thickness of more than 5.0m and of lower strength and Vs velocity	≤1.4	V_s = 200 - 400 m/s $N_{SPT} > 20$ Su >70KPa
D	D_1	Recent soil deposits of substantial thickness (up to 60m), with the prevailing formations being soft clays of a high plasticity index (PI>40), with a high water content and low values of strength parameters	≤ 2.0	$V_s \leq 200$ m/s $N_{SPT} < 20$ Su <70KPa
	D_2	Recent soil deposits of substantial thickness (up to 60m), with prevailing fairly loose sandy to sandy-silty formations with a substantial fines percentage (so as not to be considered susceptible to liquefaction)	≤2.0	$V_s \leq 200$ m/s $N_{SPT} < 20$
	D_3	Soil formations of category C with Vs >300m/s and great overall thickness (>60.0m), interrupted at the first 40 meters by soil layers of category D1 or D2 of a small thickness (5 – 15m),	≤ 1.2	
E		Surface soil formations of small thickness (5m - 20m), small strength and stiffness, likely to be classified in category C or D according to geotechnical properties, which overlie category A formations (Vs≥ 800 m/s).	≤ 0.5	Surface soil layers: V_s = 150 - 300 m/s
X		- Loose fine sandy-silty soils beneath the water table, susceptible to liquefaction (unless a special study proves no such danger, or if the soil's mechanical properties are improved). - Soils near well documented seismically active tectonic faults. - Steep slopes covered with loose lateral deposits. - Loose granular or soft silty-clayey soils, provided they have been proven to be hazardous in terms of dynamic compaction or loss of strength, Recent loose landfills. - Soils with a very high percentage in organic material.		

(1), (2), (3) : *mean values over the whole soil column until the bedrock.*

2. Collect a seismological and geotechnical data set of recording station

- ITACA recording stations characterized by geotechnical and geophysical information, which recorded seismic events and stations used by UNIBAS for seismic microzoning
- Calculation of parameters related to soil amplification
- Data analysis

SITO	SIGLA	lat (WGS84)	long (WGS84)	Prova geofisica	n° registrazioni
Abruzzo					
Chieti	CHT	42.369828	14.147809	Sismica a rifrazione	21
Valle dell'Aterno	AQV	42.377222	13.343889	CH	16
Basilicata					
Brienza	BRN	40.4719444	15.634444	CH	5
Rionero in Vulture	RNR	40.927248	15.668799	CH	3
Tricarico	TRR	40.619071	16.156220	CH	3
Campania					
Auletta	ALT	40.5561070	15.394932	CH	2
Arienzo	ARN	41.0269310	14.468894	CH	5
Bagnoli Irpino	BGI	40.830860	15.068013	CH	2
Benevento	BNV	41.1170150	14.797453	CH	1
Bisaccia	BSC	41.009794	15.375982	CH	1
Calitri	CLT	40.898387	15.438577	CH	6
Garigliano	GRG	41.258311	13.832760	CH	3
Mercato San Severino	MRT	40.789459	14.762770	CH	3
Sturno	STR	41.020843	15.114993	CH	6

List of RAN station characterized by geophysical data

Emilia Romagna					
Cesena	CSN	44.137	12.241000	CH	1
Forlì	FOR	44.199	12.042000	CH	1
Friuli					
Buia	BUI	46.222046	13.090150	CH	7
Forgaria Cornino	FRC	46.221099	12.994472	CH	23
Forgaria San Rocco	SRCO	46.226376	12.998366	CH	8
Majano Prato	MAP	46.187022	13.069499	CH	3
Tarcento	TRC	46.226396	13.210102	CH	5
Tolmezzo	TLB	46.384996	12.981686	CH	6
Marche					
Ancona Palombina	ANP	43.6022222	13.474167	CH	8
Ancona Rocca	ANR	43.6211111	13.512778	CH	3
Colfiorito	CLF	43.035898	12.920538	DH	21
Molise					
San Giuliano di Puglia (A)	SGIUA	41.684	14.684000	DH	9
San Giuliano di Puglia (B)	SGIUB	41.688	14.963000	DH	10
Puglia					
			15.34220		

List of RAN station characterized by geophysical data

Toscana					
Bagnone	BGN	44.3205556	9.990278	DH	1
Bibbiena	BBB	43.7094444	11.825833	DH	1
Dicomano	DCM	43.891235	11.518011	DH	--------
Fivizzano	FVZ	44.238247	10.131089	DH	--------
Piazza al Serchio	PZS	44.188549	10.288610	DH	--------
Pieve Santo Stefano	PVS	43.6688889	12.043889	DH	--------
San Casciano dei Bagni	SSC	42.874725	11.876788	DH	--------
San Sepolcro	SNS	43.567390	12.143375	DH	--------
Umbria					
Bevagna	BVG	42.932389	12.611056	CH	5
Gubbio piana	GBP	43.313816	12.589550	DH	14
Nocera Umbra	NCR	43.111583	12.784666	DH	25
Norcia	NOR	42.792	13.092	DH	41
Sellano est	SELE	42.889216	12.927975	DH	18
Sellano ovest	SELO	42.886210	12.921806	DH	35

List of RAN station characterized by geophysical data

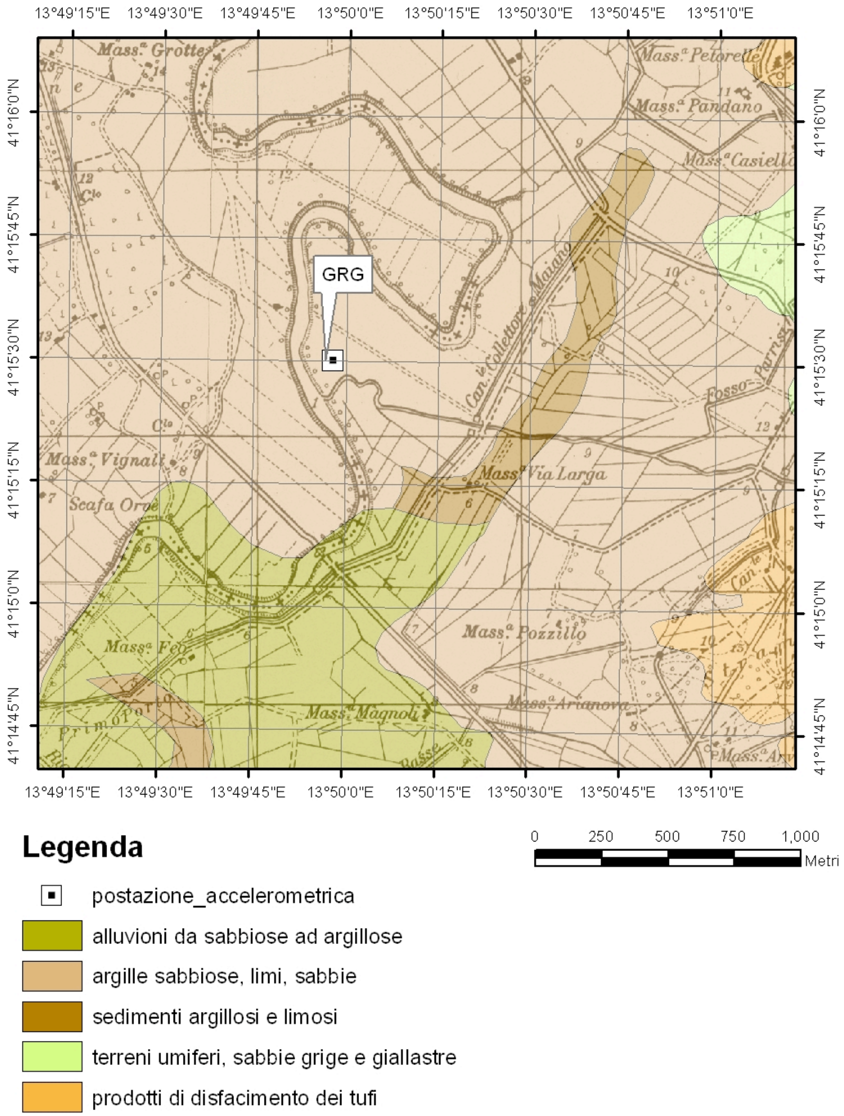
Data set UNIBAS

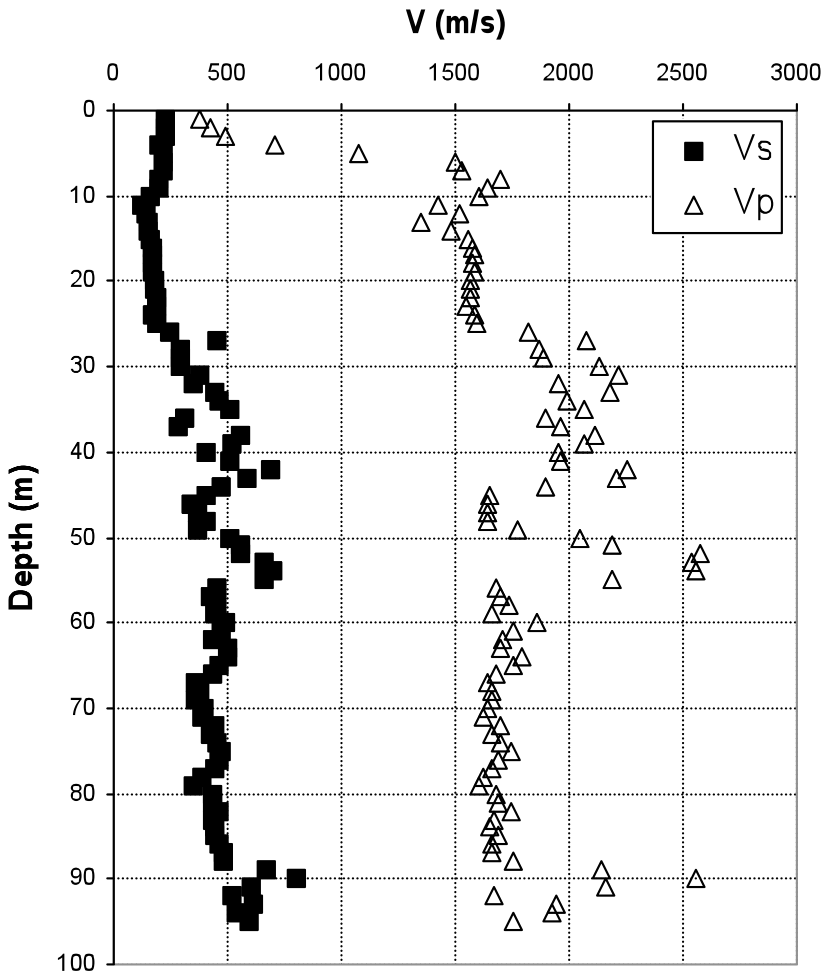
Nome	Regione	# siti	Prova
Costa Gaveta	Basilicata	1	DH
Cagli	Marche	3	3 DH
Latronico scuola	Basilicata	1	
Marsico Nuovo	Basilicata	1	DH
Metaponto	Basilicata	1	DH
Offida	Marche	3	3 DH
Policoro Agrifele	Basilicata	1	DH
Policoro Municipio	Basilicata	1	DH
Scanzano Municipio	Basilicata	1	DH
Scanzano Porto Greco	Basilicata	1	DH
Senigallia Marchetti	Marche	1	
Senigallia Saline	Marche	1	DH
Senigallia Parco Pace	Marche	1	
Serra de Conti	Marche	3	3 DH
Tito Scalo	Basilicata	1	DH
Treia	Marche	3	
Tricarico	Basilicata	1	DH

25 sites in Marche and Basilicata
Characterized by geophysical measurements and earthquake / noise records

Example: Garigliano

Garigliano



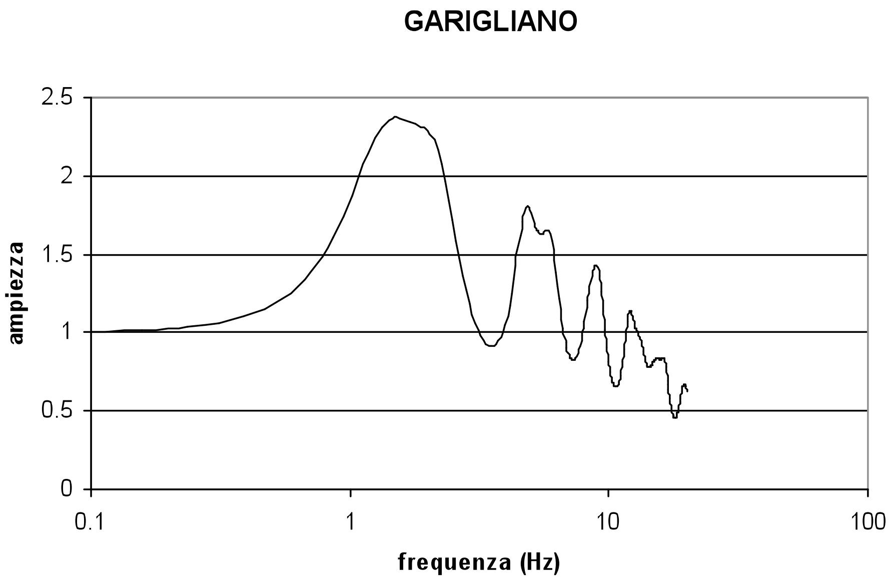


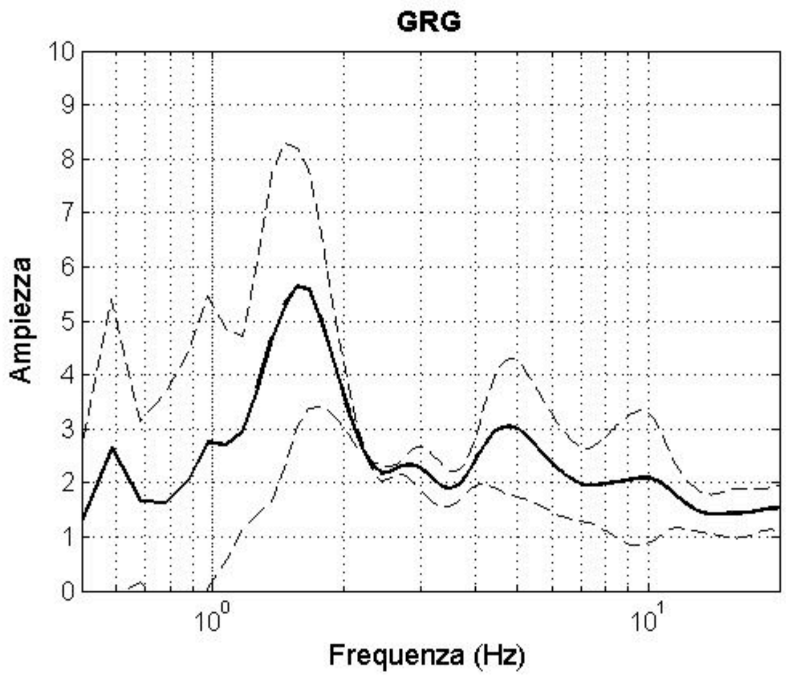
Vs/Vp profile

EC8 classification

GRG	**203**	C

Garigliano: evaluation of site response





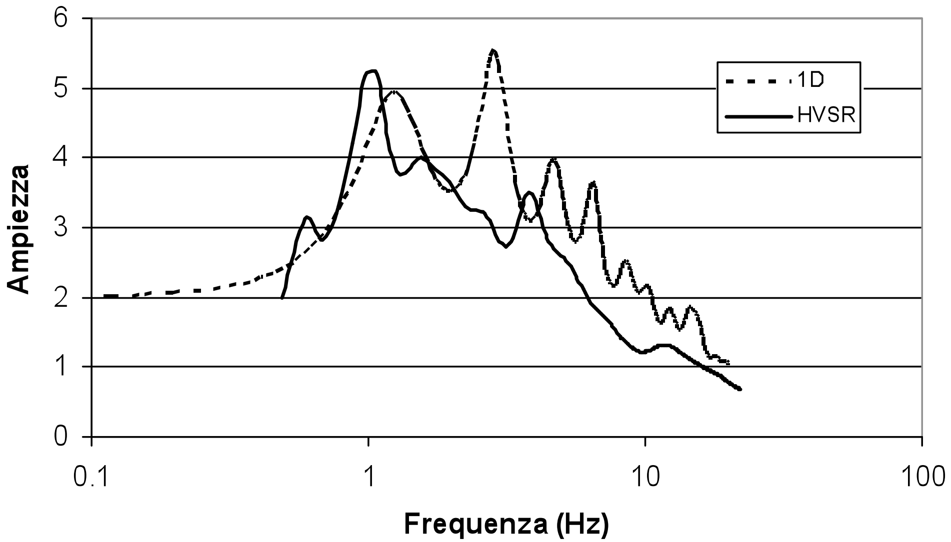
1D linear response (Haskell-Thomson)

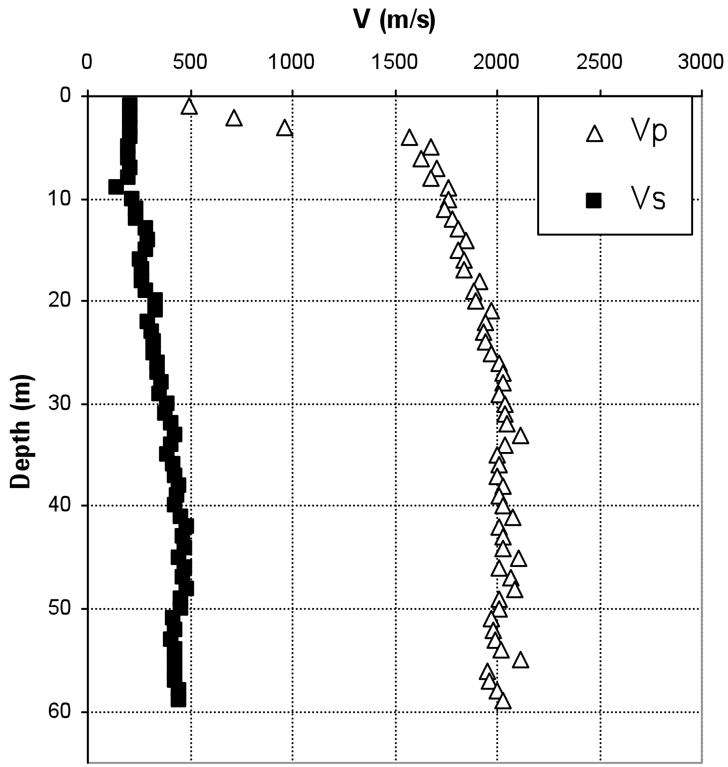
HVSR following the project guidelines

Example: Ancona Palombina

$Vs_{,30}$ (m/s)	Classe EC8	$Vs_{,copertura}$ (m/s)
262.7	C	-

f_0 = 1 Hz

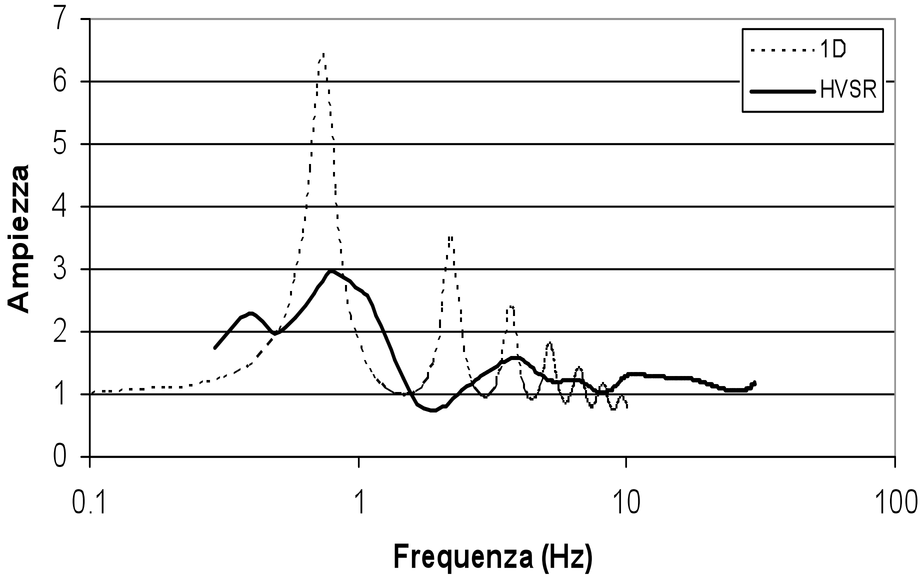


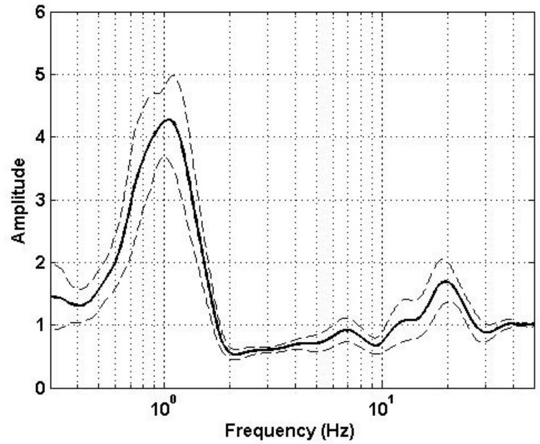


Vs profile from ENEA

Example: Colfiorito

Vs$_{,30}$ (m/s)	Classe EC8	Vs$_{,54}$ (m/s)
110.6	D	150





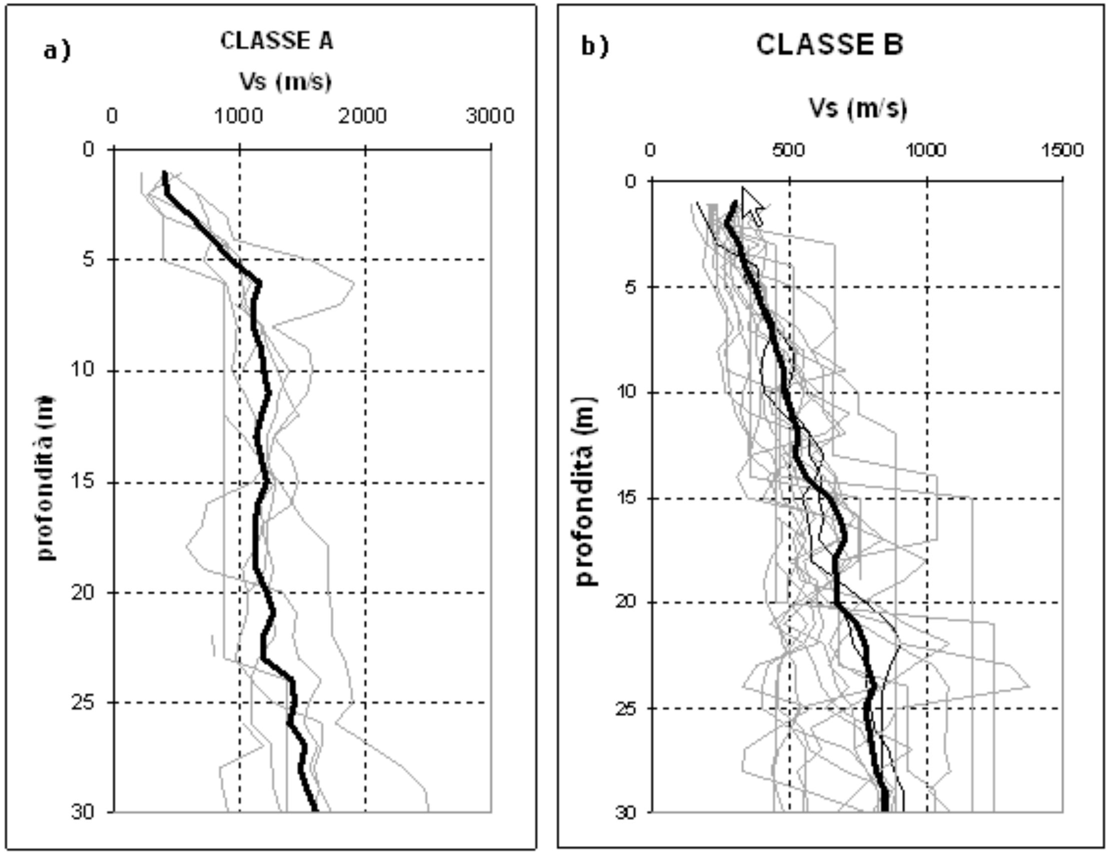
HVSR ambient noise (S6 project)

Vs profile by Di Giulio et al. (2006)

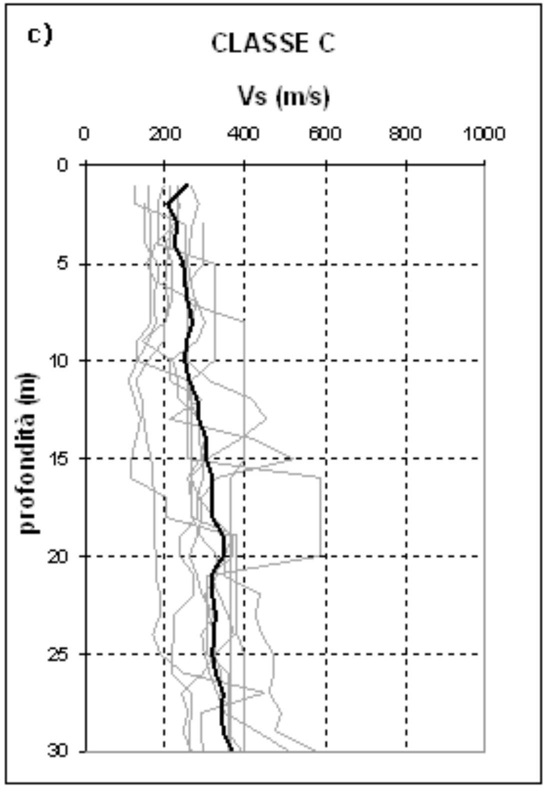
Parameters

Vs30	Average shear wave velocity in the first 30 m
Vs,bedrock	Average velocity to the bedrock depth
Vs,H	Average shear wave velocity for different depth
$f0_{hvsr}$	Resonant frequency obtained for HVSR (earthquakes, microtremors)
$f0_{1D}$	Resonant frequency obtained using 1D models
A_{hvsr}	Amplitude at $f0_{hvsr}$
A_{1D}	Amplitude at $f0_{1D}$
Lito	Lithotechnical class

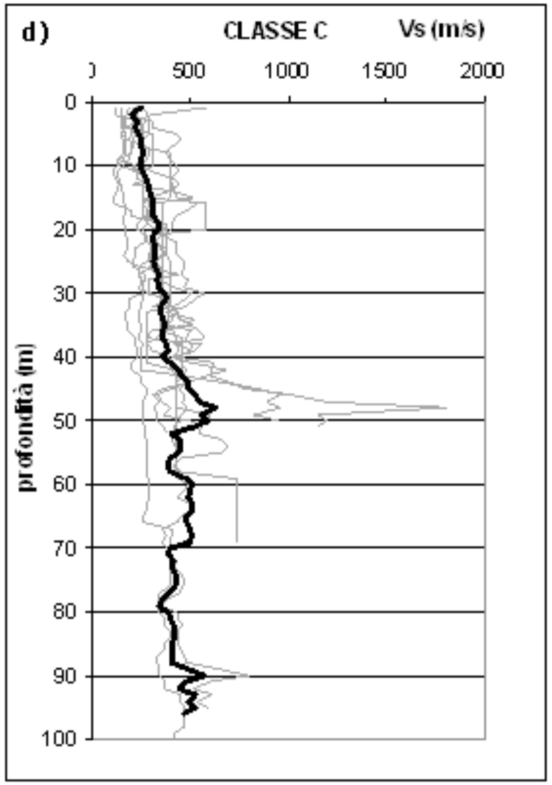
RAN station Vs profiles



RAN station Vs profiles

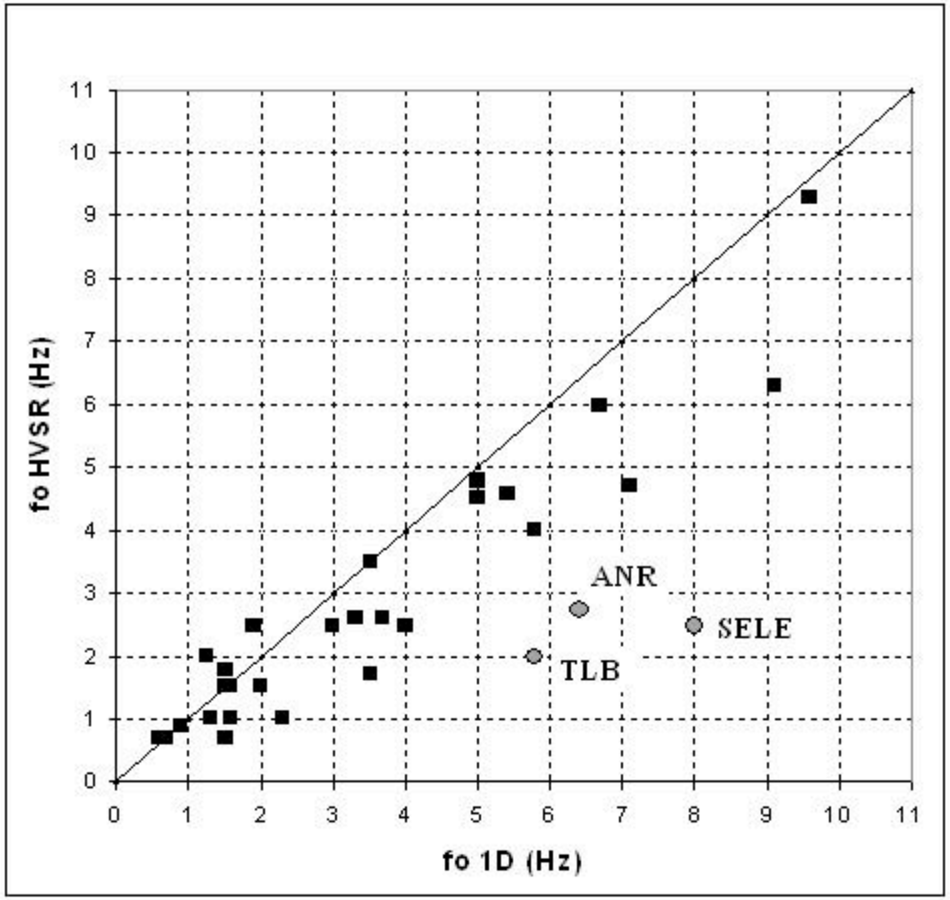


First 30 m

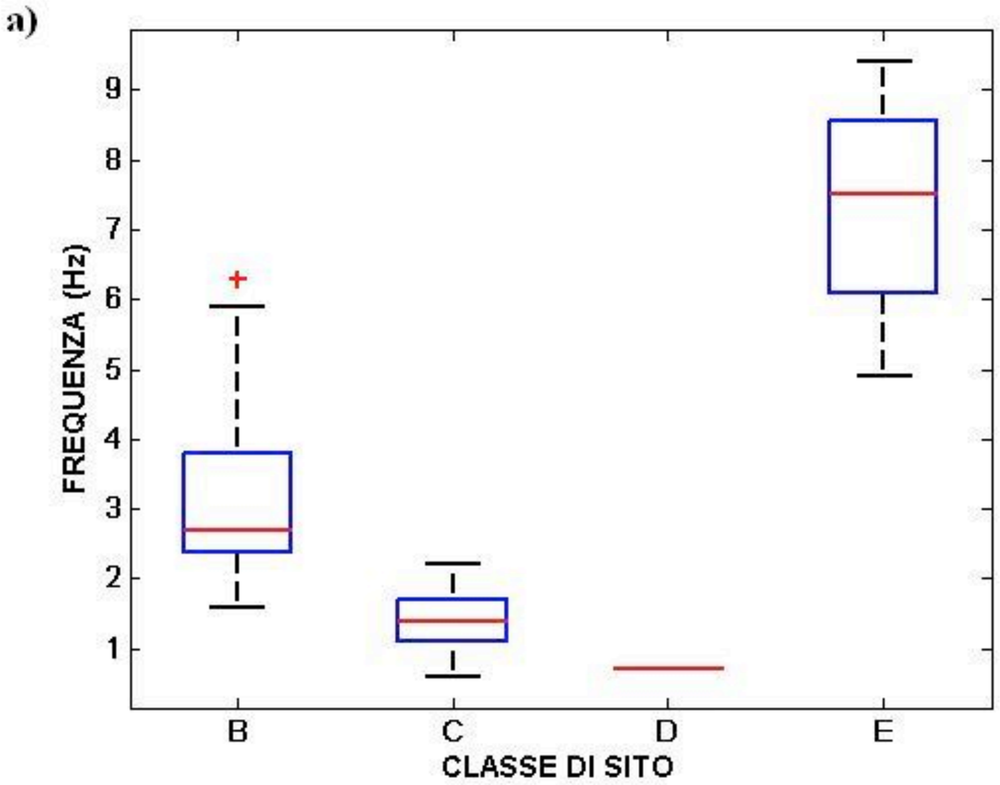


To the borehole depth

1D vs HVSR resonant frequency

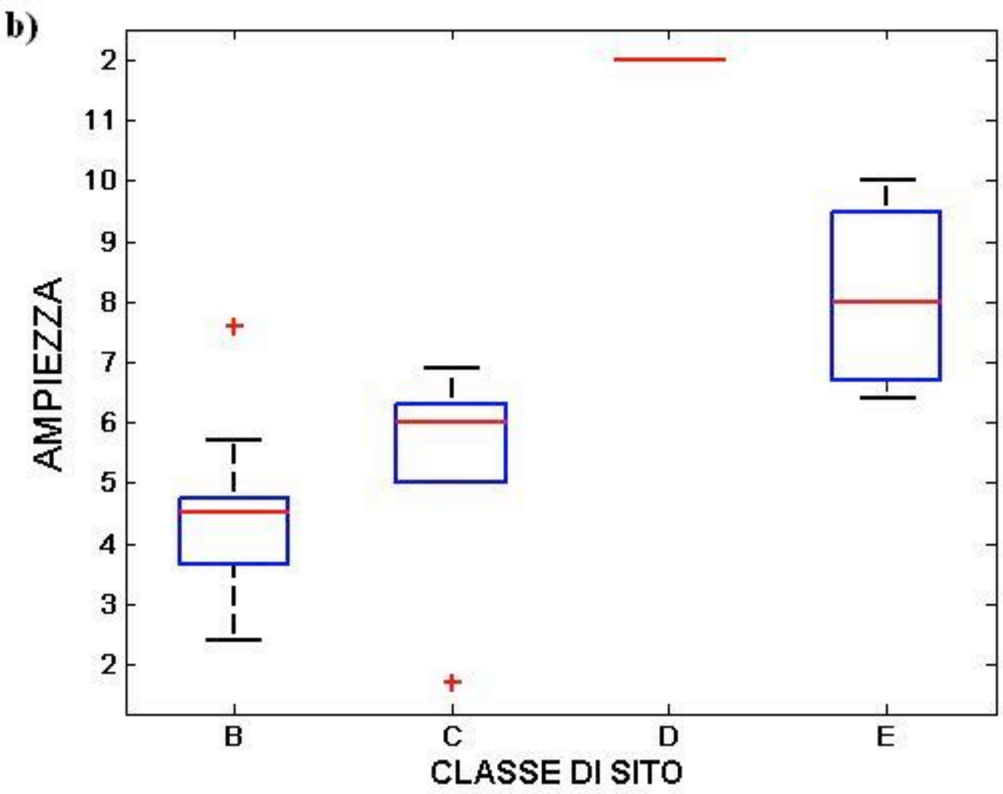


Distribution of the resonant frequency for EC8 classes



Distribuzione della frequenza di risonanza in funzione della classe di suolo EC8 (da HVSR)

Distribution of the amplitudes for EC8 classes



Distribuzione dell'ampiezza corrispondente a f0 in funzione della classe di suolo EC8 (ricavati dal modello teorico 1-D).

4. Test soil classification

Analysis of the error distribution in GMPE

At the moment the soil classification used by Sabetta and Pugliese (1987) is adopted