Task 5: Classificazione sismica dei siti ITACA

Responsabili task:
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Aims of the task

1. 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
2. Provide the database end-user further parameters obtained with low cost methods, suitable for alternative site classification techniques
3. 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

Deliverables

D10 *Responsibles* RU2-INGV-RM1 RU6-Uni-RM1 *Deadline* 24m	Revised seismic classification of the ITACA stations, according to the EC8 and the Italian norms site classes (Technical report) **Product of immediate interest to DPC**	This report will summarize the work carried out in Task 2 on the collection and filing of geological/geotechnical data about ITACA station. It will provide as well the revised classification with the grade of reliability. Validations of simplified classification criteria based on information from geological maps will be included as well
D11 *Responsible* RU7-Uni-Siena Deadline 24m	Seismic classification of the ITACA bedrock sites, with the identification of reference sites for seismic hazard studies and engineering applications (Technical report) **Product of immediate interest to DPC**	This report will contain the scientific activity (5.2) and will provide reference results for seismic hazard assessment at regional/national scale (Project S2) and for production of shake maps (Project S3).
D12 *Responsibles* RU1-INGV-MI RU5-Uni-BAS Deadline 12m	Critical review of methods proposed in the literature for site classification (Technical report). **Research product, for future applications of interest to DPC**	This report will summarize available methods and proposals for seismic site classifications alternative to $V_{s,30}$, will check their applicability using the ITACA data set, and will propose new descriptive parameters of site conditions
D13 *Responsibles* RU1-INGV-MI RU5-Uni-BAS Deadline 24m	Identification of new site parameters for improved seismic classification criteria (Technical report) **Research product, for future applications of interest to DPC**	This report will summarize the work carried out in the activity 5.3, and will provide the site information to build new classification schemes.

1. State of the art

- collect published papers on site classification and International and Italian seismic codes
- carry out the state-of-the-art in site classification with special emphasis on the parameters used to discriminate among soil classes

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

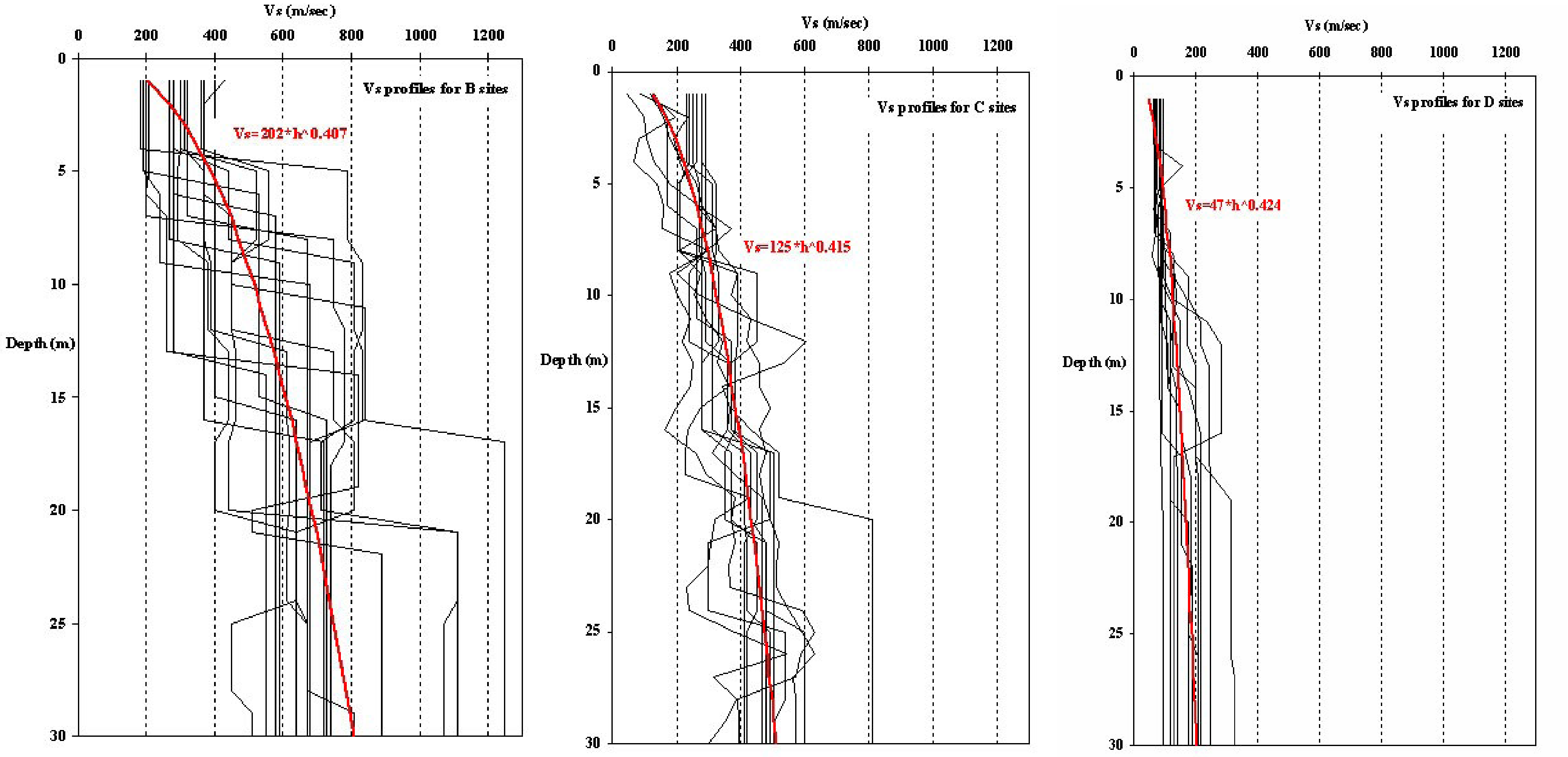
Pitilakis, K. et al. (2003) Experimental and theoretical analyses of site effects toward the improvement of soil classification and design spectra in EC8 and Greek Seismic Code. Final Report Organization of Seismic Planning and Protection

SOIL CATEG.		DESCRIPTION	To (sec)	REMARKS
A	A_1	Healthy rock formations		Vs ≥1500 m/s
	A_2	Slightly weathered/segmented rock formations,(thickness of weathered layer < 5.0m)	≤0.2	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 $N_{SPT(2)} > 50$ $S_{u(3)}$>200KPa
		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 >200Kpa
	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 >200Kpa
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 >200KPa
	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 >70KPa
	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 ≤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 ≤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.*

Vs profile for B, C and D classes (EC8)

from Mucciarelli and Gallipoli (ECEES 2006)



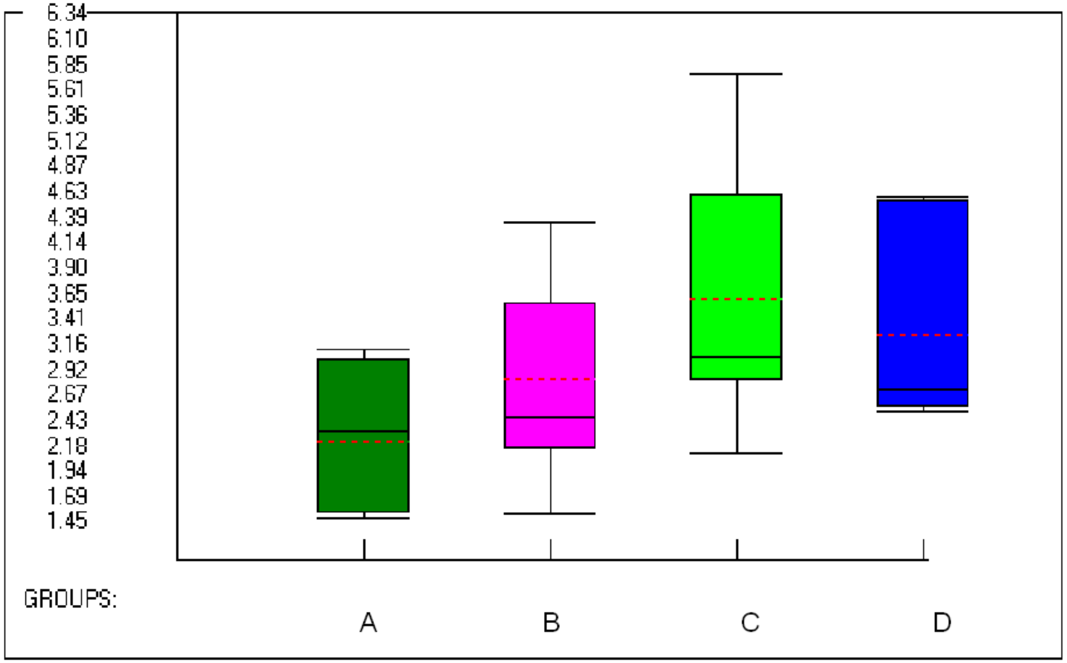
B C D

Amplification for different EC8 classes

from Mucciarelli and Gallipoli (ECEES 2006)

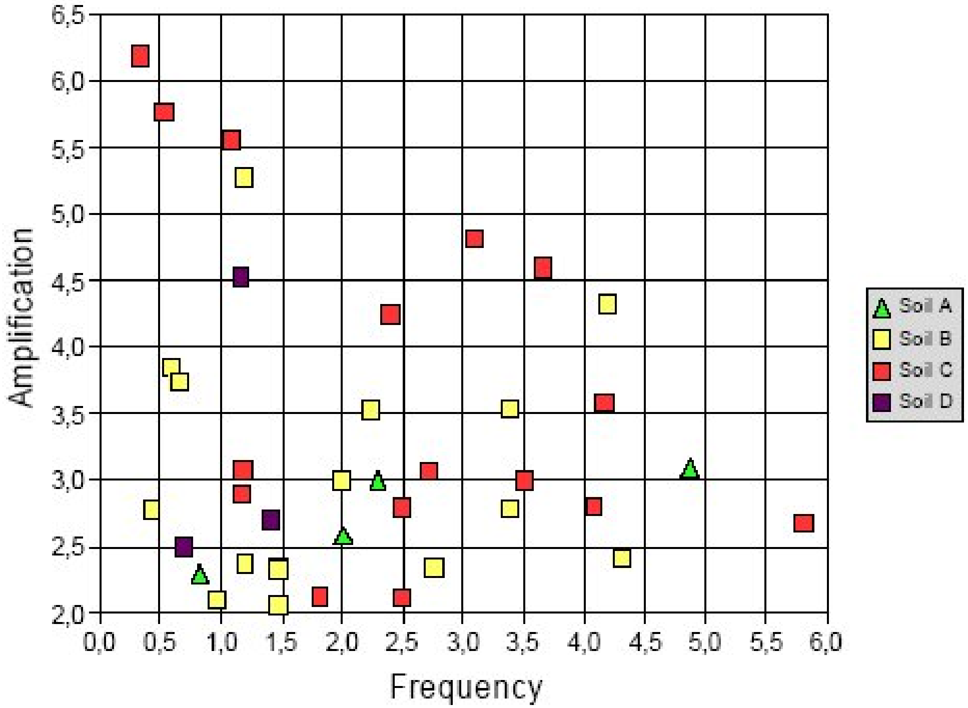
Max HVSR at 46 seismic stations *vs* soil class

RED: mean, BLACK: median, BOX: 25th to 75th percentile, WISKERS: 10th and 90th percentile



"Both average and median are increasing with soil category but the median of class A and median of class B are almost the same. There are several sites belonging to class B and few of class C sites that do not show amplification (HVSR<2). Finally, there are few sites in class D for a meaningful statistic, but they show less amplification than class C."

Amplification versus frequency for different EC8 classes from Mucciarelli and Gallipoli (ECEES 2006)



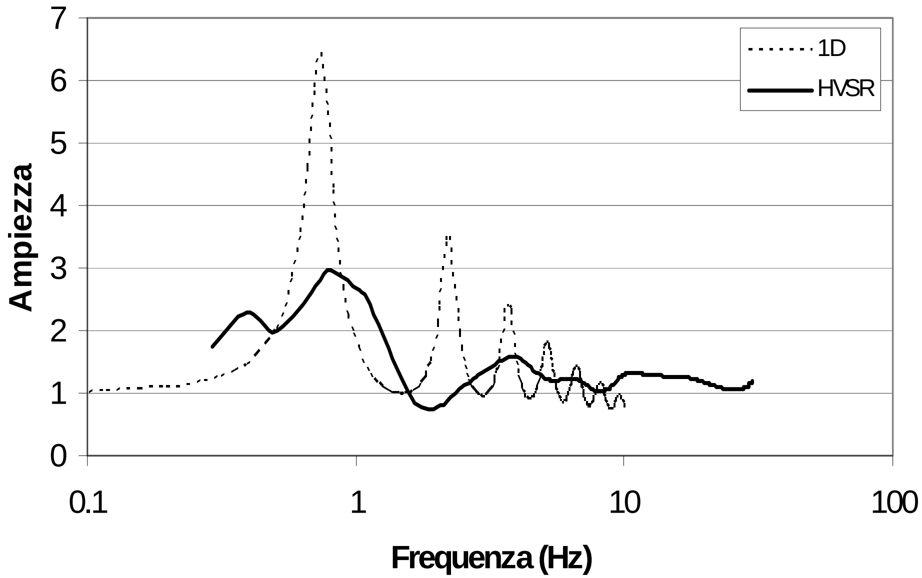
“There is no clear correlation between frequency and amplification for different soil classes. Large amplifications at low frequencies occur at sites that are located within large sedimentary basins. This is surprising, because being HVSRs, these amplifications should be connected with 1-d effects and not with 2-d effects.”

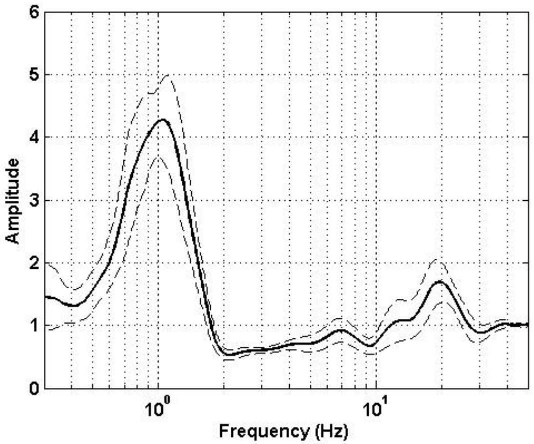
2. Collect a recording station data set

- ITACA recording stations characterized by geotechnical and geophysical information, which recorded seismic events
- ITACA stations integrated with the sites used for seismic microzoning in the Marche region

Example 1: Colfiorito

Vs,30 (m/s)	Classe EC8	Vs,54 (m/s)
110.6	D	150





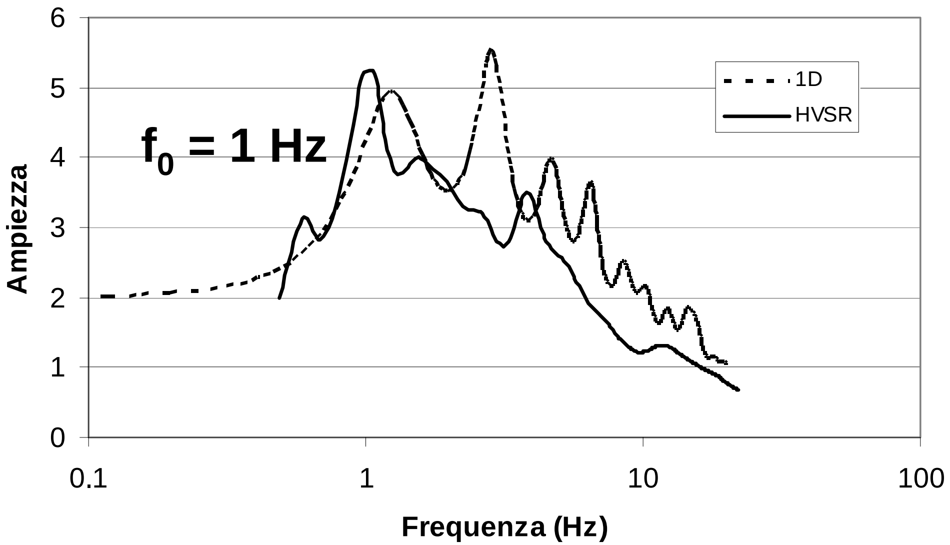
HVSR ambient noise (S6 project)

Spessore (m)	Densità (KN/m³)	Velocità (m/s)	Q
54	17.7	160	12.5
0	20.6	1496	100

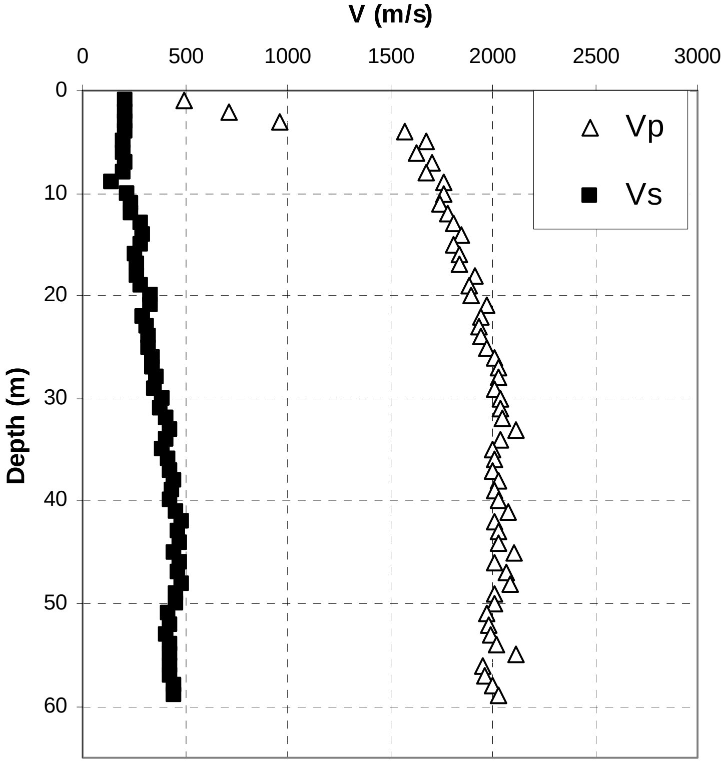
From Vs profile by Di Giulio et al. (2006)

Example: Ancona Palombina

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



Spessore (m)	Densità (KN/m^3)	Velocità (m/s)	Q
10.0	17.7	201.3	10.0
10.0	17.7	274.1	12.0
10.0	17.7	337.2	12.0
10.0	19.6	418.8	12.0
10.0	19.6	466.9	12.0
10.0	19.6	429.4	12.0
40.0	20.0	500.0	12.0
0.0	21.0	1000.0	50.0



Vs profile from ENEA

3. Establish classification schemes alternative to the proposed standards

The classification can be based on a set of parameters with increasing degree of detail and availability:

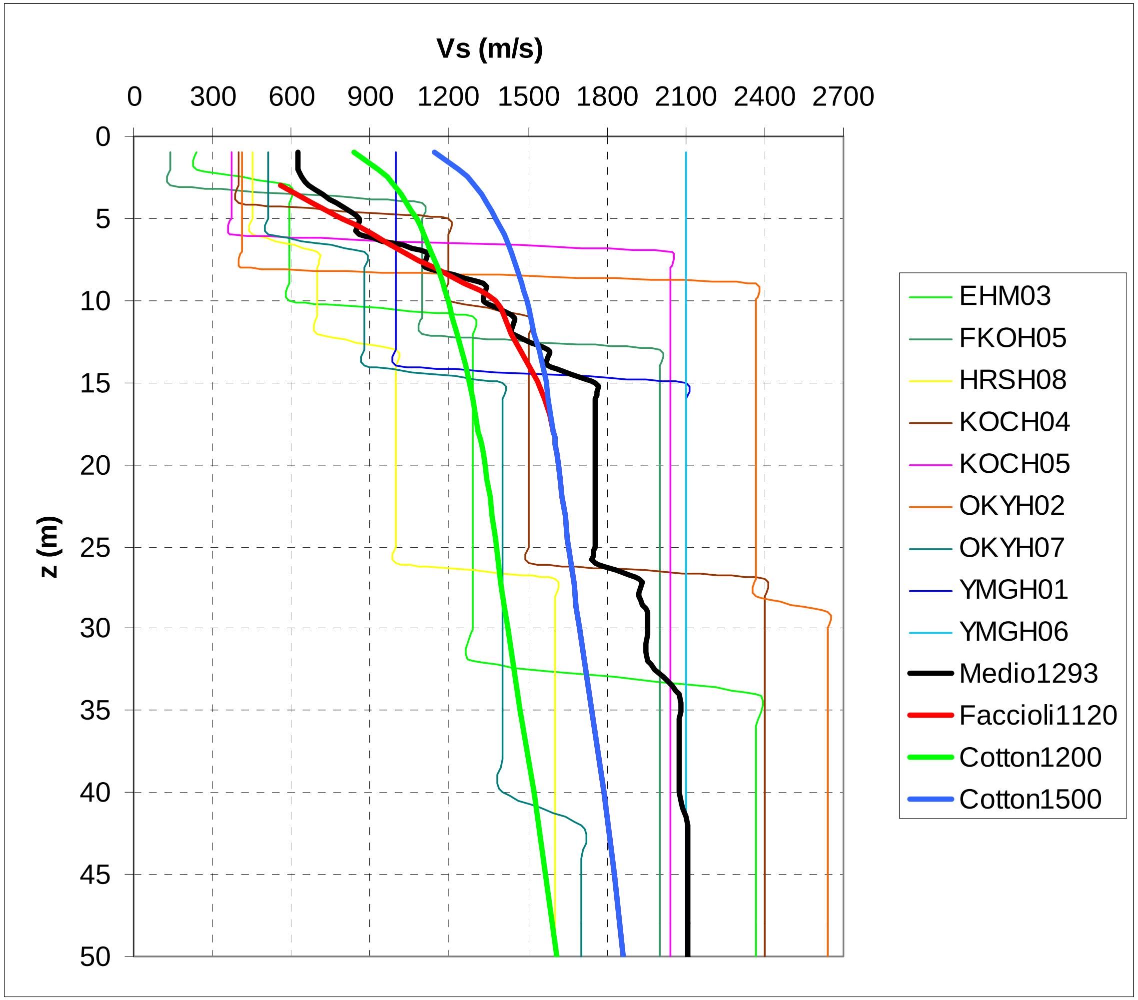
- Qualitative description (geology + geomorphology)
- Depth to bedrock
- Site fundamental frequency obtained with empirical and theoretical models (H/V of strong or weak motion or ambient noise, H/V of response spectra, SSR, 1D or 2D modelling)
- Average V_s at different depths

Rock sites

Special efforts will also be spent in the classification of rock and very stiff soil sites (usually grouped as EC8-Class A):

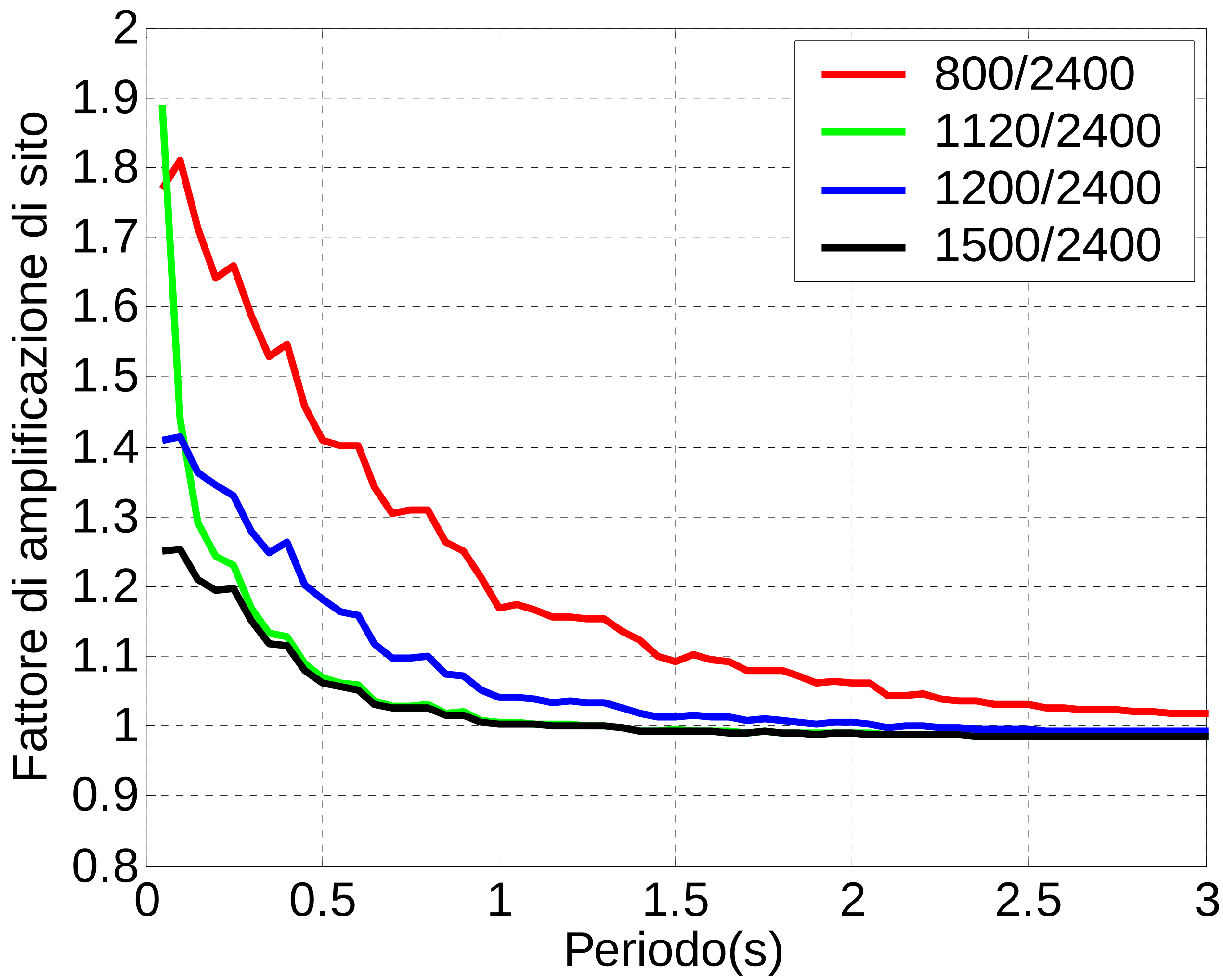
- in Italy rock sites cannot be reduced to one class, because of their variability due to alteration phenomena induced by faulting, jointing and weathering
- the discrimination of different rock types, or sub-classes of class A, will guide the ITACA users to a proper selection of reference ground motions

Rock site classification: Vs profiles for Kik-Net class A (Ec8)



Medio1293 is the average shear wave velocity on the upper 30m

1D amplification function for rock sites



Open questions:

- Are there differences between Alps and Apennines Vs rock profiles

- Does it make sense a subdivision of rock sites into sub-classes?

- Are array techniques suitable to characterise these sites?

Aim:

- Improve rock site classification

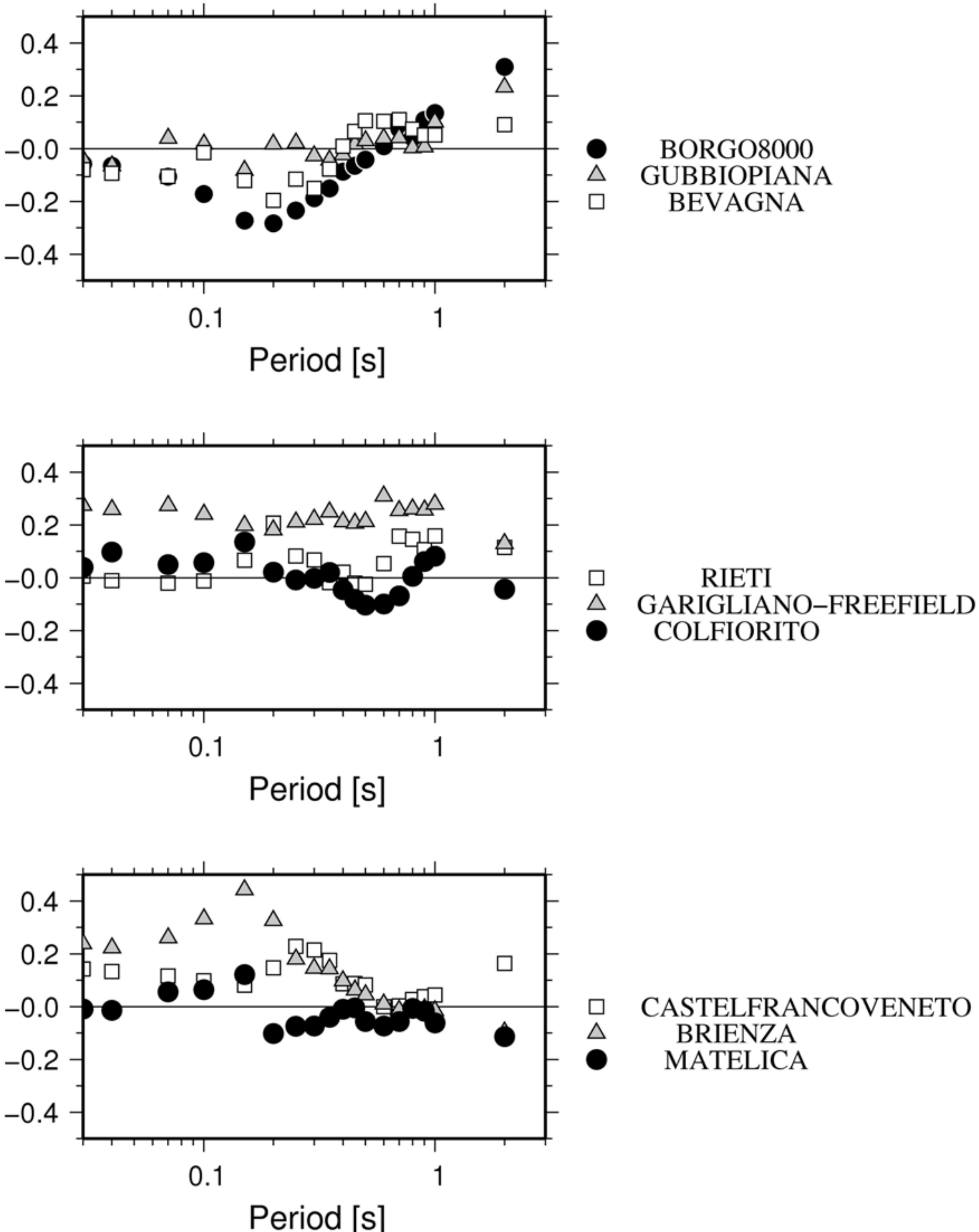
- Individuate ITACA rock sites that can be used as reference sites for hazard studies

4. Test soil classification

1. Analysis of the error distribution in GMPE
2. Other

Method 1 (UR1 Milano – Pavia)

- GMPE are evaluated using the *random effect model* (Searle, 1979; Abrahamson and Youngs, 1992) is applied to separate inter-event (γ) and inter-station (δ) from the record-to-record distribution of errors, following Bindi et al. (2006)
- the residuals between the observed and predicted values are calculated
- the residuals are corrected for the inter-event error
- the inter-station (δ) errors are analyzed to discuss the variability of the site response



Example: δ - test of the Sabetta and Pugliese classification scheme

CLASS 2
deposits with depth > 20m

This classification scheme involves a remarkable error dispersion, which suggests a large variability of the site response, due to the different geologic and geomorphologic conditions (deep basins, such as Borgo Ottomila 1500 m deep, Brienza 30m deep)

Method 2 (UR INGV Roma1)

Presentazione di A. Rovelli

Operativamente

- Fornire a chi si occupa dei task2 e task 3 le specifiche sui parametri (classe geologica, classe geomorfologica, profondità primo contrasto di impedenza, profilo Vs, Vs30 o Vs media al bedrock con profondità inferiore a 30, f0, picco associato ad f0)
- Chi ha il compito di calcolare gli HVSR? Task4? Rovelli