THE RECORDING STATIONS OF THE ITALIAN STRONG MOTION NETWORK: GENERAL INFORMATION AND SITE CLASSIFICATION

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ABSTRACT

One of the main objectives of the ITACA (ITalian ACcelerometric Archive) strong motion database, promoted by the Italian Department of Civil Protection, was to improve the characterization of the recording sites from a geological and geophysical point of view and to provide their seismic classification according to the seismic norms pertinent to Italy, namely the Eurocode 8 (EC8) and the National Technical Norms for Constructions (NTC-08).

A standard format to summarize the available information for the recording stations was first produced, in terms of a technical report dynamically linked to the database, i.e., some of the relevant information is automatically updated when the corresponding fields of the database are modified. Then, an important activity of collection, qualification and synthesis of available data was carried out, especially for stations that recorded the strongest earthquakes in Italy in the last 40 years, and for which a relevant number of studies have been published.

In spite of this activity, among the more than 700 strong motion stations present in the ITACA database, only a limited number of them could be characterized by quantitative information on subsurface soil properties. For this reason, a dual seismic site classification criterion was implemented, either based on the standard $V_{s,30}$ scheme, or, in the absence of such information, based on an expert opinion supported by shallow geology maps, mostly at 1:100,000 scale, and when available on the H/V ratios calculated on recordings. Owing to the relevance in the Italian geographic and morphological context, a special care was also given to the topographic classification of stations, based on suitable criteria developed within a GIS environment.

Keywords: ITACA database, strong motion station, general characterization, site classification.

1. Introduction

One of the main limitations in the practical use of strong motion accelerograms is the proper characterization of the site conditions of the recording stations, in terms of a mix of information ranging from the geological and morphological setting, the vicinity of landslides and/or faults, the interaction with surrounding buildings, the quantitative evaluation of the soil profile, possibly down to the bedrock, the observed response to microtremors and/or to available weak and strong ground motions. As a final synthesis of such characterization, the seismic classification of the site according to the seismic norms, in the Italian case either the EuroCode 8 (CEN, 2003) or the national code provisions NTC-08 (NTC, 2008), is a crucial step towards the rationale selection of accelerograms for engineering applications (see e.g., Iervolino et al., 2011, this issue).

This work stems from the research activities related to the creation of the new Italian strong motion database ITACA (ITalian ACcelerometric Archive, internet site http://itaca.mi.ingv.it), which this issue of the Bulletin of Earthquake Engineering is devoted to. Referring to Pacor et al. (2011, this isseu) for details about the development of ITACA within two projects, S6 and S4, funded by the Italian Department of Civil Protection (DPC), from 2006 to 2010, we will illustrate in this paper the studies made in the latter project (S4) to improve the previous catalogue of geological, geotechnical and geophysical information of strong motion stations, prepared within Project S6 (Luzi et al., 2008 and 2010).

Although ITACA includes as well strong motion records from several local and temporary networks in Italy (Pacor et al., 2011, this issue), we will mainly refer to the stations belonging to the National Accelerometric Network (RAN - Rete Accelerometrica Nazionale), that constitute about 85% of the ITACA stations.

The main goals of this study are: (a) the compilation and synthesis of geological, geomorphological, geotechnical and geophysical data for 695 out of 742 strong motion stations included in ITACA and a reliability assessment of the data; (b) the provision of a summary information for each station in a standard format and (c) the classification of site conditions (Di Capua and Lanzo, 2010).

Several approaches were used to perform the site classification, depending on the quantity and quality of information available. As a matter of fact, detailed geotechnical and geophysical information, suitable to provide a reliable site classification based on $V_{s,30}$ (EC8, NTC-08), was available only for a limited number of stations (16%). The rest of the sites were classified according to an “expert” opinion, mainly based on the local geology, supported by considerations on the horizontal-to-vertical spectral ratios (H/V) on microtremors, available for about 30% of the station sites.

Finally, owing to the relevance in the Italian geographic and morphological context, a special care was also given to the topographic classification of stations, based on suitable criteria developed within a GIS environment.

2. Collection of data

The information for the RAN stations comes from different sources and was mainly collected during the Project S6 (Luzi et al., 2010). Geologic 1:100,000 scale maps were made available for most of the ITACA stations, in order to have a minimum and uniform level of geologic information, since the standardization of information for all stations was one of the primary objective. For 200 sites, geological cross-sections have been prepared too.

When available, more accurate documentation was acquired and used for a better characterization of the stations, as follows:

- Lithologic and geologic maps at 1:25,000 and 1:10,000 scale of four regions (Lazio, Calabria, Molise, Umbria);
- 126 geological reports prepared by SOGIN (*SOcietà Gestione Impianti Nucleari S.p.A.* - Management Company Nuclear Power Plants) for digital accelerometric stations that provided information on location (Region, Province, Municipality, address, site location on a road map), geology map at 1:25,000, geological cross section at 1:25,000 and 1:2,000 scale, an ortophoto of site and photo of the station housing;

- 206 ENEL (Italian Electricity Board) forms, which generally include only geologic maps at 1:50,000 or 1:100,000 scale around the station and a representative geologic cross-section. Among them, 7 stations that recorded the 1976 Friuli earthquake (Fontanive et al., 1985) and 16 stations of the 1980 Irpinia event (Irpinia Project: Palazzo, 1991a,b) have been deeply investigated by geological and geotechnical data, including laboratory and in situ tests; for the 1980 Irpinia event ENEL forms, as well as geologic maps at 1:5,000 scale with corresponding geologic cross-sections were also provided;
- seismic velocity profiles obtained by using the controlled source spectral analysis of surface waves (SASW) for 18 sites that recorded the 1997-1998 Umbria Marche earthquake sequence (Kayen et al., 2008);
- stratigraphies, Vs profiles, seismic refraction profiles and geotechnical parameters for about ten digital stations come from the Project S6 (Luzi et al., 2010).

For geomorphologic analyses, the topographic maps at 1:25,000 scale by IGM (Italian Geographical Military Institute: http://www.igmi.org/) were used together with Google Earth satellite images. 198 stations were classified by visual inspection, station by station, into morphologic conditions; results are illustrated in Table 1.

Data from the Inventory of Italian Landslides (ISPRA, 2008) were also integrated. From these data, it turned out that 63 stations were located on, or close to, active/quiescent landslides (Cruden and Varnes, 1996), also of considerable size (area > 700,000 m^2). Some examples are illustrated in Figure 1a and b. This information has been reported on station forms.

2.1 Shear wave velocity data

Another important source of data comes the numerous shear wave velocity profiles (V_s) gathered during project S4, either by in-field surveys (Foti et al., 2011, this issue), or by previous research projects: a total of 111 V_s profiles was made available.

Profiles for a total of 52 sites were extracted from literature (e.g., Luzi et al., 2010), all investigated by means of down-hole or cross-hole tests. The information from literature derives from: (1) investigations at selected instrument sites that recorded the 1976 Friuli and 1980 Irpinia earthquakes; (2) microzonation and other studies for local municipalities or regions; and (3) site studies by consulting engineers and geologists.

Of the 18 velocity profiles investigated by Kayen et al. (2008) with SASW technique, only 9 were included in the database, because results from borehole seismic methods were preferred to those obtained with SASW technique.

Additionally, 59 strong motion stations were surveyed within the S4 project. The selection of sites to be investigated was driven by several criteria: in general, attention has been first paid to stations that recorded important events and to the newest digital stations. To have a good coverage for the whole Italian territory, regions with no or limited surveys were preferred. On-site surface wave measurements were performed using active methods such as MASW (Multi Channel Analysis o Surface Waves) and passive methods (ReMi, ESAC, f-k) (Foti et al., 2009). Generally, MASW technique was used at sites with very shallow rock whereas, in sites with very deep rock, only passive methods with 2D arrays were considered. It must be noticed that two strong motion stations triggered by the L'Aquila earthquake (namely AQA and AQG) were tested by both down-hole and surface wave methods (Foti et al., 2011, this issue).

3. Site classification procedures

One of the project requirements was to provide a seismic site classification for the totality of ITACA stations. A lithological map at a national scale (1:100,000), developed by INGV in a Shakemap project in Italy (Michelini et al., 2008) was used for preliminary site classifications (Figure 2). The lithological map derives from the Geologic Map of Italy at 1:100,000 scale, by aggregating different geologic units according to geologic age criteria. In this way broad lithologic classes have been created with a raw correspondence with the EC8 ground types (A, B, C, D, E) by the following steps:

1) for each geologic formation the predominant lithological unit has been considered (e.g., for the Geologic Formation of San Bartolomeo Flysch it consists of sandstone);
2) geological units with similar predominant lithological units were then merged into a single class (e.g., sandstone class);
3) each lithological class has been associated with an EC8 class on the basis of its lithological description (e.g., EC8 class A for sandstone).

The locations of the strong motion stations have been overlaid on the EC8 class map (Figure 2). Some early studies during the first phase of the project revealed the limits of the "geologic" classification, particularly when the site is close to a boundary between two different ground types, with thickness of soil deposit less than 20 m (generally characterizing small deposits not depicted on a 1:100,000 geologic map) or when landslides are present.

The site classification according to shallow geological information has been released for 686 ITACA stations (see Appendix A in Di Capua and Lanzo, 2010). Most sites are classified as A (45%), while the proportion of C class sites (28%) is slightly larger than that of B class sites (24%). Few sites fall into D class. No sites are classified as E class, as the definition of this class requires the detailed knowledge of the subsoil stratigraphy.

The EC8 classification according to shallow geological information was subsequently considered in deeper detail by taking into account shear wave velocity profiles from in situ measurements and the predominant period of the station site.

3.1. Equivalent shear wave velocity ($V_{s,30}$)

The V_s profile was used to provide site classification according to EC8. Indeed the code divides soil sites into five “Ground Types” (namely A, B, C, D and E and two special classes, i.e. S1 and S2) which are preferably identified based on the equivalent shear wave velocity in the upper 30 m ($V_{s,30}$). Hence, 111 sites have been assigned a $V_{s,30}$ value. When the velocity profile was available only to a depth less than 30 m, a relationship between shear wave velocity relative to this depth and the $V_{s,30}$ was used, based on the velocity data of the KikNet network (Figini, 2006). The relationship is the following:

$$\log V_{s,30} = a + b \log V_{s,d} \tag{1}$$

where $V_{s,d}$ is the equivalent shear wave velocity to depth d, calculated according to the following equation:

$$V_{s,d} = \frac{d}{\sum \frac{h_i}{V_{s,i}}} \tag{2}$$

$$d = \sum h_i \tag{3}$$

where a and b are regression coefficients tabulated for each depth d. The a and b values are summarized in Table 2.

All stations classified according to EC8 are tabulated in Appendix A together with the $V_{s,30}$ values. In particular Appendix 1A lists the 52 stations for which V_s data is obtained from literature whereas Appendix 1B reports 59 stations with V_s data obtained from in situ tests performed within the S4 project. As mentioned before AQA and AQG stations were tested with two different tecniques. Considering the whole set of data, it can be seen that 56% of them falls in B class (62 stations), 34% in A (16) and C (22) classes, almost equally distributed, while the remaining 10% can be classified as D and E (6 and 5, respectively).

3.2. Horizontal to vertical (H/V) spectral ratio

Based on Zhao et al. (2006) and Fukushima et al. (2007), a site classification scheme has been adopted by Di Alessandro et al. (2008) according to the predominant period T of the station site. The predominant period of site is identified from the average horizontal-to-vertical (H/V) spectral ratios of the 5%-damped response spectra of recorded accelerograms. It is computed on a data subset including seismic events with moment magnitude M_w >4.0 and epicentre-station distance R > 200 km. The classification is made by identifying the location of the predominant peak in the spectral domain. Seven classes, CL-I to CL-VII, are recognized. Specifically, the classes CL-I to CL-IV refer to average spectral curves showing a clear peak (exceeding threshold amplitude of 2) and correspond respectively to the period intervals 0-0.2 s, 0.2-0.4s, 0.4-0.6 s and greater than 0.6 s. In the case that the average spectral ratio curve is approximately flat and that the peak ratio is less than 2, the station is classified as CL-V, which suggests a hard rock site (corresponding to the ground type A in EC8). If the observed average response spectral ratio does not present a peak but rather a broadband amplification or multiple peaks, the site can be classified as CL-VI or CL-VII considering an amplification occurring at periods T > 0.2 s or T < 0.2 s, respectively.

The sites were classified whenever at least one accelerogram is available. In total 209 sites were classified. The percentage of spectral site classes is shown in Table 3.

3.3. Topographic features

For all the ITACA stations a practical procedure for the identification of sites with topographic seismic amplification effects was implemented trough a morphometric analyses of high resolution digital elevation models (DEM), with the support of Geographic Information Systems (GIS). To this end a 30x30 m resolution Global Digital Elevation Model (ASTER GDEM, 2009) was used with an elevation accuracy of 20 m at 95% confidence level.

GIS technology includes a suite of integrated applications to perform mapping, geographic analysis, data editing, data management, visualization, and geo-processing tasks. In the present case, GIS capabilities were used to classify the relieves according to the seismic norms by calculating critical ranges of slope and identifying ridges or reliefs with significant gradients. In fact, EC8 and NTC-08 suggest topographic amplification factors to seismic actions depending on morphological parameters, such as the average ground inclination (*i*), the type of relief and the location of the site relative to the ridge.

In accordance with EC8 and NTC-08 indications, four landforms classes were individuated:

T_1: flat surfaces, isolated slopes or reliefs with $i \leq 15°$.

T_2: Slopes with $i > 15°$.

T_3: Reliefs with ridge top width much smaller than the base, and $15° \leq i \leq 30°$.

T_4: Reliefs with ridge top width much smaller than the base, and $i > 30°$.

Slope maps were generated by GIS as the maximum rate of change in elevation over each cell and its eight neighbours, and all the territory was classified in three ranges of average inclination $i < 15°$, $15° \leq i < 30°$ and $i \geq 30°$. The identification of ridges, that is critical for a proper identification of the topography class, is achieved through the development of a proper RIDGE application that chain together sequences of GIS tools (mainly curvature, slope, flow accumulation and focal statistics) and automate the identification process (Pessina et al., 2010). An example of ridge detection is illustrated in Figure 3.

These two conditions were stored into raster layers: the slope ranges were transformed into a raster layer with integer values (0, 1, 2 for $i < 15°$, $15° \leq i < 30°$ and $i \geq 30°$ respectively) and the presence of ridge was characterized by a value equal to 1 (0 = no ridge). Within a buffer area calculated with 100 m ray from the station, the combination of the two parameters was checked by calculating the minimum (MIN), maximum (MAX) and SUM statistical values of both layers. These statistical values fully describe the morphology of the sites: for instance, a high SUM value of the ridge layer indicates that the station is on the ridge or very close to it, while the distance to the ridge increases with the decrease of the SUM value.

The combination of the statistical values for the ridge and slope layers leads to the topography classifications, according to the EC8 definitions, as illustrated in Table 4. The technical details of the procedures are illustrated in Pessina (2010).

Some useful considerations have to be done to highlight the limits of the proposed procedure. First, analysis was generally performed in a buffer area of the station, in order to reduce errors due to the possible inaccuracy in station locations. Then the classification does not always worked customary: this is the case of about 60 stations having buffer areas partially or totally overlaid (see Figure 4) which topographic characterization was performed by visual checking inspection for each station. The same inspection has to be done, using topographic maps and/or satellite images, for all those NC (Not univocally Classifiable) cases in Table 4. There are 98 stations (~14% of the total) that can not be automatically classified by the implemented GIS procedure because the combinations of slope and ridge codes do not permit an unequivocal class assignment. Most of those stations are located at the base of slope and belonging to class T_1 or T_2: in these cases, a one-by-one visual inpsection was performed. In any case, the one-by-one visual check cannot resolve all the NC cases, which in general present a large margin of uncertainties.

In general, the semiautomatic topographic classification can be used as a first step of discrimination between T_1 flat sites and those with possible amplification phenomena. The attribution of T_1 can be assumed with a high level of confidence: they represent about 69% of the stations. The remaining 31% of the stations deserves deeper investigations. For instance, most of the T_2 cases refer to stations located on slope, without indication on their relative position (located at the base of the slope, in the middle or at the top of it) and, being the amplification phenomena proportional to the distance from the ridge, they ought to be singly examined.

To verify the dependency of the proposed identification method by the resolution of the Digital Elevation Model (DEM) and by the morphological features of the terrain, GIS sensitivity analyses were performed (Pessina et al., 2010).

4. Results

4.1. The recording station form

A new version of the standard station form was released in order to homogenize data from different sources so as to provide a consistency level of information. The standard form allows for an homogeneous archive of data about the RAN stations, including general site information, geological and geomorphological setting of the area, generalized ground conditions and other pertinent information. The form is accessible through the website (http://esse4.mi.ingv.it/images/stories/deliverable_d3.pdf). In detail, the standard form is composed of 12 modules and supplementary sub-modules presenting available information, as reported in Table 5. Several tables, graphs and images, in English, are used for presentation.

The most significant improvement over the previous station form developed for ITACA database are:

(a) *geomorphology attributes* describing site morphology by the use of geometrical conditions (e.g. plain, valley, slope, saddle, ridge, etc.) and the presence of morphogenetic processes (landslides) in the site, or in its proximity, that can affect the seismic local response;

(b) proximity of *tectonic elements*;

(c) qualitative and quantitative descriptions of *the rock mass conditions* (to be compiled only after survey);

(d) specific sections on *geotechnical and geophysical information*. Here, a series of modules illustrates the location of boreholes and in situ tests, the stratigraphic profile and the samples recovered, the results of standard in situ tests (CPT, SPT, piezometric measurements) and geophysical tests (down-hole, cross-hole, SASW, MASW, etc.) as well as those from laboratory tests for the measurement of physical and mechanical soil properties, when available. An example of the plots showing the variation with depth of SPT blow counts, N_{SPT}, penetration resistance, q_c, index properties, as well normalized and damping ratio curves is illustrated in Figure 5 for the San Severo site (ISMES, 1992).

(e) *horizontal to vertical (H/V) spectral ratio* determined from earthquake recordings.

(f) information relevant for shallow *geology and topographic site classification* according to EC8 or NTC-08 classification scheme.

4.2 Comparison between different site classification

The consistency between the classification from the geologically-based map with the classification based on $V_{s,30}$ was also investigated.

A very good correspondence is observed (see Table 6) for class A (81% of sites) where, on a total of 16 sites classified as A, 13 sites are classified coherently as A*. Conversely, only 19% (12/62 sites) of class B sites are consistent when shallow geology and $V_{s,30}$ are used for classification. The correspondence for C class is relatively good as it is obtained for 50% of sites. A lack of correspondence is observed for sites in class D. Sites in class E are misclassified as class A* and B*, but this is expected due to the inherent difficulty of classifying this kind of sites using only shallow geological information at 1: 100,000 scale.

Sites classified by using the shallow geology are evenly distributed among the spectral classes (Table 7) defined by the H/V ratio. The sites without any spectral amplification (CL-V) or with amplification for period minor than 0.2 s (CL-I e CL-VII) can be as a first approximation considered as rock (class A*): they are 49 over a total of 85 sites (58%). The distribution of CL-IV sites (with amplification for period > 0.6 s) is rather uniform in A*, B* and C* classes.

Class CL-V should group rock reference sites, with no amplification: on a total of 18 stations CL-V classified, 12 (67%) are congruently classified into class A*, while the remaining has been misclassified and designated to class B* (22% – 4 stations) and class C* (11% - 2 stations).

A similar comparison of the predominant period-based classification with $V_{s,30}$-based classification is not worthy because of the small number of cases (63 stations both characterized). CL-V sites are only 6 and are not statistically useful to characterize rock reference conditions. Sites without spectral amplification or with amplification for period < 0.2 s (CL-V, CL-I and CL-VII - 28 stations) are mainly classified in B class (75% - 21 stations).

The EC8 topographic classification is also provided for many stations. The final classification, performed by the GIS procedure supported by a manual inspection for the doubtful cases (NC), assigns 499, 157, 23 and 9 stations into T_1, T_2, T_3 and T_4 classes respectively, according to EC8. Even after a station by station manual checking, 7 cases present a so complex situation than cannot be ascribed to any topographic class, also for the intrinsic difficulty in the topographic classes definition.

The list of site classes is available by web (Di Capua and Lanzo, 2010).

With regard to the shallow geology classification, all the T_4 sites are classified on rock (A*), most of T_3 and T_2 are classified as A* (68%), instead the T_1 sites are somewhat distributed equally in A*, B* and C* classes. This fact is not surprising because many stations can be located on rock plateau.

5. Conclusions

The characterization of site conditions for the Italian accelerometric network stations (RAN) is a fundamental step for analyzing ground motions recorded during the last earthquakes in Italy.

In the framework of the S4 Project, data available for the site conditions of strong-motion stations has been compiled. New site investigation programs were also run within the Project.

In total, site conditions for 695 stations have been classified. All the information acquired have been systematically organized and archived in a standard format. To estimate site conditions at the recording stations, geology maps at 1:100,000 scale were extensively used, allowing a fast classification of a large number of stations and therefore providing a simple and uniform classification applied to all stations. This geological classification was then refined for the stations provided of other types of data, primarily shear wave velocity profile (111 RAN stations have shallow V_s profile). The geological site classes were also examined and revised by using the average horizontal to vertical response spectral ratio of recorded accelerograms (data available for 209 stations).

A topographic classification was performed using GIS tools and DEM data. Critical sites have been identified according to the prescriptions on EC8 and Italian code. This classification was strengthened by single visual investigations when the automatic procedure provides doubtful cases of station classification or unresolved problem of locations (i.e. high vicinity of stations).

In conclusion, the updated site classifications of RAN stations, in accordance with EC8 and national code provisions (NTC-08), is now available in the ITACA database (http://itaca.mi.ingv.it) and on the S4 Project website (Appendix E, Di Capua and Lanzo, 2010). The level of knowledge on stations is a preliminary step for Italian strong-motion stations site conditions and can be improved with further geological, geotechnical and geophysical investigations on RAN sites.

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FIGURES

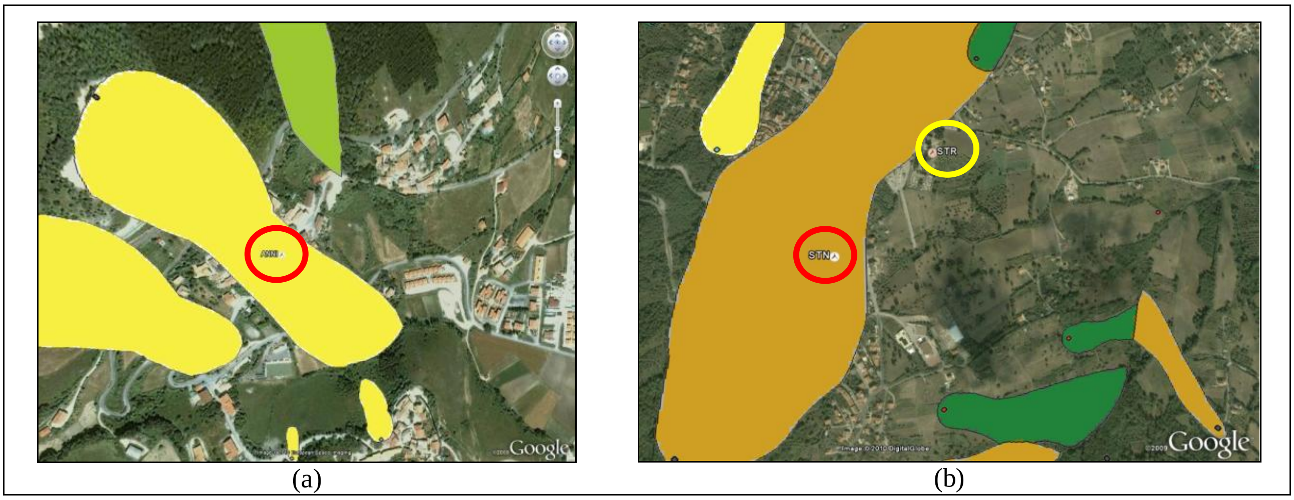


Figure 1. ITACA station sites affected by landslides (from IFFI Project) or located on different morphological situations. (a) Annifo station (ANNI): quiescent rotational slide (red circle). (b) Sturno stations (STR and STN): quiescent complex slide in the STN site (red circle), while STR site (yellow circle) is close to the landslide.

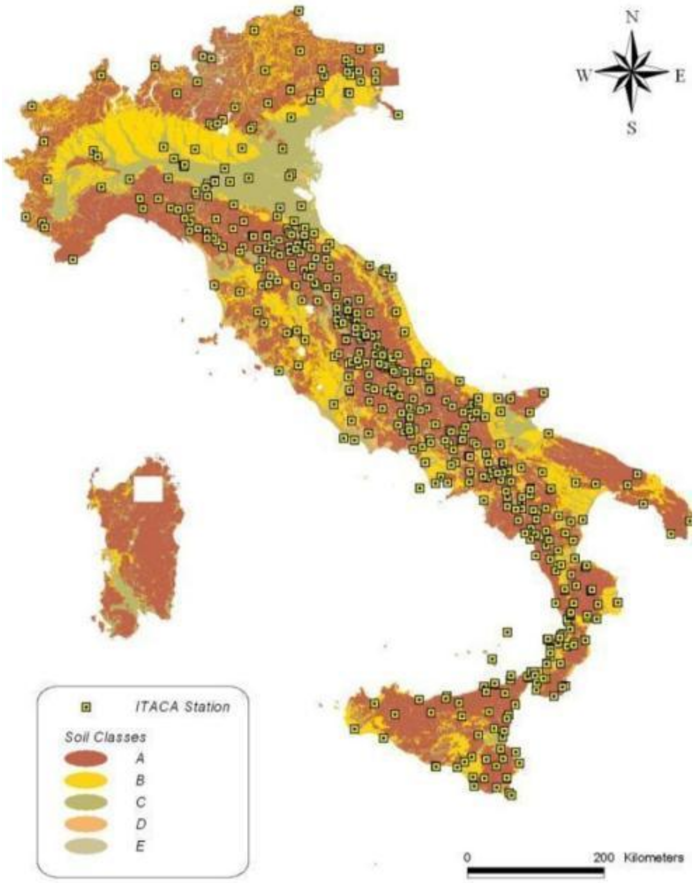
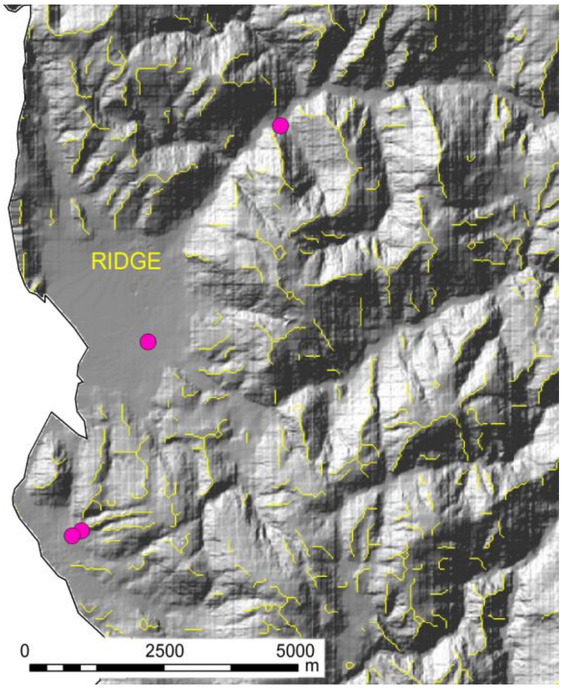


Figure 2. EC8 ground types map for Italy and locations of the ITACA stations.



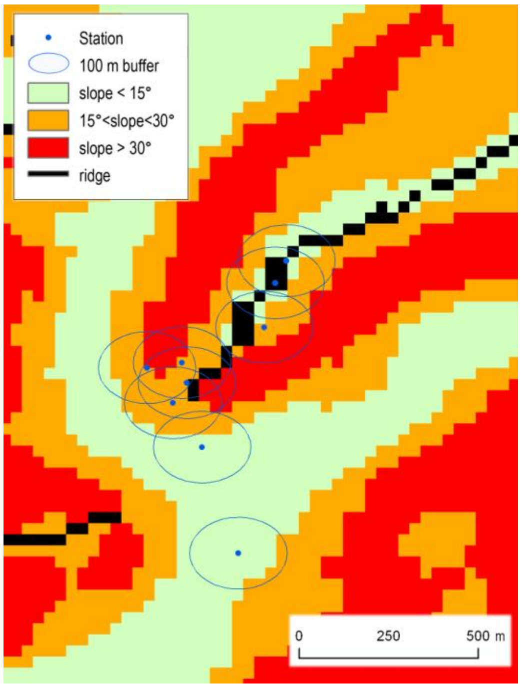


Figure 3. Results of ridge detection (yellow lines) in the Appennine mountains (Pessina et al., 2010); circles represent the recording station position.

Figure 4. Overlaid buffers (dark ellipses) for the stations located on the hill of Cerreto di Spoleto.

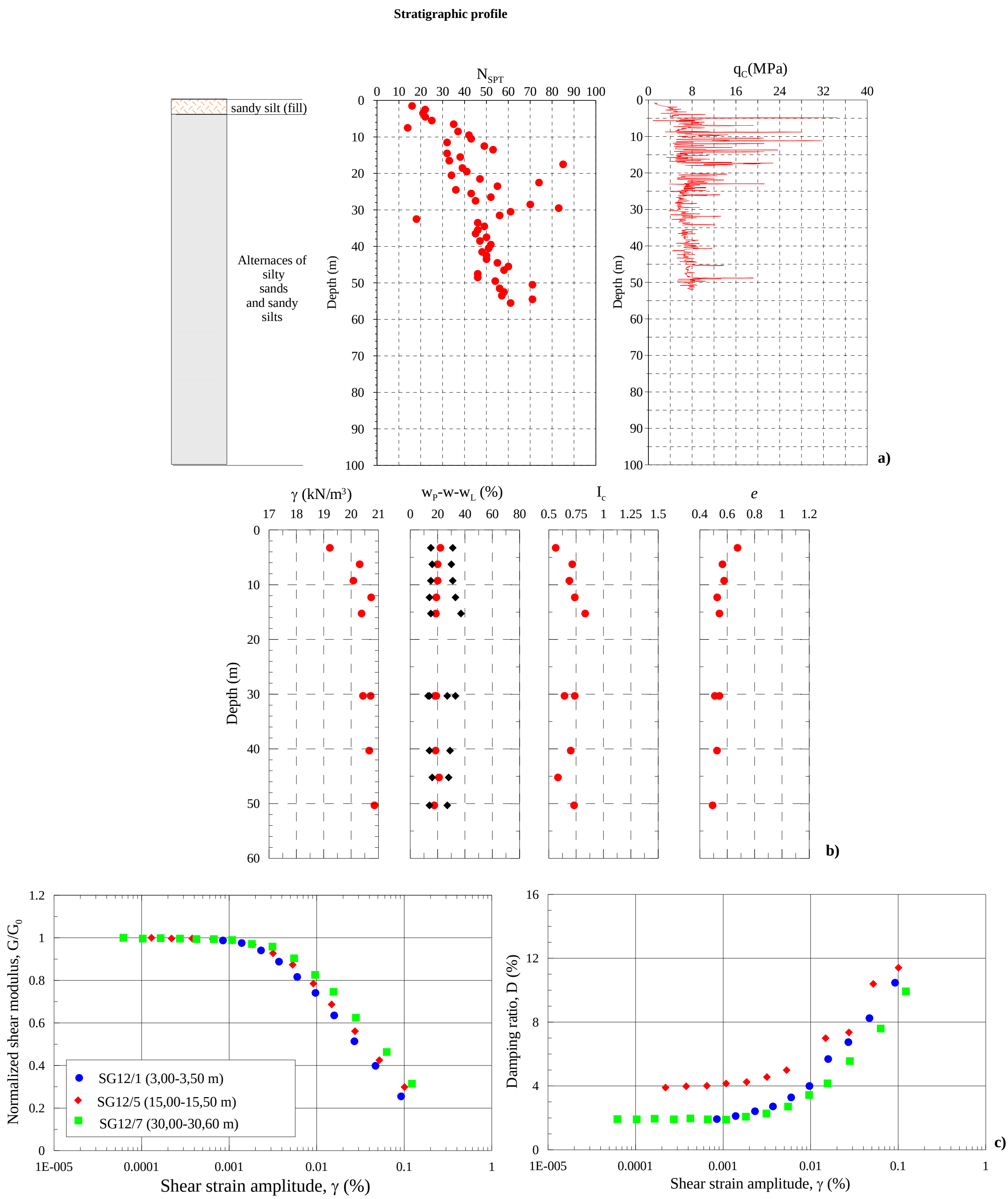


Figure 5. Representation of geotechnical data at San Severo site (SSV): (a) variation with depth of SPT blow counts and penetration resistance, (b) index properties, (c) variation on normalized shear modulus and damping ratio with shear strain amplitude.

THE RECORDING STATIONS OF THE ITALIAN STRONG MOTION NETWORK: GENERAL INFORMATION AND SITE CLASSIFICATION

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TABLES

Table 1. Morphological classification.

Morphologic condition	N. of cases
Plain	24
Centre of valley	17
Edge of valley	17
Alluvian fan	3
Saddle	4
Slope	88
Edge of scarp	11
Ridge	34

Table 2. Values of the regression coefficients for calculating $V_{s,30}$ from $V_{s,d}$ ($d < 30$m).

d (m)	*a*	*b*	*d* (m)	*a*	*b*
5	1.228	0.609	18	0.295	0.93
6	1.155	0.637	19	0.255	0.941
7	1.078	0.665	20	0.22	0.951
8	1.02	0.686	21	0.187	0.96
9	0.909	0.726	22	0.157	0.967
10	0.812	0.761	23	0.131	0.974
11	0.722	0.792	24	0.109	0.978
12	0.643	0.819	25	0.086	0.984
13	0.566	0.846	26	0.065	0.988
14	0.497	0.868	27	0.047	0.992
15	0.436	0.888	28	0.031	0.995
16	0.389	0.902	29	0.014	0.998
17	0.339	0.917	30	0	1

Table 3. Percentage distribution of spectral site classes, according to Di Alessandro et al. (2008).

Predominant period site classes	%
CL-I	18
CL-II	21
CL-III	11
CL-IV	18
CL-V	9
CL-VI	9
CL-VII	14

Table 4. Result of the automatic assignment of EC8 topographic classes.

EC8 classes	N. of cases
T1	477
T2	108
T3	8
T4	4
NC	98

Table 5. Modules and sub-modules included in the monography.

No.	Module	Sub-module
1	General information	-
2	Geographical information	location, coordinates, cartography
3	Geomorphology	site morphology, landslides
4	Geology	Cartography, geological cross section and fault proximity
5	Geomechanical information	location of geomechanical survey, data survyed and lithotechnical map
6	Geotechnical & Geophysical information	location, stratigraphic profile, in situ tests, laboratory tests
7	Microtremor H/V spectral ratio	-
8	Earthquake H/V spectral ratio	-
9	Site classification (EC8, NTC-08)	lithostratigraphic classification – estimated by shallow geology and based on in-situ measurements, topography classification
10	Synthesis of information	grouped into: information relevant to site classification; geological, geomorphological and geomechanical information; other information relevant to seismic site response; distinctive features of site response
11	References	-
12	Enclosures	-

Table 6. Comparison between the geologically-based map classification and that based on $V_{s,30}$

EC8 classes	Shallow geology					
	A*	B*	C*	D*	NC	**Tot.**
A	13	0	3	0	0	**16**
B	29	12	15	0	6	**62**
C	4	4	11	1	2	**22**
D	0	0	5	0	1	**6**
E	3	2	0	0	0	**5**
Tot.	**49**	**18**	**34**	**1**	**9**	**111**

Table 7. Comparison between the geologically-based map and the predominant period classifications.

Spectral classes	Shallow geology					
	A*	B*	C*	D*	NC	**Tot.**
CL-I	22	5	10	0	0	**37**
CL-II	26	8	11	0	0	**45**
CL-III	19	3	2	0	0	**24**
CL-IV	14	10	13	0	0	**37**
CL-V	12	4	2	0	0	**18**
CL-VI	8	3	5	2	0	**18**
CL-VII	15	7	8	0	0	**30**
Tot.	**116**	**40**	**51**	**2**	**0**	**209**

Appendix 1A. List of strong motion stations with shear wave velocity profile obtained from collected data and EC8 site classification according to V_{S30}.

#	Name	Code	V_{S30} (m/s)	EC8
1	AULETTA	ALT	1,149	A
2	BISACCIA	BSC	997	A
3	SANNICANDRO GARGANICO	SNN	965	A
4	TARCENTO	TRC	901	A
5	ANCONA ROCCA	ANR	549	B
6	BAGNOLI IRPINO	BGI	498	B
7	BAGNONE	BGN	640	B
8	BENEVENTO	BNV	716	B
9	BORGO CERRETO CS	BCC	486	B
10	BOVINO	BVN	364	B
11	BRIENZA	BRN	402	B
12	CALITRI	CLT	495	B
13	CASCIA	CSC	540	B
14	CASCIA CABINA PETRUCCI	CSR	430	B
15	CESENA	CSN	540	B
16	CITTÀ DI CASTELLO	CTC	390	B
17	FOLIGNO S. MARIA INFRAPORTAS	FSMI	380	B
18	FORGARIA CORNINO	FRC	454	B
19	GUBBIO	GBB	790	B
20	LAURIA GALDO	LRG	603	B
21	MATELICA	MTL	491	B
22	MERCATO S. SEVERINO	MRT	483	B
23	NOCERA UMBRA BISCONTINI	NCB	393	B
24	NOCERA UMBRA SALMATA	NCM	585	B
25	NORCIA	NRC	687	B
26	PIEVE S. STEFANO	PVS	613	B
27	RIONERO IN VULTURE	RNR	538	B
28	S. SEVERO	SSV	390	B
29	SELLANO EST	SELE	520	B
30	SELLANO OVEST	SELW	518	B
31	STURNO	STR	382	B
32	TOLMEZZO DIGA AMBIESTA	TLM1	522	B
33	TRICARICO	TRR	467	B
34	VALLE ATERNO CENTRO VALLE	AQV	474	B
35	VIESTE	VSS	440	B
36	ANCONA PALOMBINA	ANP	256	C
37	BOJANO	BOJ	306	C
38	BUIA	BUI	258	C
39	CASTELNUOVO ASSISI	CSAD	293	C
40	FIRENZUOLA	FRE1	312	C
41	FORLÌ	FOR	295	C
42	GARIGLIANO	GRG2	191	C
43	GUBBIO PIANA	GBP	224	C
44	MAJANO PRATO	MAP	344	C
45	NORCIA ALTAVILLA	NRA	218	C
46	S. GIULIANO SCUOLA	SGIUB	391	C
47	SAN SEPOLCRO	SNS	322	C
48	COLFIORITO	CLF	140	D
49	ARIENZO	ARN	578	E
50	FIVIZZANO	FVZ	495	E
51	NOCERA UMBRA	NCR	534	E
52	S. CASCIANO DEI BAGNI	SSC	485	E

Appendix 1B. List of strong motion stations with shear wave velocity profile obtained from in situ tests carried out within the S4 project and EC8 site classification according to V_{S30}.

#	Name	Code	V_{S30} (m/s)	EC8
1	AQUILA PETTINO	AQP	830	A
2	BIBBIENA NUOVA	BBN	1,000	A
3	DICOMANO	DCM	1,000	A
4	GENOVA	GNV	987	A
5	ISPICA	ISI	1,482	A
6	MARATEA	MRA	1,020	A
7	MONTECASSINO	MTC	1,000	A
8	MORMANNO	MRM	1,400	A
9	PESCASSEROLI	PSC	1,000	A
10	RAGUSA	RGS	1,092	A
11	SANTA CROCE CAMERINA	SCR	896	A
12	SCANNO	SCN	840	A
13	AQUILA FIUME ATERNO	AQA	552	B
14	AQUILA COLLE GRILLI	AQG	685	B
15	AQUILPARK	AQK	717	B
16	ASSERGI	GSA	488	B
17	BAZZANO	BZZ	679	B
18	CALTAGIRONE	CLG	373	B
19	CAPESTRANO	CPS	730	B
20	CASSINO	CSS	630	B
21	ECOURS	LS4	473	B
22	GEMONA	GMN	445	B
23	LAGONEGRO	LGN	431	B
24	LASALLE	LS2	496	B
25	MARSICO VETERE	MRV	686	B
26	NORCIA ZONA INDUSTRIALE	NRZI	557	B
27	NOTO	NTE	710	B
28	ONNA	MI03	378	B
29	PACHINO	PCH	593	B
30	PIGNOLA	PGA	420	B
31	PINEROLO	PNR	383	B
32	RONCO SCRIVIA	RNS	737	B
33	SANT’ARCANGELO	SNA	420	B
34	SATRIANO DI LUCANIA	STL	395	B
35	SESTRI LEVANTE	SEL	606	B
36	TORRE FARO (MESSINA) (CAB. ENEL)	TRF0	302	B
37	TORRE PELLICE 4	TP4	547	B
38	TORTONA	TRT	483	B
39	TORTORICI	TOR	526	B
40	TRICARICO	TRO	780	B
41	VARESE LIGURE	VRL	758	B
42	VIBO MARINA	VBM	450	B
43	VIBO VALENTIA	VBV	510	B
44	AVEZZANO	AVZ	199	C
45	CATTOLICA	CTL	208	C
46	FAENZA	FAZ	293	C
47	GELA	GEA	245	C
48	GRUMENTO NOVA	GRM	283	C
49	MODENA	MDN	213	C
50	NOVELLARA	NVL	190	C
51	PATTI (CAB. ENEL)	PTT0	251	C
52	SPEZZANO SILA	SPS	320	C
53	TORRE PELLICE 7	TP7	290	C
54	ARGENTA	ARG	170	D
55	BEVAGNA	BVG	162	D
56	BORGO8000	BTT	92	D
57	CATANIA - PIANA	CAT	160	D
58	RIETI	RTI	170	D
59	PALAZZOLO ACREIDE	PLZ	670	E