The paper was published in the proceedings of the 7th International Conference on Earthquake Geotechnical Engineering and was edited by Francesco Silvestri, Nicola Moraci and Susanna Antonielli. The conference was held in Rome, Italy, 17 – 20 June 2019.

Earthquake Geotechnical Engineering for Protection and Development of Environment and Constructions – Silvestri & Moraci (Eds)
© 2019 Associazione Geotecnica Italiana, Rome, Italy, ISBN 978-0-367-14328-2

Overview of the Seismic Microzonation Project: The role of the Italian scientific community

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ABSTRACT: In the last years, major efforts have been devoted by the Italian scientific community to support public Administrations to develop and apply effective interventions to reduce seismic risk. In this context, seismic microzonation plays a major role and an Italian project for a widespread application of this kind of analysis is illustrated. It relies on the development of effective guidelines to homogenize procedures devoted to this kind of studies, on the financial support of the Central Administration to local Authorities and on the training of local practitioners in charge for the field work. The effectiveness of this approach has been tested during the last damaging earthquakes, where seismic microzonation studies have been widely applied to address reconstruction plans. The main aspects of these applications are shortly outlined, by focusing on experiences gained by managing seismic microzonation studies for 138 Municipalities in the area of Central Italy shaken by the disastrous 2016-2017 seismic sequence.

1 INTRODUCTION

Earthquakes occurred in Italy in the last years, have shown, once more, the high vulnerability of Italian settlements, with hundreds of casualties and damages for billions of Euros resulting from the occurrence of moderate size events. This makes as mandatory the development of effective prevention activities aiming at reducing seismic risk over the whole Italian territory. To be sustainable, such an action must be graduated by taking into account available resources. On purpose, availability of seismic hazard maps is of outmost importance to identify most critical situations to prioritize retrofitting interventions, reduce exposure of goods by suitable city planning actions and prepare emergency plans. In order to warrant effectiveness of these maps, they must be formulated by taking into account at least 1:5000-1:10000 scale seismo-stratigraphical and geomorphological features, which control ground motion in the range of frequency of engineering interest. Few years ago, just after the disastrous Central Italy earthquake in 2009 ('L'Aquila' earthquake), the Italian Government promoted and co-funded an extensive seismic microzonation project involving the most hazardous part of the Italian territory. This project is currently being completed on approx. 4000 of the about 8000 Municipalities of the Italian territory. The main features of this project were:

1. *the assumption that all Italian citizens require the same level of protection, irrespective to the dimension or economic importance of the town where they live;*

2. *the identification of the institutional subjects in charge for microzonation activities and applications, i.e., Municipalities with the contribution of local practitioners;*
3. *establishing a multi-year (7y) financial program (about 90 million Euros overall) to integrate resources made available by local administrations for the seismic microzonation of Municipalities characterized by higher estimated reference hazard; these funds are supplied provided that outcomes of seismic microzonation were actually implemented in city planning rules;*
4. *involving the scientific community in defining national guidelines and standards to be implemented by regional Authorities and used by trained practitioners in charge for field activities.*

This approach has a number of implications (technological, pedagogical, and political) and its potential effectiveness (or failure) will also depend on the capability of involved communities to promote and support preventive actions, taking advantage of the experience acquired in these activities. Without this bottom-up approach, directly involving local communities, it will be difficult for our society to cope with future potentially disastrous events.

The approach described above was operated in seismically quiet periods and replicated, with the appropriate improvements, just after destructive seismic events. In the following, some technical details concerning the proposed approach will be provided. Then, main outcomes and criticalities resulting from the studies carried out so far will be shortly outlined by focusing, in particular, on the experience gained by managing seismic microzonation studies for 138 Municipalities in the area of Central Italy shaken by the disastrous 2016-2017 seismic sequence.

2 THE ITALIAN GUIDELINES FOR SEISMIC MICROZONATION

On behalf of the Council of Italian Regional Administrations and Autonomous provinces and under the coordination of the Italian Department of Civil Protection, a large working group was established aiming at the definition of specific guidelines for seismic microzonation studies. The working group (Seismic Microzonation Working Group, SM-WP in the following) included academic and research institutions, technical bodies from Regional Administrations and professional associations whose experiences and skills gained in the past years were widely represented. These guidelines aimed at harmonizing the different approaches provided by the disciplines implied in this kind of studies (geology, seismology, engineering, etc.), by keeping in mind that this kind of studies is mainly devoted to support city planning activities for seismic risk reduction and not specifically the design of single structures. As a matter of fact, to support anti-seismic design the subsoil analysis should focus on to the volume of the subsoil able to affect the specific structure under study (Local Seismic Response Analysis - LSRA): thus, site specific small scale intensive characterization is required (seismic response analysis). On the contrary, city planning requires an extensive subsoil characterization since it operates at a scale much larger than that typical of LSRA. Furthermore, it does not focus on any specific structure: this implies that the dimension of the subsoil volumes to be explored is larger than those required by LSRA.

In order to warrant the feasibility of this kind of analysis to be performed in a large number of sites (in Italy there are about 8100 Municipalities) each characterized by specific problems both in terms of subsoil geological complexity and resources availability, a multi-level approach has been planned by the working group (SM-Working Group, 2008). In particular, three levels of seismic microzonation are identified, which are characterized by growing complexity and commitment (and financial effort): specific outcomes are expected from each level (Fig.1). This organization allows graduating field activities as a function of available resources, specific goals and eventual presence of local criticalities. The main features of each level will be shortly outlined in the following, along with the relevant expected outcomes.

2.1 *Level 1 seismic microzonation*

The first level seismic microzonation is qualitative in essence and aims at developing the reference geologic model (oriented to seismic response characterization) by identifying parts of the

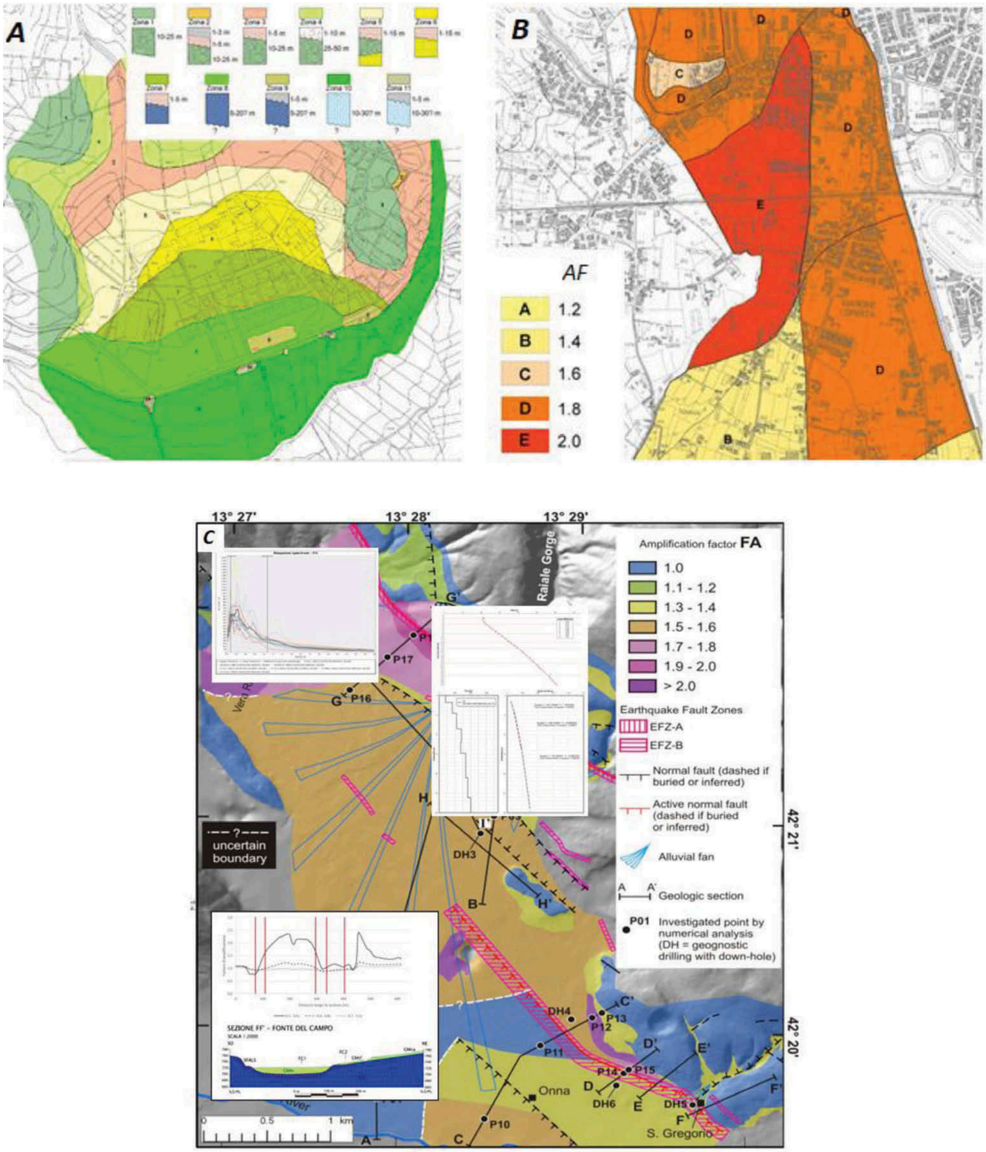

Figure 1. Typical outcomes of microzonation by following the Italian Guidelines. Level 1; Level 2 and Level 3 microzonation outcomes are respectively reported as A, B and C. pictures. In the first case (A), typical stratigraphic configuration relative to each HSMP is reported in the inset. In the second case (B), to each HMSP a corresponding AF factor (deduced from the relevant abacus) are reported. In the third case (C), Vs profiles, response spectra form 1D and 2D numerical modelling are also reported (in the insets some examples) relative to relevant HSMPs.

study area characterized by similar seismic effect. In particular, three different situations are considered with respect to the reference ground motion at a rock site: i) no amplification is expected, ii) amplification is expected due to the local seismo-stratigraphic and geo-morphologic condition and, finally, iii) earthquake induced soil instabilities (such as liquefaction, landslides

or fault rupture) are expected. This implies the partition of the study area into a set of 'microzones' considered as internally homogeneous from the seismic point of view

(Homogeneous Microzones in Seismic Perspective - HMSP). The main tool for this analysis is the reappraisal of information available stored in public archives (Municipalities) and geological survey focused on the geotechnical characterization of the geological bodies present in the area in terms of a set of GeoTechnical Units (GTUs) specifically codified in the guidelines (http://www.protezionecivile.gov.it/jcms/en/standard_studi_ms.wp?request_locale=en)

Each HMSP is then characterized by a synthetic seismostratigraphic column reporting the stack of the GTUs, which characterizes the HMSP. Possible thickness ranges inferred on the basis of available information are also reported. To this aim, available information (drillings, geophysical surveys, geotechnical reports, etc.) is collected and stored into a codified database. To complement this information, geophysical survey is planned by considering cost-effective surface geophysical measurements. Single station microtremor surveys by the HVSR approach are mainly considered (e.g., Foti et al., 2011) to identify the presence of seismic resonance phenomena, to assess the fundamental resonance frequency of the sedimentary cover and constrain (very roughly) the depth of the main resonant interface by the use of a simple abacus (see, e.g., Albarello et al., 2011). Geological sections are also provided to clarify the buried geometry of GTUs and identifying morphology of geological contacts where main seismic impedance contrasts are expected. Outcomes of Level 1 microzonation studies are the qualitative basis for the following levels since they allow planning further studies devoted to quantifying the expected co-seismic effects.

2.2 *Level 2 seismic microzonation*

The main aim of this level of analysis is providing a quantitative basis for evaluating the relative importance of seismic amplification effects. The key element of this phase is the estimate of an integral parameter (Amplification Factor, AF) representative of expected amplification of the local ground motion as an effect of the 1D seismostratigraphic-layering characteristic of each HMSP. A general definition of AF is the following

$$AF = \frac{\int_{T_1}^{T_2} S_a dT}{\int_{T_1}^{T_2} S_b dT} \tag{1}$$

where T is the period of the considered spectral ordinate, S_a and S_b are respectively the acceleration response spectrum at the outcrop and of the input motion at an outcropping bedrock. Following the national standards, three AF values are computed which correspond to short (0.1-0.5 s), intermediate (0.4-0.8 s) and long (0.7-1.1 s) periods. It is worth to note that, due to the integral character of this parameterization, outcomes are not expected to be directly used for anti-seismic design of structures.

In principle, the estimate of AF values requires 1D modelling of SH waves seismic propagation, including possible non-linear response of soil materials. The parameterization of the relevant computational model require expensive sampling and laboratory analyses to characterize the detailed Vs profile, shear modulus reduction and damping curves. This could hamper the possibility to apply this study to large areas as required by seismic microzonation analysis. To overcome this problem, a simplified approach is provided, which is based on the application of suitable abacuses allowing the computation of the AF values as a function of a cheap-and-fast characterization of the local situation by extensive surface geophysical surveys (mainly HVSR and MASW approaches, see Foti et al, 2011; Albarello et al., 2015) inverted by the use of simplified approaches (e.g., Castellaro and Mulargia 2009; Albarello and Gargani, 2010; Albarello et al., 2011; Albarello, 2017). These new surveys may also suggest a revision of HMSPs boundaries, to include unexpected subsoil configurations. Moreover these allows the definition of suitable proxies such as the average velocity down to the seismic bedrock or to 30 m (VsH or Vs30 respectively) or the fundamental resonance frequency of the soft covers (f_o) to enter the relevant abacus and obtain the representative AF value. The abacuses for computing AF values are provided by Regional Administrations by considering geological and geotechnical peculiarity of their territory. An example of the methodological approaches considered on purpose is reported in Peruzzi et al. (2016).

The outcome of this level of microzonation is a quantitative evaluation of the relative importance of seismic amplification effects in the Municipality. In principle, the SMHs where seismically induced permanent deformations are expected, this level of analysis is not carried out. However, since in these SMHs 1D amplification phenomena may exist, in some regional implementation, AF values are also estimated (from abacuses) for these areas also.

2.3 *Level 3 seismic microzonation*

In principle, the third level of analysis concerns specific situations that cannot be characterized by the use of simplified approaches (i.e., Level 2 studies). As concerns ground motion amplification phenomena, the presence of rugged morphologies or of significant lateral variations in the seismic impedance contrasts may require the use of advanced numerical modelling able to manage 2D-3D configurations. In the case of complex subsoil configurations realistic estimates of the AFs require a more detailed definition of main parameters (in particular the 2D/3D distribution of *Vs* values). This implies that intensive geophysical prospecting has to be planned on purpose, by also taking advantage of advanced inversion procedures (e.g., Foti et al., 2011) calibrated by comparing respective results with outcomes of local bore-hole measurements. Seismo-induced permanent ground deformations (surface faulting, landslides and liquefaction) have to be evaluated at this stage. This implies that borehole sampling and laboratory measurements have to be planned, along with specific and detailed geological and structural surveys.

Two problems arise when performing such an advanced level of microzonation. First of all the costs required to acquire information necessary for hazard estimates. This aspect should not be overlooked since, due to inherent extensive character of microzonation, the required investigations may be very expensive. This implies that, in many cases, Level 3 microzonation is restricted to specific aspects and areas (e.g., liquefaction phenomena or single landslides potentially affecting densely populated urban areas). The second problem concerns availability of sufficient professional skills of practitioners in charge for the study. In general, competences required to deal with extreme non-linearity of soil behavior (e.g., in the case of liquefaction) or advanced numerical modelling (2D-3D) are unavailable to non-specialists. This implies that academic and research Institutions may be required to play a direct role at this level of microzonation.

2.4 *The role of Central Authorities*

The application of the above described approach is demanded to local authorities (Regional and Municipal Administrations). However, it appears evident that the technical skills necessary for the correct and coherent application of the national guidelines and standards, are not generally available at the level of local administrations. Furthermore, in order to take advantage from the huge amount of data collected in the field during microzonation activities, a centralized storage of information could be of great help for controlling ongoing activities and gaining insights about overall characteristics of subsoil in the whole Country. Two institutions are in charge for these tasks. The first ad more important for the global coordination is the Civil Protection Department (DPC) of the Presidency of the Council of Ministers. It supervises the application of the whole microzonation work and manages the central database of microzonation results. The scientific counterpart of DPC is the Centre for Seismic Microzonation and its applications (CentroMS), established in 2015, which is an association of university Departments and research Institutions. CentroMS includes a core of thirteen founders: National Research Council with the four Institutes (IGAG as coordinator, IMAA, IDPA, ex IAMC), the Universities of Rome, Naples, Catania, Milan and Siena, the National Institute of Geophysics and Volcanology - INGV, the National Institute for Oceanography and Experimental Geophysics – INOGS; Italian National Agency for New Technologies, Energy and Sustainable Economic Development- ENEA; the Institute for Environmental Protection and

Research - ISPRA). On specific projects, this core group is also supported by associated university Departments involved in the field activities and laboratory investigations. As a whole, 25 research Institutions and Universities participated so far in the activities promoted by CentroMS, involving more than 100 seismologists, geologists and engineers.

CentroMS aims at providing scientific and technical support to the Institutions involved in seismic microzonation and its applications, with particular reference to urban planning and geological, geotechnical and geophysical issues related to the management of seismic emergencies. This is achieved through:

- *the development of methodologies specifically devoted to seismic microzonation;*
- *the promotion of theoretical and operational training for public technicians and practitioners;*
- *the provision of technical and scientific support for the implementation and coordination of the studies, as well as in the first emergency;*
- *the promotion of information to stakeholders and citizens.*

Due to the complex role played by local administrations and practitioners in performing seismic microzonation, CentroMS warrants a homogeneous, coherent and effective development of seismic hazard studies performed at local scale.

3 MICROZONATION ACTIVITES SUPPORTING RECONSTRUCTION IN CENTRAL ITALY AFTER THE 2016-2017 SEISMIC SEQUENCE

3.1 *The context*

Since the beginning of the seismic sequence that affected Central Italy starting from August 2016, the CentroMS was charged for coordinating microzonation activities supporting reconstruction in the damaged settlements.

This was the result of the important political choice of the Italian Government of grounding any reconstruction plan on detailed seismic hazard estimates accounting for local geological/geotechnical conditions, to prevent future seismic damages by reducing the exposure level of new settlements and provide realistic and site-dependent constraints to the design for retrofitting and reconstruction interventions. This farsighted decision, however, also slowed down the reconstruction activities and this raised up a harsh public debate about efficiency of public administration to provide a fast accommodation for the huge amount of people settled in temporary houses. A strong pressure was thus exerted on CentroMS to speed up field activities.

It was established that Level 3 microzonation activities should have been performed for the whole damaged area which, at the end of the sequence (January 2017), included 138 Municipalities distributed in 4 Administrative Regions and populated by about 500.000 inhabitants (Fig.2). Under the pressure of public opinion, the deadline for the completion of activities was fixed in 6 months. In order to better exploit available funds, (around 6 million Euros), microzonation activities were restricted to urbanized areas and only concerned settlements characterized by at least 50 inhabitants (as a whole, 533 settlements were actually considered). Moreover, Level 3 microzonation studies focused on the characterization of seismic amplification phenomena: ground instabilities were only considered for a Level 1 analysis (identification and mapping). Beyond planning reconstruction, microzonation outcomes were also supposed to provide engineers with representative seismic loads relative to each HMSP to be compared with prescriptions of the national seismic code (Ministero delle Infrastrutture e dei Trasporti, 2018). To this purpose, seismo-stratigraphic logs representative of each HMSP were considered for numerical modelling to obtain, beyond the respective AF values, representative response spectra and accelerograms.

3.2 *Organization*

The 138 seismic microzonation studies have been entrusted to professional geologists and engineers. In order to better coordinate activities of engaged practitioners, the whole area has

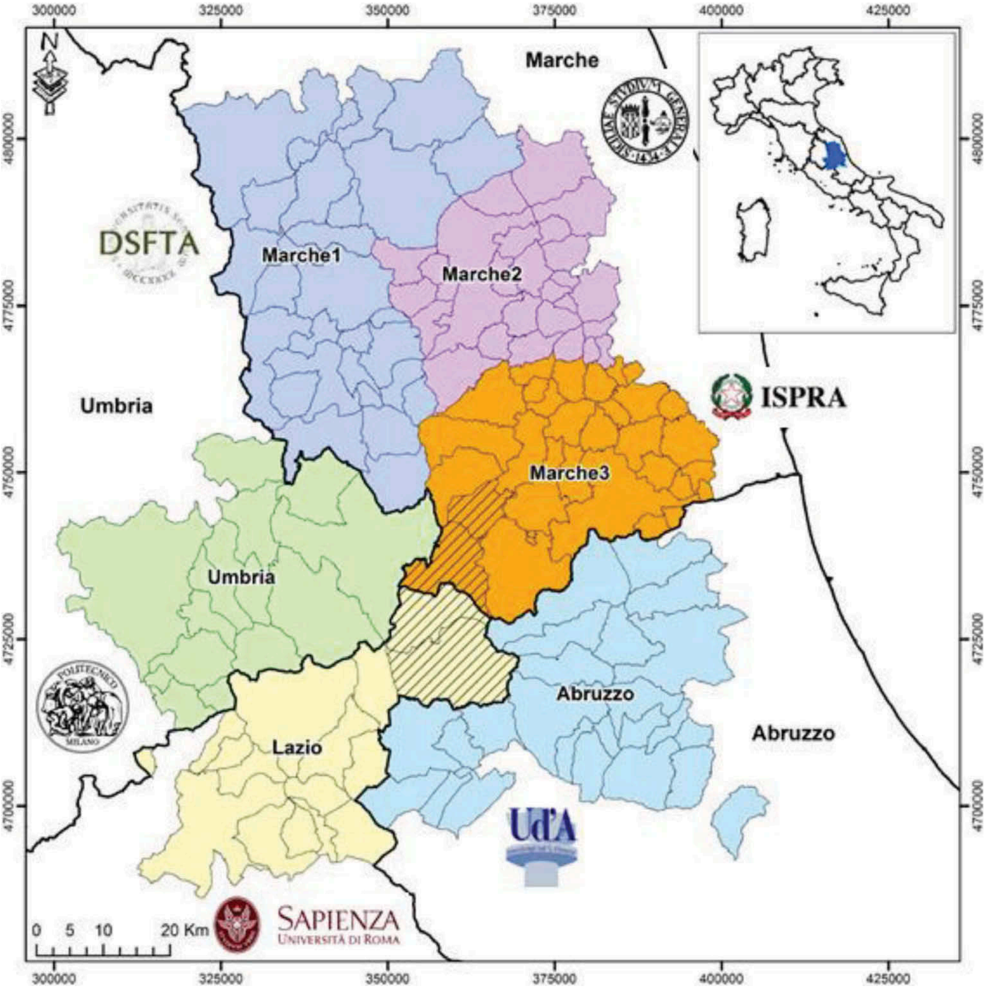

Figure 2. Area damaged by the 2016-1017 seismic sequence. Boundaries of the 138 Municipalities belonging to the four regional administrations (Marche, Umbria, Lazio, and Abruzzo Regions) are also reported. Colors indicate the partition into 6 macroareas, each under the responsibility of a single team, headed by one coordinator member of an institution associated to the CentroMS: Marche 1 - University of Siena, Marche 2 – University of Catania; Marche 3 – ISPRA; Umbria – University of Milan; Lazio – University of Rome; Abruzzo: University of Chieti. The territorial and the support units were coordinated by the Institute of Environmental Geology and Geoengineering of CNR

been subdivided into 6 macroareas under the responsibility of a coordinator managing the scientific teams operating in the respective zone (Fig.2). More than 100 researchers from Academia and research Institutions have been involved in the task. In each macroarea, CentroMS teams provided the training of practitioners operating in the field and periodic checks of ongoing activities. Beyond these 6 teams, four other teams were established, respectively devoted to: providing input motion for numerical modellings, performing down-hole measurements, providing 2D modelling and performing laboratory analyses on samples provided by drilling. A coordinating team was responsible for the overall organization of the project, management of the global database and providing the final check of microzonation outcomes.

As a whole, 114 groups of local practitioners (mainly professional geologists) were charged for field activities (geological and geophysical surveys), 1D numerical modelling of the local seismic response and feeding the general database of microzonation outcomes. They were selected by taking into account their past experience in seismic microzonation studies: all of them were involved in Level 1 microzonation in recent years. However, training was necessary to homogenize their approaches and prepare them in Level 3 activities. Public technicians operating in the Municipalities where microzonation activites were performed were also invited to attend the training courses, order to facilitate the implementation of microzonation outcomes in city planning and reconstruction activities.

After the training stage, the actions to be performed by practitioners were developed as follows:

- *A preliminary geological/technical model was developed on the basis of existing studies and on purpose geological survey;*
- *on the basis of this model, a geophysical survey was planned to retrieve geometry and Vs values relative to the main geological/geotechnical bodies;*
- *for each Municipality, one or two downhole geophysical tests are also provided by CentroMS to calibrate numerical inversions of geophysical surveys and provide samples for laboratory testing;*
- *on the basis of these measurements, the geological/geotechnical model was updated and released by identifying HMSP; logs representative of geotechnical layering of each HMSP were assessed along with representative Vs profiles;*
- *these data, along with outcomes of laboratory tests and input motions provided by CentroMS are considered for 1D numerical modelling to retrieve seismic response spectra and accelerometric time series representative of each HMSP;*
- *seismo-geological sections representative of most complex configurations were also provided to the team in charge for 2D modelling*
- *outcomes of 2D analyses were compared with outcomes of 1D modelling: the most conservative estimate were the considered as the final outcomes*
- *all the collected data and maps of Level 3 microzonation were implemented into the national database under the supervision of the CentroMS team responsible for each area;*
- *a final validation was then performed by the CentroMS as concerns the formal structure of the database and cartographic outcomes.*

Notwithstanding all these tasks to be developed within a short time (6 months), involving so many people operating over a relatively large area, the big efforts made by CentroMS and practitioners in charge of the studies. By the way, all the process was completed on time and most outcomes were submitted to the Government Commissioner responsible for reconstruction on January 2018, having the process started on July 2017.

3.3 *Main methodological issues*

The one described above was the first attempt at World level to carry out a microzonation study for the reconstruction of an extremely large area, with the concurrent contribution of professionals and scientific institutions. In fact, the complexity of the project has forced the CentroMS to face a large number of practical and, above all, methodological issues.

The first methodological problem was related to the strong differences existing about the amount of data available for previous Level 1 microzonation studies, when available. In some Regions, Level 1 microzonation studies were actually available and were imple-mented in the Level 3 studies. However, also in these cases, many studies needed to the renewed because they did not respect the current standards. In particular, local geological models were revised and a new representation in terms of standardized geotechnical units was provided on the basis of a reinterpretation of existing data or new geological surveys. A huge amount of geophysical surveys were actually available in the area (12305 HVSR and 831 MASW tests), but their uneven distribution required an extensive geophysical survey to integrate existing measurements (Table 1).

Standard procedures were established for field deployment, data processing and interpretation of geophysical data. To reduce costs surface seismic prospecting were preferred (HVSR

Table 1. Number of geophysical surveys, laboratory tests and advanced numerical modelling performed in the frame of the project.

Surveing and modelling	Number
HVSR	5051
MASW, Refraction, etc.	1738
Down-hole tests	162
Laboratory tests	92
2D numerical models	115

and MASW, mainly): borehole measurements (not deeper than 30m due to the budget limitations) were used only for calibration purposes (Tab.1).

Great attention was devoted to train practitioners on the interpretation and inversion of geophysical data. In order to provide reasonable estimates of the relevant Vs profiles, ambient vibration spectral ratios and Rayleigh waves phase velocity dispersion curves (respectively deduced from HVSR and MASW approaches respectively) were jointly inverted to assess local Vs profiles and relative uncertainty. To this purpose, free-ware software (HVInv, https://w3.ual.es/GruposInv/hv-inv/and Geopsy, http://www.geopsy.org/index.html) was preferred for this kind of inversion. Particular attention was devoted to evaluate uncertainty affecting inversion outcomes. Practitioners were strongly invited to parametrize variation intervals relative to the resulting Vs profiles as an effect of multiplicity of possible Vs profiles fitting observations and the presence of possible lateral variability within the same HMSP. These results, along with input ground motions specific for each Municipality and modulus reduction and damping curves (provided by the CentroMS based on specific laboratory tests) were implemented in the numerical code to compute representative response spectra for each HMSP. To this purpose, the free-ware software STRATA (https://github.com/arkottke/strata) was considered, which implements the linear equivalent approach by also allowing to explore the impact on outcomes of uncertainty affecting input data.

4 CONCLUSIONS

The Italian approach to seismic microzonation is the result of a long history starting from the beginning of the last century and summarizes knowledge cumulated after the disastrous earthquakes that struck Italy in the last century. This knowledge includes technical aspects and political issues. These indicate that, the only way to reduce seismic risk and improve resilience of exposed population is establishing long-term prevention policies supporting anti-seismic design of new structures, supporting and retrofitting of the existing ones, reducing exposure of goods by adopting suitable city planning and increasing preparedness of citizens. All these actions are costly and this requires the full support of involved population to be sustainable. The best way to obtain this support is making populations aware of the specific risk of the site where they live and ensure them that resources available for prevention are used in the most effective way. Both these aspects require a hazard assessment at the scale of Municipality, whose Authorities are directly in charge for prevention activities. Seismic microzonation represents the fundamental informative basis for these action. This is why main efforts have been developed in Italy in the last years in order to provide an approach suitable for extensive application. To this purpose, a multi-level approach has been developed which allows microzonation activities also in the lack of strong financial resources. Being essentially devoted to support politics aimed at develop prevention activities at municipal scale, microzonation outcomes should not be directly used for anti-seismic design of single structures and do not replace specific local seismic response studies. On the other hand, microzonation due to its wide scale perspective may provide important constraints to design-oriented studies, e.g, by pointing out the presence of important lateral variations in the seismic properties of the subsoil, which require advanced numerical modelling. In this sense, microzonation studies can direct the design engineers with the support of the geologists in defining the proper subsoil model to be used for the evaluation of the local seismic response

Microzonation activities carried out to support reconstruction after the damaging seismic sequence that struck Central Italy in 2016-2017 represented an important benchmark for the proposed approach. Actually, for the first time in Italy (and probably in the World) such an ambitious microzonation study has been carried on in such a short time for such a large area. Beyond the technical importance of the microzonation studies for driving post-seismic reconstruction, three main results have been obtained by the project. First, the scientific community was able to cooperate beyond any disciplinary boundary: geologists, engineers and seismologists coming from different institutions, created technical interdisciplinary teams where target-oriented efforts allowed the development of a common scientific language resulting in operational protocols. Secondly, a huge amount of homogeneous and validated data has been collected and stored within an homogenous GIS database that will be made available soon to the scientific community the practitioners and, not less important, the citizens. Finally, about two hundreds of practitioners (mainly professional geologists) have been trained in microzonation studies and seismic hazard assessment. At the same time, a large number of regional and municipal administrations including their technicians have been involved in microzonation and respective populations made aware of seismic hazard of their village or town. This has been achieved by promoting meetings involving citizens and local administrations where outcomes of seismic microzonation are illustrated by the practitioner in charge for the study and, eventually, members of the CentroMS team. This sensitized citizens and technicians represent a well-distributed "presidium" that will results of great help in supporting future activities devoted to seismic risk reduction in the whole Country

REFERENCES

Albarello D, Gargani F., 2010. Providing NEHRP soil classification from the direct interpretation of effective Rayleigh waves dispersion curves. Bull Seismol Soc Am 100:3284–3294. doi:10.1785/0120100052

Albarello D., Cesi C., Eulilli V., Guerrini F., Lunedei E., Paolucci E., Pileggi D., Puzzilli L.M., 2011. The contribution of the ambient vibration prospecting in seismic microzoning: an example from the area damaged by the 26th April 2009 l'Aquila (Italy) earthquake, Boll.Geofis.Teor.Appl., 52, 3, 513–538, DOI 10.4430/bgta0013

Albarello D., Socco V.L., Picozzi M., Foti S., 2015. Seismic Hazard and land management policies in Italy: the role of seismic investigations. First Break, 33, 87–93

Albarello D., 2017. Le indagini geofisiche di campo per la microzonazione. In Carbonetto G. (a cura di) 'Sisma: dal Friuli all'Italia di oggi', Fondazione Centro Studi del Consiglio Nazionale dei Geologi, ISBN 978-88-909473-7-, pp. 91–102

Castellaro S, Mulargia F (2009) Vs30 estimates using constrained H/V measurements. Bull Seismol Soc Am 99:761–773. doi:10.1785/0120080179

Foti S., Parolai S., Albarello D., Picozzi M. (2011), Application of Surface wave methods for seismic site characterization. Surv. Geophys., 32, 6, 777–825, DOI 10.1007/s10712-011-9134-2

Ministero delle Infrastrutture e dei Trasporti (2018). Aggiornamento delle Norme Tecniche per le Costruzioni. Gazzetta Ufficiale n. 42 del 20 febbraio, 2018 (in Italian).

Peruzzi G., Albarello D., Baglione M., D'Intinosante V., Fabbroni P., Pileggi D., 2016. Assessing 1D seismic response in microzoning studies studies in Italy, Bull.Earthq. Eng., 14:373–389, DOI 10.1007/s10518-015-9841-z

SM Working Group, 2008. Guidelines for Seismic Microzonation, Conference of Regions and Autonomous Provinces of Italy – Civil Protection Department, Rome,

http://www.protezionecivile.gov.it/httpdocs/cms/attach_extra/GuidelinesForSeismicMicrozonation.pdf?.