MICROZONING STRATEGY IN NEAR FIELD AREAS: SOME EVIDENCES AND OPEN PROBLEMS
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Introduction. The recent “strong motion” earthquake sequences recorded along the Italian territory since 2009, showed common characters: 1) surficial hypocenter (lower then 12 km depth); 2) relevant shaking suffered within a radius of 30 km from the epicenter and 3) differentiated damages on structures mainly due to local seismic amplification of surficial

Fig. 1 – a) Intensity map of 2009 L’Aquila earthquake on April 6th at 3:32 local time; b) seismic hazard map for microzoning studies issued by OPCM N. 3519 (2006); c) intensity map of the 2012 Emilia Romagna earthquakes after all shocks up to June 3rd (after Quest Working Group, 2012).
sediments. Consequently, an intensive microzoning activity has been developed in the last four years in those territories, such as L’Aquila crater and Ferrara province, placed in the epicentral areas of the “unexpected earthquakes” of April 6th, 2009 and May 20th and 29th, 2012. Plural scientific approaches have been testing on Italian territory to address microzoning studies for urban planning. These activities must be focused on 1) near field conditions and 2) on several seismic records from the last strong motion events. Moreover, they shall be compliant with the maps of maximum expected seismic intensities based on the Italian historical earthquake catalogues and databases that are sound and complete enough to support the prediction of earthquakes with a return period higher than 475 years. In this paper, some critical aspects of microzoning strategies commonly used in Italy have been pointed out and new proposals are provided to be discussed.

**Recent evolutions of Italian seismic microzonation rules.** The need to identify seismic homogeneous zones in urban areas was born after the 1997 Umbria-Marche and 2002 San Giuliano di Puglia earthquakes. These events caused differentiated damages, casualties and disruptions, that enforced the evidence that local seismic effects play a relevant role also in near field conditions. The fruitful debate developed within the Italian scientific community on the best practices and most meaningful parameters for the seismic Italian territory classification and zonation, gave birth in 2006 (OPCM N. 3519) to the seismic Italian hazard map for different return periods. Moreover, the National Office for Civil protection was commissioned by the government to develop and issue novel guidelines and best practices for microzoning studies. The international guidelines from Technical Committee for earthquake geotechnical Engineering, TC4, ISSMGE (1999) were taken as a reference. Then, the Italian microzoning guidelines and criteria were published in 2008 (DPC, 2008) based on three subsequent levels of detail in microzoning studies: level 1, mapping homogeneous geological units with respect to seismic behavior by means of surface geological relieves; level 2, mapping numerical indexes for homogeneous susceptible areas by means of simplified approaches according to standard procedure prescribed by DPC; level 3, mapping homogeneous seismic responses drawn from site specific experimental surveys and one, two- and even three-dimensional numerical analyses when needed. Meanwhile the scientific community was discussing how these guidelines and criteria can be applied over the whole national territory for decreasing the seismic risk, the first “unexpected” main shock of L’Aquila earthquake occurred on April 6th, 2009 at 3:32 local time, causing 306 fatalities, more than 60,000 people displaced and heavy damages to civil structures and buildings: the old town of L’Aquila was strongly damaged and Onna city was completely destroyed under the near field 5.8 Ml (local magnitude) earthquake with 9 km hypocenter depth.

After that, the Italian microzoning guidelines and criteria were applied by the Working group MS–AQ (2010) to those portions of L’Aquila crater where the macroseismic intensity map (Fig. 1a) reported values higher than V MCS and within the epicenter area where it pointed out relevant differentiated amplification effects (Galli and Camassi, 2009). These differentiated responses were also recorded by accelerometer stations (Fig. 2c). Meanwhile discussion on these topics were on, other three “unexpected” main shocks of Emilia Romagna earthquake hit the provinces of Ferrara and at a lesser extent of Modena: May 20th at 4:03 local time with Ml 5.9 and 6.3 km depth and May 29th at 9:00 with Ml 5.8 and 10.2 km depth, and Ml 5.3 and 6.8 km depth at 12:55 local time events (QUEST Working Group 2012). These seismic events occurred in an area where the hazard map (OPCM N. 3519) (Fig. 1b) predicted low hazard level although the intensity maps did not (Fig. 1a). Furthermore, a differentiated damaged level was plotted by Quest Working Group (2012) (Fig. 1c) within 20 km from the epicenter. Finally, 21/06/2013 at 10:33:57 UTC a seismic event of Ml 5.2 was recorded in Lunigiana at a 5.1 km depth. In field surveys performed by Quest Working Group (2013) by the end of June 2013 showed maximum intensity degree of 5-6 and 6 MCS within epicentral area. Although this last earthquake was not as severe as the others two, uncommonly, this earthquake
was “expected” and such reduced effects on building structures can also be attributed to the last ten year policy of prevention and vulnerability reduction performed on the most hazardous portions of Tuscan territory. To this end, Tuscany Region Office for Seismic protection has been financing a project for estimating local seismic effects, called VEL project since 1998. It was a pioneering project accomplished by some good working strategies for microzoning studies that are still up to date and showed their efficiency where applied. Hereafter, some good practices for Italian seismic zonation are briefly reported from the writing authors’ experience in VEL projects as far as from international microzoning activities, according to the following points: 1) maximum intensity maps to be used for a preliminary zonation of the most hazardous areas; 2) integrating multidisciplinary experimental techniques to seismic characterization of sites.

Point historical approach versus continuous attenuation laws. Since 1976 after Friuli earthquake, when the first microzoning studies were performed, it was quite evident that, based on historical catalogues of the seismic events, the strong earthquakes occur where they occurred in the past. Although different Magnitudes can be felt at different return periods, Signanini et al. (1983) showed that the seismic local amplification can increase the felt intensity up to 2-3 intensity degrees of MCS. After more than ten years, Favali et al. (1995), Midorikawa (2002) and lately after the 2012 Emilia Romagna earthquake, Paolini et al. (2012) focused on the maximum felt intensity maps derived by complete historical seismic catalogues as the key tool for guiding the choice of microzoning studies within the most hazardous areas in urbanized territories. Such a selection is needed because, especially in Italian territory, money is limited whereas the whole national territory is affected by earthquakes.

Thus, microzoning surveys in near field areas shall be performed in those territories that suffered repeated destructions and fatalities in the past, according to the maximum intensity maps, such as the one from Boschi et al. (1995) (Fig. 2a, black circles). This latter was drawn based on thorough analysis of historical documents on past earthquakes from the years 1 BC to 1992 and it shows the expected intensity higher than VI degree in Mercalli Cancani Sieberg (MCS) scale. This choice on the intensity degree is commonly used to highlight the areas where seismic events caused from severe damages to collapse of urbanized environment (from IX to XI). As can be noted, this map shows limited areas irregularly shaped that suffered partial or complete destructions. Based on such a map, the recent “unexpected” strong events of L’Aquila and Emilia Romagna earthquakes could have been predicted (compare Fig. 1a, c with Fig. 2a).

The reason of the misleading information from Italian seismic hazard map is related to the prediction of the ground motion amplitude at a site through the peak ground acceleration (PGA) attenuation laws. The estimation of these ground motion prediction equations (GMPE), whether or not truly representative of seismic shaking, is affected by too much uncertainties related to 1) the models used for seismogenic zonation of the national territory and 2) the interpolation of mean trend in PGAs databases from national and worldwide records. These uncertainties dramatically increase when the PGA estimation is referred to near field areas. This is evidence from recent studies by Faccioli (2010) shown by Fig. 2b: here, the uncertainty in predicting the GMPE based on local seismic event databases especially for hypocentral distance higher than 20 km. Thus, is it realistic to consider that PGA values continuously decrease, in the first 10-20 km far from the seismic source? The records tell us a different story (Galli and Camassi, 2009; Lanzo et al., 2010; Bergamaschi et al. 2011; Di Giulio et al., 2011): PGAs are distributed spot-like nearby the seismic source increasing abruptly where soft sediments lie on stiff bedrock and subsurface geometries as basin shapes are filled by soft sediments (Fig. 2c).
Surface and subsurface geology investigated by multidisciplinary approaches. Concerning the level one in microzoning studies, it must be remembered that the knowledge of the subsurface successions with respect to lithologies, their dipping and buried geometries and dynamic parameters shall be a compulsory step towards the performance of local site response analyses. To get a realistic model of those portions of territory hurt by seismic wave propagation, in field investigations can be accomplished by means of integrating direct and indirect methods such as geophysical, geotechnical and geological approaches. The multidisciplinary approach allows to get twofold goals: 1) to increase the details on the sediment response to the shaking and to 2) calibrate those indirect investigation methods whose result quality relies on an adequate “dispersion curves” or “propagation curves” representing the subsurface geology. Thus, geophysical methods are generally widely used to investigate the subsurface deposit properties such as the compression and share wave velocities, $V_S$ and $V_P$, the geometries of the “seismic layers”, the presence of buried “slip surfaces”, the characteristic frequency of the site. The results of indirect geophysical investigations shall be calibrated by means of direct local inspections of geological successions and geometries. Again, the preliminary selection of the sites to be investigated shall be led by the maximum felt intensity maps. Geological relieves alone can give neither the technicians nor the local administrators reliable information on the local seismic amplification of the sediments, instable mechanical conditions, liquefaction potential: such phenomena result from the complex interactions among many factors and site features that can be appreciated by integrated investigation methods. A good example comes from the VEL project: the supposed active fault under the Fivizzano hospital was correctly predicted not moving by combining geological survey, geophysical refraction lines and point borehole inspections. After the Lunigiana earthquake, the hospital is still working with no damages and many point structural interventions on buildings showed their effectiveness. These buildings were chosen by means of the multidisciplinary approach in those areas where possible amplification or faulting effects were confirmed by a comprehensive approach: local historical documents, maximum felt intensity maps and in field investigations.

Conclusions. In this paper, a working strategy for microzoning studies in near field areas, implemented by the writing authors during the VEL project and derived from recent seismic records can be drawn according to the following points: 1) the portions of the Italian territory where developing microzonation of level 3 shall be selected by means of maximum intensity maps as well as geologic, geomorphologic and geotechnical surveys; 2) the GMPEs shall be
calibrated by local records and used for predicting the hazard level outside the near fault areas; 3) the multidisciplinary approach is the best way for seismic characterization of sites. Further studies on the several records from the recent strong seismic events are needed to improve the effectiveness of the good practices and to discard others.

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