Editoriale

Geotechnical Aspects of the April 6th, 2009 Abruzzo Earthquake

Foreword

In the last 15 years four destructive earthquakes occurred along the Apennine Chain in Italy, i.e. one every five years on the average; the data in table I show that the induced damage and number of fatalities was very variable, despite the comparable magnitude. Such statistics once more demonstrate that the social costs of earthquakes in Italy are not directly related to the seismogenic activity, but also to the local variability of subsoil conditions, structural and infrastructural vulnerability and exposition.

The influence of subsoil conditions on ground motion and related effects was increasingly highlighted by these earthquakes: the first three of them showed significant phenomena of site amplification, ground deformation and landslides, while in the last one diffused liquefaction were also observed. The Italian Geotechnical Society produced a significant effort in supporting the Civil Protection Department (DPC) and the communities stricken by these earthquakes, by different experimental and analytical activities regarding the geotechnical aspects of the emergency and reconstruction plans. Such supporting activities significantly addressed the development of advanced research in earthquake geotechnical engineering, stimulating fruitful technical and scientific interaction among the fields of seismology, geophysics, geology, structural and infrastructural engineering.

The main results of interdisciplinary studies on the seismic sequence occurred in Umbria-Marche during 1997 were published in a Special Issue of this Journal, printed in two volumes (No. 2 and 4) in 2001. They included 24 papers, written in English, related to the geotechnical and structural aspects of the damage, the seismic microzonation of Fabriano, Nocera Umbra and Sellano, and the countermeasures for the reduction of seismic risk.

In 2009, another Special Issue (No. 3) was dedicated to the most significant case history of Molise earthquake, the village of San Giuliano di Puglia, where all the fatalities were practically induced by the collapse of an unique building; however, such event triggered a significant process of reviewing both the national seismic hazard map and the seismic design guidelines, respectively published in 2004 and 2008. In this Special Issue, 5 invited papers describe the different aspects of the case study, spanning from the simulation of the reference motion, through the subsoil modelling, to the analysis of structural damage related to site amplification.

As table I clearly shows, the Abruzzo seismic sequence in 2009 was particularly striking for the unusually high ratio between the number of fatalities and the estimated economic damage. The event occurred very close to L'Aquila city, in a seismogenic area historically quite active but where the building heritage was indeed under-protected. Nevertheless, the significant role played by subsoil conditions on the uneven damage distribution throughout the main city and the surrounding small towns was immediately apparent from the investigations of the GEER reconnaissance team formed by Italian and foreign experts (see Lanzo *et al.*, 2009). As a matter of fact, the most significant anomalies in macro seismic intensity attributed to the villages of Onna and Castelnuovo (I_{MCS}=IX-X) were recognized as dependent on stratigraphic and topographic amplification effects, respectively. Soon after, the combined effects of source mechanism and soil amplification on ground motion was also recognized through the analysis of seismic records of the RAN stations deployed in the Aterno valley [Maugeri *et al.*, 2011; Lanzo and Pagliaroli, 2012].

The physical environment was also observed to be affected by typical slope failure mechanisms including rockfalls and soil sliding, but also by few cases of liquefaction [Monaco *et al.*, 2011] and peculiar ground deformation phenomena sometimes related to the presence of sinkholes.

A network of laboratories of soil dynamics was also immediately set up by AGI to support the DPC for the in-situ and laboratory investigation on the subsoil properties of different sites selected for emergency reconstruction [the C.A.S.E. project, Calvi and Spaziante, 2010] and microzonation studies [MZS Working Group, 2010]. Their activities included SDMT, surface wave tests, cyclic/dynamic torsional/simple shear tests [Monaco *et al.*, 2012]. Afterwards, predictive analyses of seismic response of several centres under code-compatible reference input motions were carried out for Grade-3 microzonation studies (see MZS Working Group, 2010; Lanzo *et al.*, 2011). Finally, an AGI working group actively contributed to the editing of Guidelines for the geotechnical investigations addressed to reconstruction or retrofitting of damaged buildings [Aversa e*t al.*, 2012].

Tab. I – Characteristics and effects of last destructive earthquakes in Italy (* data source: http://www.protezionecivile.it; + data source: http://www.ngdc.noaa.gov).

Region	Mainshock date	Mainshock magnitude (M_w)	Fatalities (*)	Estimated damage, M€ (+)
Umbria-Marche	26.IX.1997	6.0	11	3428
Molise	31.X.2002	5.7	30	603
Abruzzo	6.IV.2009	6.3	308	1894
Emilia Romagna	20.V.2012	5.9	24	11970

All the above listed activities contributed to build the premises for the growth of different trends of more specific research on the geotechnical aspects of the L'Aquila earthquake. This Special Issue, which was launched with a call for papers in 2012, is therefore dedicated to host 7 selected contributions, which are divided into two volumes. The first contains 4 papers mainly addressed to the geotechnical characterisation, while the second hosts 3 papers mostly dedicated to seismic response analysis and ground deformation.

Contents of the current volume

This second issue is opened by the work of Chamlagain *et al.*, devoted to the numerical simulation of the site effects observed in the upper Aterno Valley during the aftershock sequence of the L'Aquila earthquake. The Authors carefully back-analyze the array observations by 1D and 2D numerical analyses, which prove to perform better for the small magnitude events as compared to the moderate magnitude ones. More specifically, in this latter case the spectral shapes are adequately reproduced, while PGA and maximum spectral amplitudes are not. This finding is attributed by the Authors to near-fault effects. A set of modified analyses is thus proposed in the paper, aimed at overcoming some of the limitations of the adopted numerical model when dealing with near-source events, namely including the vertical component of the input motion: this does not significantly improve the results, leading to the conclusion that other fundamental hypotheses, such as vertical incidence of input waves and their synchronous application at the base of the subsoil model, should be critically reviewed. We look forward to publishing in the next future a possible second part of this study, which will include all the above new features!

The second paper is signed by Madiai and Simoni and focuses on the numerical simulation of morphological and stratigraphic effects at the so called "macro-zone 4" of the middle Aterno Valley. In this interesting work the Authors apply five different artificial acceleration time histories to three sub-sections of the studied area, analyzing them by 1D and 2D finite element models. A remarkable difference is observed between the amplification predicted at surface via 1D analyses as compared to the more realistic 2D ones, given the presence of sediment-filled basins along the section. In particular, the paper clearly highlights the relevance of the selection of appropriate amplification factors to analyze and compare results obtained by different acceleration time histories, indicating that integral ground motion parameters such as Housner intensity are more effective at this scope than the usual peak ground acceleration amplitude.

The final paper of this issue, written by d'Onofrio *et al.*, deals with a specific aspect of the L'Aquila event: the performance of the gas network supplying an area of about 550 km^2 in the Aterno Valley during and after the earthquake. The Authors adapt the well-known HAZUS methodology integrating into a GIS environment information about the earthquake motion, the subsoil properties, as well as the inventory, typology and specific properties of the pipelines. In particular, the mainshock was simulated by means of a Shakemap biased through site conditions, using non-linear stratigraphic amplification coefficients. The seismic demand was then estimated by taking into account both transient ground motion (TGD), in terms of peak ground velocity, and permanent ground deformation (PGD), defined by seismic slope displacements. The damage was expressed through fragility curves in terms of number of repairs per unit length of pipeline associated to both estimates of the seismic demand. The Authors provide a critical and detailed insight into the methodology, which leads to the formulation of a damage scenario, partly corroborated by the distribution of pipe ruptures observed after the 6th of April mainshock. In their conclusions, it emerges that the approach, although possibly over-conservative, can be very useful as a tool for both planning purposes and preliminary loss estimates.

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