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Abstract

The study presented here evaluates the ground motion amplification effects at the site of San Felice Martire church, a historical construction located at Poggio Pienze (L'Aquila, Italy). To characterize the soil profile at the site of investigation field geological observations, boreholes and geophysical tests from previous campaigns were gathered. Dynamic soil properties of the identified soil profile were obtained by the test results from selected literature. Then, the amplification effects at San Felice church's site was estimated using fully 1D stochastic site response analyses and for the object motion seven real records compatible to the Italian code-based spectrum referred to 475-year return period. The set of real records was downloaded from SEISM-HOME web portal. The stochastic analyses allowed to simulate 1,000 different soil profiles and to run 1,000 simulations, taking into account the inherent variability and uncertainty in the soil profile and on the seismic demand.

Keywords

Ground motion amplification • 1D stochastic analysis • Seismic hazard

204.1 Introduction

The 6.3 Mw L'Aquila earthquake (April 6, 2009) caused damage to structures over an area of approximately 600 km², including the urban centre of L'Aquila and several villages of the middle Aterno valley. The number of fatalities was 308, more than 1,500 people were injured and more than

65,000 were evacuated. The results presented here, which based on the full report at Tarque et al. (2013), focuses on the assessment of possible amplification effects, through a 1D stochastic analysis, of the ground motion due to the specific lithostratigraphic conditions at the site under investigation in Poggio Pienze, a small village located 17 km far away from L'Aquila. The procedure to carry out stochastic ground response analysis is explained in following sections. Each of these steps has been applied to the site under investigation and are explained as follows.

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204.2 Definition of the Seismic Input

In this work, the reference seismic action has been represented by uniform hazard acceleration spectra (obtained from the NTC 2008) and seven natural acceleration time histories for 475-years return period, referred to outcropping rock and ground levelled topographic conditions. The set of real records was downloaded from the SEISM-HOME portal (<http://www.eucentre.it/seismhome.html>).

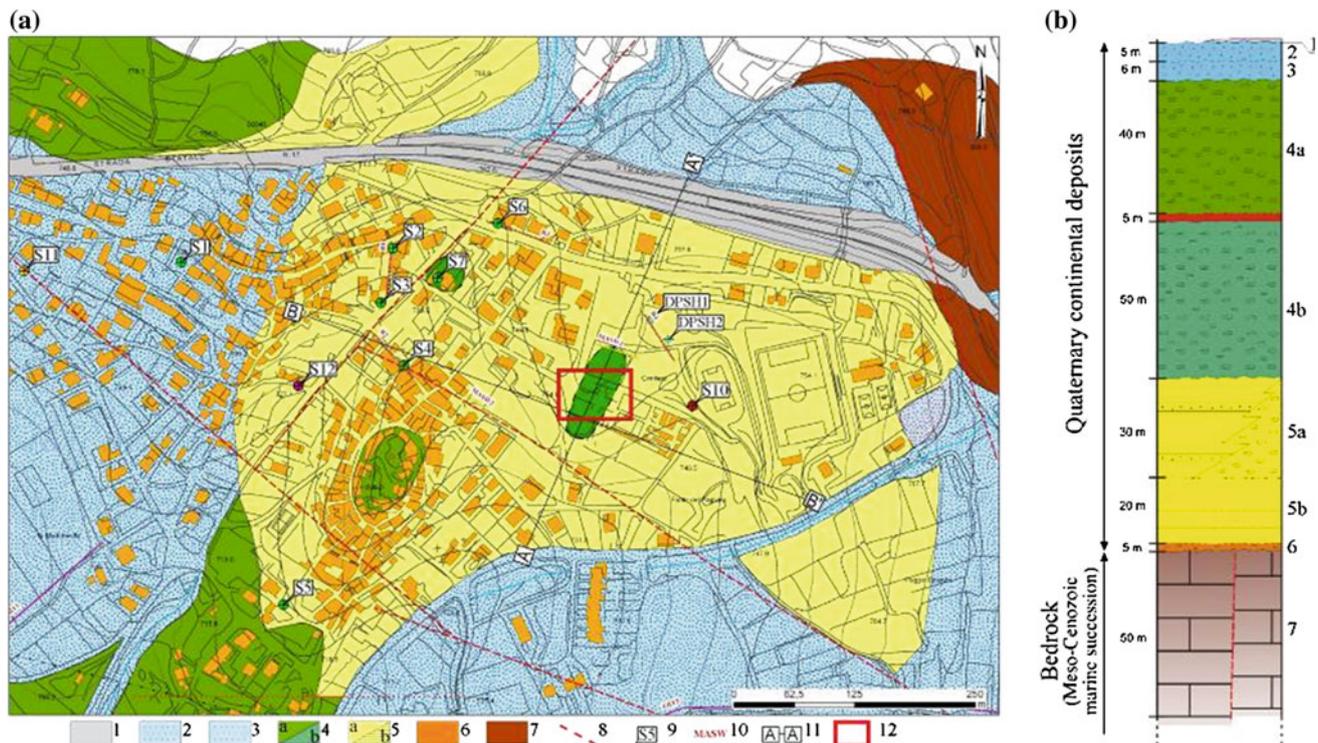


Fig. 204.1 a Geological map of Poggio Picenze area. Quaternary continental deposits: 1 backfill deposits; 2 recent colluvial deposits; 3 ancient colluvial deposits; 4 alluvial fan deposits (a upper part, b lower part); 5 fluvial and lacustrine deposits (a upper part, b lower part); 6 slope deposits. Bedrock (Meso-Cenozoic marine succession): 7

limestones. Symbols: 8 inferred fault; 9 borehole and geotechnical investigations; 10 geophysical field investigations; 11 geological profiles; 12 study site. b Stratigraphic and lithologic scheme of the Poggio Picenze area

204.3 Seismic Geotechnical Site Characterization

According to the geological framework, Poggio Picenze village, within the Aterno valley in the NE part of the Apennines chain, is located in a very complex geological sector placed over Quaternary continental deposits. Geological setting and Pliocene-Quaternary continental deposits setting have been studied since the beginning of last century, and recently after the 2009 earthquake, focusing on tectonics, stratigraphy, geomorphology, particularly concerning present and relict landforms (Bosi and Bertini 1970; Bertini and Bosi 1993; Bagnaia et al. 1992; Miccadei et al. 1999, 2004; Giaccio et al. 2012; Santo et al. 2013). The Poggio Picenze area is located at the boundary of the Paganica-San Demetrio basin, a morphological depression of extensional tectonic origin, filled with an up to >200 m thick Quaternary alluvial and lacustrine succession (Boncio et al. 2011; Giaccio et al. 2012). Such tectonic basin is part of the middle Aterno river valley, composed of a complex arrangement of several, laterally connected, fault-bounded sedimentary basins, such as the upper valley of Aterno River basin, the

Scoppito Basin, the western L'Aquila-Coppito basin Basin and the Castelnuovo-Civitaretenga basin, all of Late Pliocene-Quaternary age (Bosi and Bertini 1970; Bertini and Bosi 1993; Cavinato et al. 2010; Giaccio et al. 2012). Such intermountain basins formed after the NE-SW oriented, regional extension that affected the central Apennines since Late Pliocene.

A geological map was realized by means of field survey and borehole analysis. It shows the distribution of Quaternary continental deposits (i.e. colluvial deposits, alluvial fan deposits, fluvial and lacustrine deposits; Fig. 204.1a) in the Poggio Picenze area.

For geotechnical information and geophysical field investigation, drillings and geophysical tests retrieved from previous investigation campaigns have been collected in order to investigate the soil profile in the studied zone. The tests give just information about the first 30 m of the fluvial and lacustrine deposits (see 5a layer in Fig. 204.1b). Any tests reached the depth of the bedrock. These lacking information was indirectly overcome by detail field geological mapping of the surrounding areas and the correlation with existing subsurface data in the geological cross sections. Due to the length extension of this manuscript readers

Table 204.1 Proposal soil profile for the study zone. The numbers on second column refer to Fig. 204.1

Layer	Type	Depth (m)	Vs (m/s)	γ (kN/m ³)	Mat
I	Conglomerate (4b)	4	400	20	Mat1
II	Sandy silt (upper 5)	21	341	19.8	Mat2
III	Clayey silt (middle 5)	25	467	20.3	Mat2
IV	Silt (mid-lower 5)	31	413	20.3	Mat2
V	Gray clayey silts and calcarenitic (lower 5)	54	600	20.8	Mat2
VI	Breccia-conglomerate (6)	59	800	21.0	Mat3
VII	Bedrock (7)	–	1,250	22.0	Mat4

are referred to Tarque et al. (2013) for further details. In summary, four general layers are identified down the church (also described in Table 204.1): conglomerate (4b in Fig. 204.1b), white calcareous silts (5 in Fig. 204.1b), breccia and conglomerate (6 in Fig. 204.1b) and bedrock (7 in Fig. 204.1).

204.4 Statistical Characterization of the Soil Profile

To perform a stochastic analyses of the 1D response of a media, it is necessary to provide statistical information as mean values and probability density functions of some parameters as thickness (h), shear wave velocity (V_s), specific weight (γ), etc., to define a wide range of variability in the media. Since the gathered data did not directly provide this information, so it was necessary to evaluate some available data (which are not reported here) and to compute the standard deviation values (σ) taking into consideration some assumptions. A summary of the proposed geometry and material properties for the soil profile is specified in Table 204.1. In all cases the coefficient of variation (CoV) was increased to 15 % in all layers. The degradation curves for shear module and damping were obtained according to Table 204.1 of Working Group MS-AQ (2010) where some soil tests were performed for Poggio Picenze (see Tarque et al. 2013 for more details).

204.5 Stochastic 1D Site Response Analysis

In Matlab (<http://www.mathworks.com>), and following a Monte Carlo simulation, a total 1,000 soil profiles were generated for the interested zone with the Latin Hypercube sampling technique. The soil properties used for the stochastic analysis (see Table 204.1) were assumed to follow a Normal distribution. The minimum and maximum value of V_s , thickness and specific weight were in the interval of \pm three standard deviations. Then, an input file (*.txt) was automatically written to be used with Shake91 (software

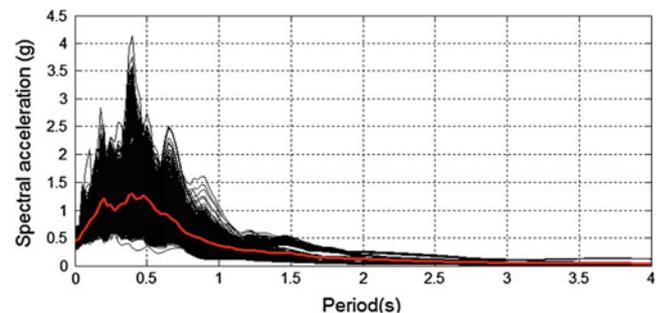


Fig. 204.2 Elastic spectral acceleration of the set of 1,000 accelerograms for the 475 year return period computed at the ground surface (adapted from Tarque et al. 2013)

developed by Schnabel et al. 1972), where each soil layer is completely defined by its thickness, shear wave velocity, specific weight, and degradation curve for shear modulus and damping. The input accelerograms for each of the 1,000 analyses was randomly selected from the set of seven natural accelerograms following a uniform distribution. The procedure for each ground response analysis was equal to the one done in the deterministic analysis: the acceleration at the bedrock was computed by deconvolution and finally the ground response was obtained by convolution of the seismic record from the bedrock to the ground surface. The 1,000 elastic spectral accelerations at the ground surface and its mean value are shown in Fig. 204.2. The mean of the maximum accelerations at the ground surface (PGA) is 0.46 g. According to the Italian code a PGA of 0.26 g should be used for soil type A. Therefore, an amplification factor of $0.46/0.26 = 1.8$ could be proposed for the interested zone.

204.6 Conclusions

The stochastic procedure allowed analyzing 1,000 simulations, which means 1,000 soil profiles with a random uniform selection of seven input motions. The results indicated a clear amplification of the PGA with respect to a soil type A at the ground surface of the San Felice church, from 0.26 to 0.46 g. Furthermore, the results show that the soil response

highly depends on the frequency content of the record and on the frequency of the soil layer, so they exemplify that a stochastic analyses is recommended to provide a more refined solution for the seismic demand.

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