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Experimental and numerical site response analysis for the definition of macroseismic anomalies in Liguria, Italy

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Definition of site amplification effects in areas characterized by complex geomorphological and/or particular soil conditions is one of the most important issues in seismology and earthquake engineering. As shown by macroseismic studies, the damage distribution produced by historical earthquakes is often related to site effects. In this work, we analyze the macroseismic fields of the main historical earthquakes occurred in western Liguria (e.g., 1887 earthquake with magnitude 7) in order to identify possible relations between damage patterns and local geological settings. In western Liguria, evidences of anomalies in the distributions of macroseismic intensities may be explained by the presence of Pliocene soil deposits, which mainly consist of marly clays (Argille di Ortovero Formation).Thus, both experimental and numerical site response methods were applied in order to investigate the influence of such deposits on ground response and, consequently, to justify the “anomalies” observed in the macroseismic fields. Concerning experimental methods, a number of HVSR measurements based on noise recordings were carried out in different sites characterized by the presence of the Pliocene deposits. For all sites analyzed, the H/V curves show marked amplification peaks between 2 and 5Hz. Based on such empirical evidence, 1D ground response analyses were carried out using Shake91 with the aim of investigating the correlation between such frequencies and the response of the Pliocene deposits. To this end, a set of ten real accelerograms consistent with the local seismic hazard and seismic hazard disaggregation scenarios was first selected and then driven at the base of different soil columns. A database of geotechnical and geophysical properties, including more than 50 soil profiles, was specifically compiled in order to define 1D models representative of typical local stratigraphic settings. Since, in the study area, the Pliocene deposits (of different thickness) directly overlay the bedrock, two-layer models were deemed appropriate to characterize the response of such materials. We examined three alternative models considering different ranges of thickness of the Pliocene deposits (between 5 and 35m, 60 and 105m, 30 and 65m). Besides the uncertainty in the soil thickness, we took into account the uncertainty in the shear wave velocity, unit weight, modulus reduction and damping curves of each soil layer. To this end, 2000 Monte Carlo simulations were carried out for each target soil column. Results show marked amplification effects, corresponding to amplifications factors (here defined as the ratio of the acceleration spectrum intensity at the surface to that at the rock outcrop) that often exceed the value of 1.35 (which is proposed by EC08 for soils with Vs,30 comprised between 360 and 800m/s). Specifically, site amplification is concentrated between 1 and 3Hz, 2 and 5Hz, 3 and 10Hz for the three target cases. Such frequency ranges are in agreement with those derived from experimental measurements, which are therefore representative of the resonance frequencies of the Pliocene deposits. Following our findings, such deposits canbe assumed as an essential factor in producing the “anomalies” observed in the damage patterns of the macroseismic fields of the historical earthquakes in western Liguria.