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Environmental effects and building damage induced by the vertical component of ground motion during the August 24, 2016 Amatrice (Central Italy) earthquake

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On August 24, 2016 an Mw 6.0 earthquake struck central Italy resulting in 299 fatalities, 388 injuries and about 3000 homeless. The provided focal mechanisms demonstrated a NW-SE striking seismic normal fault which is consistent with the spatial distribution of the coseismic surface ruptures observed along the western slope of Mt Vettore.

Based on our field reconnaissance in the affected area immediately after the earthquake, extensive secondary environmental effects including landslides, rockfalls and ground cracks were also observed. Most landslides were generated within the Amatrice intermontane basin, which, instead of a flat surface, comprises isolated flat hills and ridges with relatively high and steep slopes extending several meters above the low-lying part of the basin consisting of Quaternary deposits and with several villages founded at their top. Landslides generated along the steep slopes of Amatrice, Accumoli and Pescara del Tronto flat hills were due to topographical amplification of the earthquake motion derived from accelerometric recordings analysis along with the action of the vertical component of the ground motion and the already established instability conditions resulting from river incision and erosion at the base of the hills.

Strong evidences of the effect of the vertical ground motion in reinforced concrete (RC) buildings are the symmetrical buckling of reinforcement, compression damage and crushing at midheight and in other parts of columns, undamaged windows and unbroken glass panels as well as partial collapse of the buildings that usually occur along the vertical axis within the plan of the building. On the contrary, high flexible structures such as castle and bell towers in Arcuata del Tronto and Amatrice respectively were not affected by the vertical ground motion.

During the action of the vertical component of the ground motion in Amatrice affected area, stationary waves were formed vertically in the observed structures resulting in the collapse of one or more floors at any level of the buildings. At the same time, the overlying or underlying adjacent floors were completely horizontal and the corresponding parts of the building remained almost intact as if the partial collapse had not taken place. In partially collapsed buildings (e.g. in Amatrice), the remaining still-standing parts were practically undamaged. A reasonable interpretation leads to consider the effect of a strong vertical component. The intact parts of the buildings prove that they had a quite satisfactory lateral behavior and the unbroken windows show modest horizontal actions. Moreover, collapsed load-bearing and infill walls in unreinforced masonry and RC buildings respectively were symmetrically thrown away around the vertical axis of the buildings as if they were blown out by an explosion suggesting the predominance of vertical powerful actions over horizontal displacements.

All damage described above suggests the predominant effect of the vertical component of earthquake ground motion in the natural environment and buildings in this shallow near-field earthquake. These findings are discussed and compared with damage and response of structures in epicentral regions after destructive earthquakes generated in Dinar (1995), Athens (1999), L' Aquila (2009), Emilia Romagna (2012) and Nepal (2015).