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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INTRODUCTION

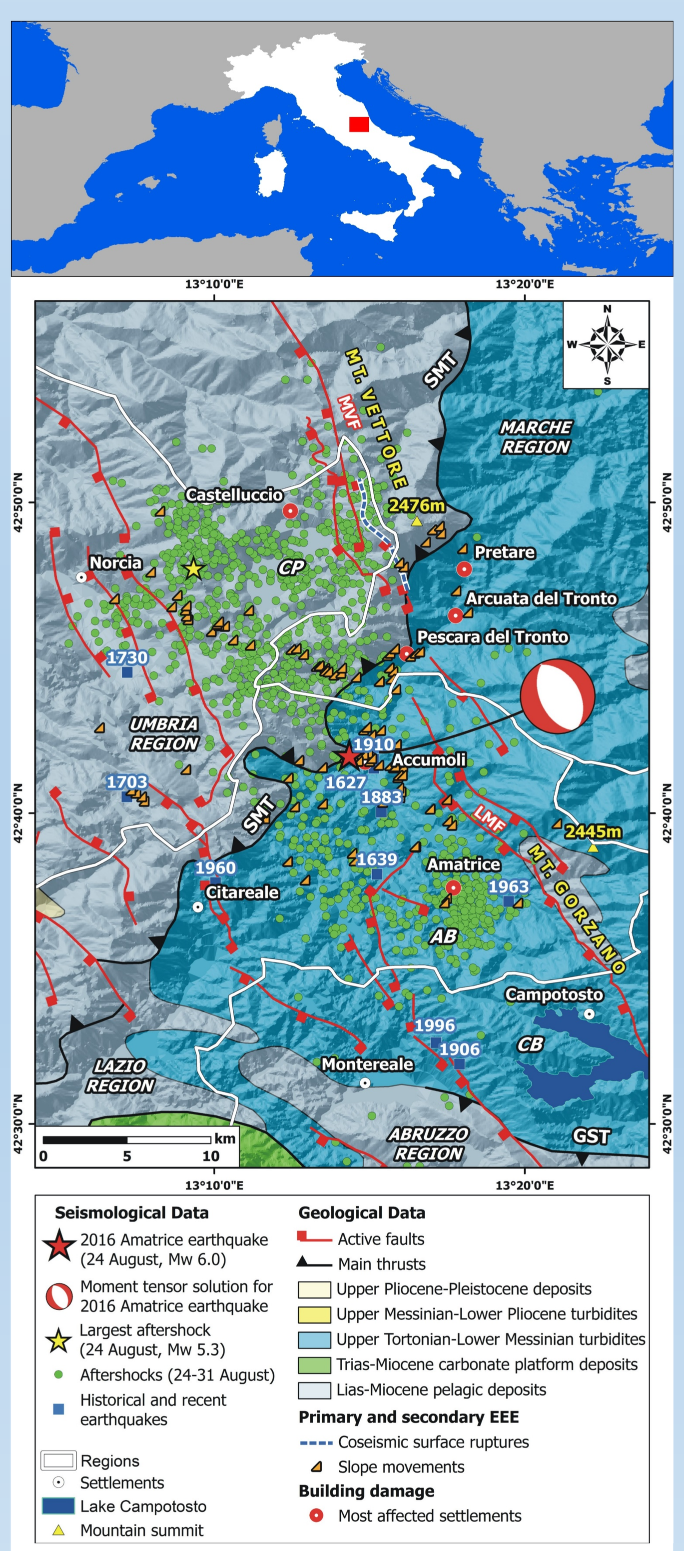
At the dawn of Monday 24 August 2016 (01:36:33 UTC; 03:36:33 local time) a strong earthquake struck Central Italy. It was assessed as Mw 6.0 (INGV) and predominantly felt on the Umbria, Marche, Abruzzo and Lazio regions resulting in 299 fatalities, more than 380 injuries and about 4500 homeless in villages in the borders of Marche and Lazio regions. It also caused earthquake environmental effects including seismic fault ruptures, ground cracks and slope movements. The causative fault of the 2016 Amatrice earthquake is the Mt. Vettore fault.

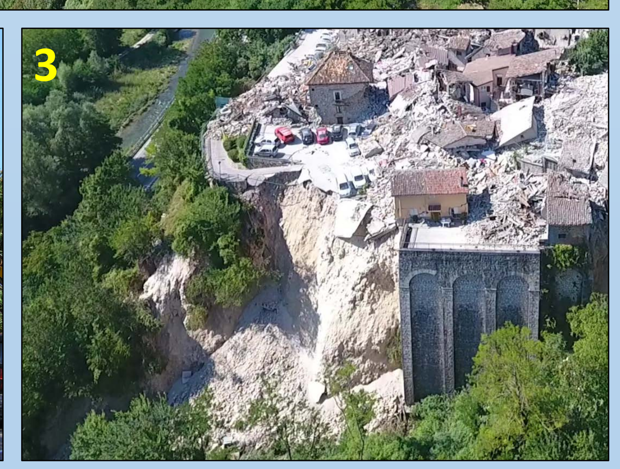
EARTHQUAKE ENVIRONMENTAL EFFECTS

Slope movements in the footwall (FW) of the Mt. Vettore fault were observed in seven localities within the Pretare and Arcuata del Tronto areas and in a site east of Amatrice town (Fig. 1). Their distance from the aforementioned faults was short, ranging from 1.5 to 3 km (Fig. 1). They were of low concentration and of small scale resulting in negligible to slight damage to road network.

In contrast, slope movements in the hangingwall (HW) were much more (98 localities) than those in the FW (Fig. 1). Their distance from the aforementioned faults was larger, ranging from 0 to 15 km (Fig. 1). They were comparatively of higher concentration and of larger scale causing severe damage to buildings and infrastructures and increasing human fatalities in settlements founded on top of flat hills, especially in Pescara del Tronto village (Figs. 2, 3) and Amatrice town (Figs. 4, 5).

Landslides generated along the steep slopes of the Pescara del Tronto and Amatrice flat hills are attributed to the destructive effect of the vertical component and to topographical amplification of earthquake motion along with the already established instability conditions resulted from river incision and erosion at the base of the hill. They resulted in partial or total collapse of buildings found at the edge of the hills and damage to infrastructures.





REINFORCED CONCRETE (RC) BUILDINGS

RC buildings comprise generally an RC frame and infill walls and are classified into: (a) non-ductile RC buildings with normal strength concrete dated back to the post-WWII period and now at the end of their conventional life cycle with probable decay problems affecting the mechanical properties of their elements and (b) recent RC buildings constructed during the last decades according to modern antiseismic specifications.

UNREINFORCED MASONRY (URM) BUILDINGS

Traditional URM buildings comprise the majority of the building stock in the affected area, date back as far as medieval times. They consist of masonry load-bearing walls characterized by irregular stonework mixed with pebbles and clay brick fragments often bound with mortars of poor and inadequate quality. They are non-engineered and not earthquake resistant (Figs. 6-8).

EFFECTS OF VERTICAL GROUND MOTION IN BUILDINGS IN THE 2016 AMATRICE EARTHQUAKE AFFECTED AREA (Figs. 9-16)

Strong evidences of the effect of the vertical ground motion in the RC buildings in the 2016 Amatrice earthquake affected area are:

(a) the symmetrical buckling of reinforcement,
(b) the compression damage and crushing at midheight and in other parts of columns,
(c) the undamaged windows and the unbroken glass panels as well as
(d) the partial collapse of the buildings that usually occur along the vertical axis within the plan of the building.

During the action of the vertical component of the earthquake ground motion, stationary waves were formed vertically in the observed structures resulting in the collapse of one or more floors at any level of the building. 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 town), the remaining still-standing parts are practically undamaged. Although significant changes in the quality of construction between the collapsed and the intact portions of the building cannot be excluded, thus explaining their significantly different behavior, a reasonable interpretation leads to consider the effect of the 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 URM and RC buildings respectively were thrown away of the buildings as if they were blown out by an explosion suggesting the predominance of vertical powerful actions over horizontal displacements.

CONCLUSIONS

All damage presented herein suggests the predominant effect of the vertical component of earthquake ground motion in the 2016 Amatrice shallow near-field earthquake. Similar conclusions were drawn by Benedetti and Carydis (1999) and Di Sarno et al. (2011) and references therein after studying building damage induced by similar earthquakes generated in Europe [1995 Aegion (Greece), 1995 Dinar (Turkey), 1999 Athens (Greece), 2009 L' Aquila (Italy) earthquakes].

REFERENCES

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Di Sarno, L., Elnashai, A.S., Manfredi, G. (2011). Assessment of RC columns subjected to horizontal and vertical ground motions recorded during the 2009 L'Aquila (Italy) earthquake. Engineering Structures, 33, 1514-1535.

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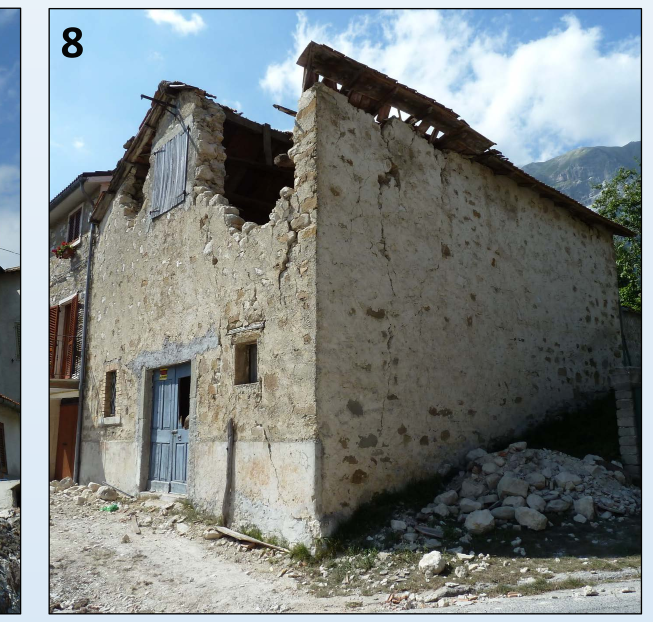

On 2016.08.25, after the main shock

On 2016.08.26 After an Mw 4.8 aftershock