Using structures of the August 24, 2016 Amatrice earthquake affected area as seismoscopes for assessing ground motion characteristics and parameters of the main shock and its largest aftershocks

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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.

REINFORCED CONCRETE (RC) BUILDINGS

Main characteristics

Reinforced concrete (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.

Non-structural damage Horizontal cracking of infill and internal partition walls, detachment of infill walls from the surrounding RC frame and of large pieces of plaster from walls.

Structural damage They varied from light damage in RC elements to partial or total collapse of the building. More specifically, it comprised light cracks in columns, soft story failure due to absence of infill walls, symmetrical buckling of rods, compression damage at midheight of columns and bursting of over-stressed columns resulting in partial or total collapse. Strong evidences of the effect of the vertical ground motion in RC buildings are the symmetrical buckling of reinforcement, the compression damage and crushing at midheight and in other parts of columns, the undamaged windows and the unbroken glass panels as well as the partial collapse of the buildings that usually occur along the vertical axis within the plan of the building.

Damage to RC buildings due to

(a) poor quality of concrete with compressional strength lower than the expected and inadequate reinforcement,

(b) absence of earthquake resistant features even in recent constructions,

(c) inappropriate foundation close to the edge of the slopes of flat hills that also leads to differential settlements creating cracks homologous to those seismically induced,

(d) the destructive effect of the vertical component of the earthquake ground motion.

UNREINFORCED MASONRY (URM) BUILDINGS

Main Characteristics They 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 due to construction in a period during which the earthquake-resistant construction as well as strengthening against earthquakes did not exist as a way of prevention and mitigation of the destructive earthquake effects, as the first rudimentary rules for antiseismic structures were drawn during the 18th century after the 1783 Messina, 1857 Ancona and 1859 Norcia earthquakes.

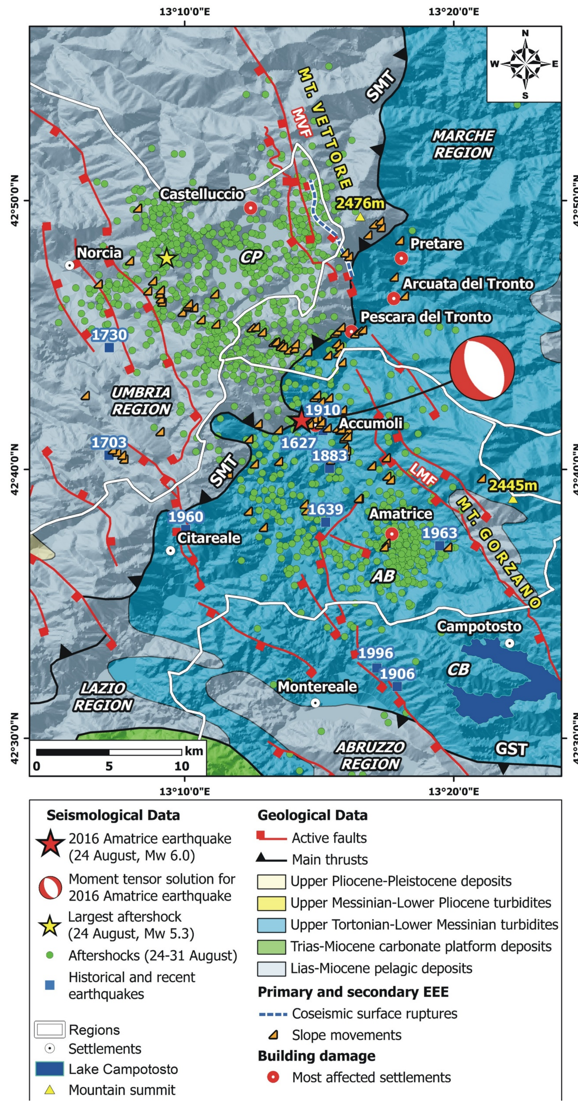
Structural and non-structural damage Damage varies from cracks and detachment of large pieces of plaster from walls to mainly and mostly destruction of the building. Moreover, damage to masonry walls, piers, floors and roofs was also observed.

Damage to URM buildings due to

(a) the poor workmanship with randomly placed materials of poor and inadequate quality bound by low-strength mortars and without any antiseismic precautions

(b) the effect of the vertical component of ground motion to buildings as well as

(c) inadequate interventions and modifications after previous earthquake damage.



(1, 2) Non-structural damage observed in reinforced-concrete (RC) buildings in Amatrice town. (3, 4) Non-structural and structural damage to unreinforced masonry (URM) buildings in Amatrice (3) and Accumoli (4) towns. Both towns are located close to the causative fault of Mt. Vettore.

The main shock and its largest aftershocks caused damage including spatial homothetic motions of RC buildings (5, 6) and URM buildings (7, 8). Photos on the left (5, 7) were taken on 2016.08.25 after the main shock and an Mw 4.3 aftershock and photos on the right (6, 8) on 2016.08.26 after a shallow near-field Mw 4.8 aftershock with focal mechanism indicating normal faulting.

Engravings made by Jacques Philippe Le Bas on 1757 illustrating damage caused by the 1755 Great Lisbon earthquake showing the Lisbon Cathedral (9), the St. Roch Tower (10), St. Paul's Church (11) and the St. Nicholas Church (12). The roofs of the studied buildings partially collapsed along the vertical direction and within their own footprint indicating the prevalence of the vertical component.

USING BUILDINGS AS SEISMOSCOPES

During on-site inspection in the affected area immediately after the earthquake, the authors had the opportunity to observe the damage induced not only by the main shock but also by its largest aftershocks generated during the first three days of the aftershock sequence. Bearing in mind that:

(a) the soil conditions in foundations of the affected villages were neither changed nor altered,

(b) the conventional dynamic parameters of buildings did not play a significant role in their seismic response against the vertical component of the earthquake ground motion, due to its impact type of loading,

(c) the structures and materials have carried memories from the previous large shocks of this sequence and

(d) the main shock and its largest aftershocks caused damage on buildings including spatial homothetic motions,

it is concluded that:

(a) the main shock and its largest aftershocks had similar focal mechanism parameters (normal faulting),

(b) the main shock and its largest aftershocks were shallow near-field seismic events with short duration but high amplitude,

(c) the observed damage is typical of such earthquakes and

(d) the vertical component of the earthquakes' ground motion has prevailed.

These homothetic motions were not an isolated case, but they reached statistically significant levels. Therefore, the characteristics of the largest aftershocks derived from portable instruments installed after the main shock can be used for extracting relevant conclusions for the main shock and effectively addressing the lack of seismographs in the near field during its occurrence time.

USING BUILDINGS AS SEISMOSCOPES FOR HISTORIC EARTHQUAKES

THE 1755 GREAT LISBON EARTHQUAKE

Following the aforementioned approach based solely on macroseismic field observations, very important conclusions related to famous historical earthquakes may be drawn. We applied this approach to the case of the 1755 Great Lisbon earthquake in order to determine its characteristics. Macroseismic observations derived from: (a) on-site inspection of damaged historical buildings in Lisbon city and (b) artworks illustrating famous buildings that suffered damage from this sequence. In brief, the studied building collapsed along the vertical direction, within their own footprint and within the very first moments of the ground shaking. Thus, inhabitants had no time to react by escaping or protecting themselves and therefore the lethality rate was really high.

It is concluded that this damage are attributed to an earthquake with (a) a strong vertical component, (b) its epicenter located very close to Lisbon, (c) a small focal depth and (d) perhaps of not so great magnitude. Probably, due to the other evidences, the Great Lisbon earthquake, that generated the devastating tsunami, had its epicenter located in the ocean (to the W of Lisbon) and immediately followed the previous earthquake of the prevailing vertical component.

CONCLUSIONS

It is suggested that the aforementioned approach can be applied either in past historic earthquakes or complementarily in recent cases when the available seismological data are insufficient due to lack of seismographs in the near field during its occurrence time.

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