

Seismic damage recognition based on field survey and remote sensing: general remarks and examples from the 2016 Central Italy earthquake

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Abstract One of the most critical issues in the management of post-earthquake emergency is the prompt identification of the most damaged urban areas. Rapid detection of damage distribution is crucial for Civil Protection during the management of the first emergency phase, in order to both address assistance teams and identify priorities in planning the usability inspections, thus permitting people to go back, as safe as possible, to their houses. Generally, the estimation of building usability is performed by means of a building-by-building survey based on a form to be filled out by expert technicians (Masi et al. 2016). Different countries adopt different forms whose result in terms of usability is dependent essentially on building damage and, in some cases, vulnerability conditions of buildings. When the affected area is large, usability inspections can require a lot of time and a huge number of expert technicians. Therefore, great efforts have been made during past earthquakes in order to define rapid procedures to identify areas not severely damaged and then potentially with a low percentage of unusable buildings. In this framework, many experiences have been carried out worldwide in order to identify, in the immediate aftermath of an earthquake, the damage distribution through remote sensing approaches, possibly combined to field survey data (e.g., Saito and Spence 2004; Yamazaki et al. 2004; Chesnel et al. 2007; Zhai et al. 2016; An et al. 2016; Huang et al. 2016).

Keywords Earthquake · Buildings · Damage recognition · Field survey · Remote sensing

In the framework of Copernicus Project (Copernicus 2016), during the first hours after the $M_I = 6.0$ (GdL INGV 2016) earthquake occurred in Central Italy on August 24, 2016, optical images were taken in order to have a first idea of the damage distribution in the villages located in the epicentral area. Particularly for Amatrice village, the survey carried

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out by remote sensing shows that (Fig. 1), on a total number of about 400 buildings, nearly 35% suffered severe damage or collapse, about 30% suffered moderate damage, about 5% slight damage and, finally, 30% were reported in the map as no damaged buildings. Regarding the estimation of building damage reported in the Copernicus map, collapse (that is damage level $L_d = 5$, according to the EMS-98 classification) and near-collapse ($L_d = 4$) buildings were correctly identified, while, with respect to the buildings that suffered lower levels of damage (i.e., $L_d \leq 3$), some inconsistencies were found in comparison with field data collected by Santarsiero et al. (2016) in the aftermath of the August 24 event.

The field survey carried out on the area external to the historic center of Amatrice identifies many buildings having severe damage either structural and non-structural (e.g., Fig. 2), while in the map of Fig. 1 only negligible up to slight damage is displayed.

The most common damage found in this area by field survey is really difficult to be identified by means of remote sensing, because it is represented by the widespread cracking and/or collapse of masonry infills (at the lower floors) that are usually made up of two layers, one of them sometimes completely external to the structural frame. At the same time, infill panels often caused heavy damage to the beam-column joints, thus demonstrating a significant contribution to the global seismic resistance.

These inconsistencies between remote sensing and field data confirm that the identification of the most damaged areas (i.e., the areas with the higher percentage of severely damaged and collapsed buildings) can be effectively achieved through remote sensing. On the contrary, dealing with the areas with lower damage levels (i.e., where L_d is typically ≤ 3) can be more complicated and requires also field data. However, availability of remote

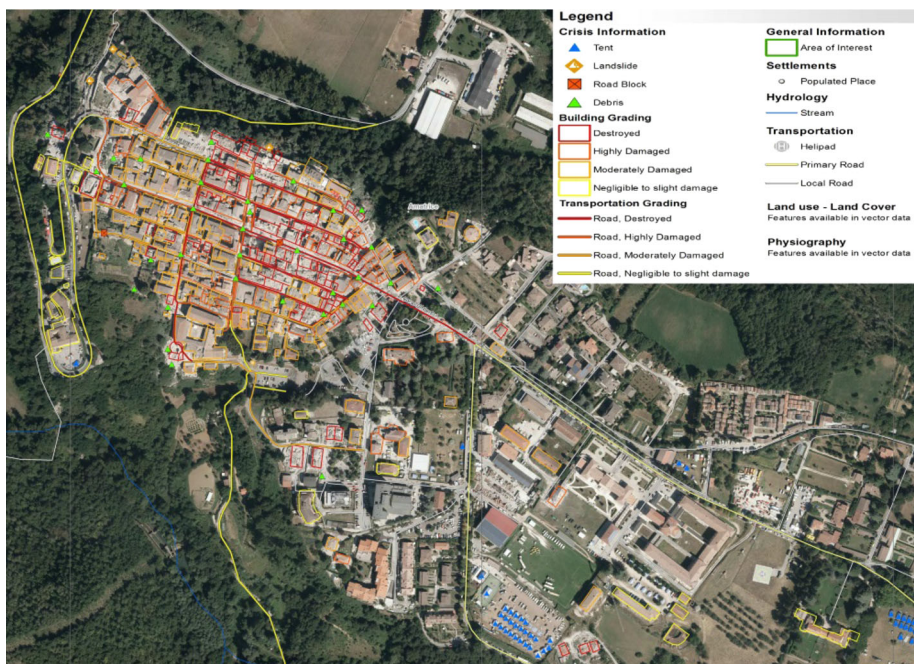


Fig. 1 Amatrice aerial (Italy). Situation as of August 25, 2016. Map produced and released by e-GEOS



Fig. 2 Damage to the cladding of a reinforced concrete building (*on the left*) and details of the damage to a beam-column joint (*on the right*)

sensing information can contribute to plan usability inspections, taking into account that the buildings with heavy damage (i.e., $L_d \geq 4$) are certainly unusable.

Currently, the seismic sequence, and thus the activities herein described, are still ongoing; therefore, further analysis and discussion are in progress.

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