



## ASSESSMENT SURVEY OF PUBLIC SCHOOL BUILDINGS AFTER AUGUST 2016 ITALY EARTHQUAKE: PRELIMINARY RESULTS

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## Abstract

The seismic events which hit Central Italy on 24 August, October 26 and October 30 2016 have caused casualties and major damage mostly to buildings and architectural heritage of the Italian Regions of Abruzzo, Lazio, Marche and Umbria; the most deadly events occurred on August 24, 2016 and caused a total of 298 victims and about 4.600 people evacuated. The mainshock occurred at 3:36 am with epicenter close to Accumoli (Rieti province) and a magnitude Mw 6.0; the aftershock occurred at 4.33 am with epicenter close to Norcia (Perugia province) and a magnitude Mw 5.3. Most of the victims were in the areas of Amatrice (Ri), Accumoli (Ri) and Arquata del Tronto (AP). The earthquakes of October 30 didn't cause any victim but only some injured thanks to the fact that people was already evacuated and also because the Civil Protection was already present on the territory. Nevertheless, the impact of this seismic event was destructive; many small towns and villages, which have survived to the first earthquake, were heavily damaged. In the days following the earthquake of august 24 the Department of Civil Protection and RELUIS started the usability surveys by using the Aedes form (Italian acronym for "accessibility and damage during seismic emergency" [1]) which guides the inspector to rapidly assess the usability of a structure, including the description of damage and all the details of the building.

The authors of this work, which formed the team of the Universities of Central Italy, visited a total of 127 structures in the period between the 25<sup>th</sup> of August and the 25<sup>th</sup> of October: 112 (88%) of them were schools, 3 (3%) were hospitals and sanitary buildings, 9 (7%) were civil and collective activities, 3 (2%) other structures. Excluded from this preliminary study are the architectural heritage buildings: because of the earthquake of the 26<sup>th</sup> of October it was not possible to collect enough data.

The goals of this work are: Collect all the available informations on the inspected buildings by means of the creation of a Database with all the informations given by the Aedes Form, the comparison between the results of Aedes inspections and other informations, as the epicentral distance of the inspected building or the local intensity recorded by the seismic stations, providing quantitative results. The comparisons allow to state, for example, how many buildings were condemned in a certain range of epicentral distance, or to relate the observed damage with the seismic intensities.

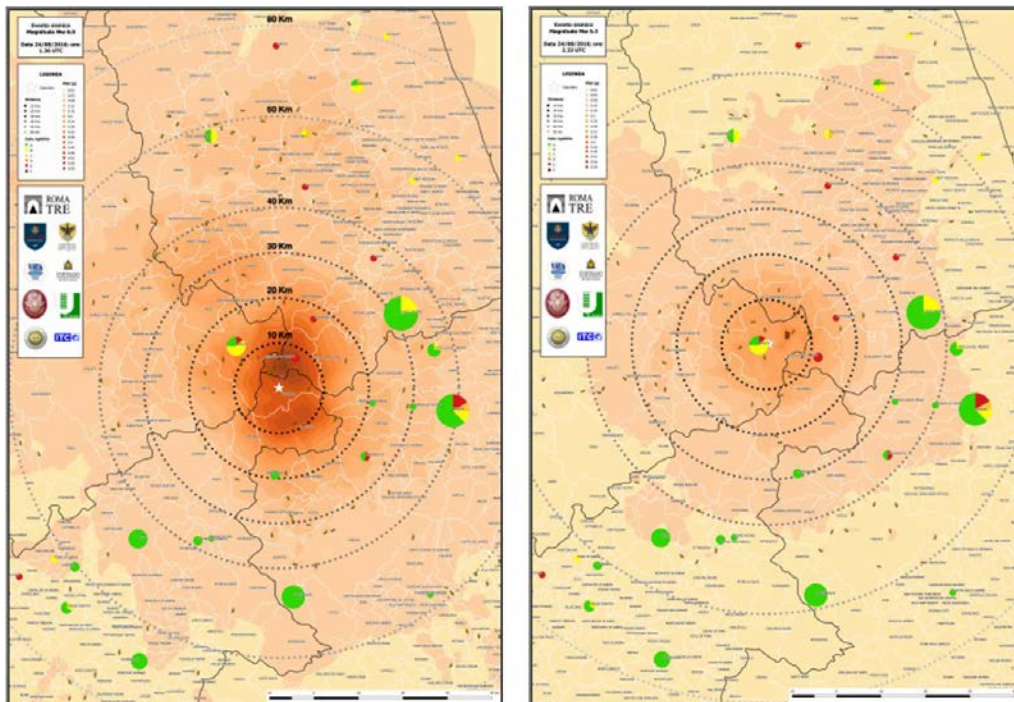


Fig. 3 General map, 1:250.000 scale. Comparison between public buildings usability and the shakemaps of the seismic events of the 24<sup>th</sup> of August: 1:36 UTC event, Mw 6.0 (left) and 2:33 UTC event, Mw 5.3 (right)



With the aim to create this Database, an information system which is based on the Open-source GIS software QGIS [2] was created. The system includes two different levels of cartography with increasing level of detail:

1. General map, 1:250.000 scale: this is an overview of the inspected municipalities. It allows to visualize for each municipality the number of inspected structures and the accessibility result. The results are defined by a letter from A to E, ranging from A=usable to E=unusable. In fact, for each municipality a plot of the accessibility of the structures, expressed as a percentage of the total number of inspected buildings, is given. At this scale it is possible to compare the geographical distribution of the accessibility results with the shakemaps [3]. The shakemaps used in this work are provided by INGV (Italian acronym for Italian Institution for geophysics and volcanology). Fig.1 shows the map at this level of detail: the areas with the pie chart represent the municipalities which were inspected. Contours in red indicate the seismic intensity in terms of PGA. Concentric circles (grey scale dotted line) represent the epicentral distance.
2. Municipality scale 1:5.000: allows to locate on the map the single building inspected, highlighted by a particular color for each accessibility result (A=green, B=yellow, E=red in Fig.4). At this scale, the system provides detailed informations on the single building (Number of floors, construction material and all the other informations included in the Database). By selecting the single building it is possible to visualize all these informations, some pictures taken during the inspection and other informations such as the plot of the response spectra of the seismic records, if available.

Preliminary results are depicted in Fig. 1. Between 0 and 10 km, in the municipality of Arquata del Tronto, all the buildings inspected are unusable (E); between 10 and 20 km the most frequent result was B, so the majority of buildings could be usable after some emergency interventions; Between 20 and 30 km there are 2 A results and 1 E; between 30 and 40 km, where are located Ascoli Piceno and Teramo, there is a majority of A results, whereas there are 10 B results and 5 E results on a total of 59 structures inspected in that range. Also in the range 40-60 km and 60-80 km there is a majority of A results. Nevertheless, also in these areas there are partially © or fully (E) unusable structures. First results show that the majority of the unusable buildings (E) lies in NE direction of the epicenter. This fact could be related to the higher values of local seismic intensity measured in comparison with inspected buildings located at the same distance from the epicenter. The Aedes forms of the public buildings inspected after the seismic event of the 30<sup>th</sup> of October can be easily uploaded in the GIS model, and compared with the corresponding shakemap.

## References

- [1] Baggio C, Bernardini A, Colozza R, Di Pasquale G, Dolce M, Goretti A, Martinelli A, Orsini G, Papa F, Zuccaro G, Pinto AV, Taucer F (2007): Field manual for post-earthquake damage and safety assessment and short term countermeasures (AeDES).
- [2] QGIS Development Team, (2016), QGIS Geographic Information System. Open Source Geospatial Foundation Project. <http://www.qgis.org/>.
- [3] Michelini, A., Faenza, L., Lauciani, V., & Malagnini, L. (2008). ShakeMap implementation in Italy. *Seismological Research Letters*, 79(5), 688-697.