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Preliminary macroseismic survey of the 2016 Amatrice seismic sequence

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Abstract

After the recent destructive L'Aquila 2009 and Emilia-Romagna 2012 earthquakes, a sudden M_W 6.0 seismic event hit Central Italy on August 24, 2016. A low population density characterizes the area but, due to its nighttime occurrence, about 300 victims were registered. This work presents the first preliminary results of a macroseismic survey conducted by teams of the University of Padova. Macroseismic intensities were assessed according to the European Macroseismic Scale (EMS98) for 180 sites.

I. INTRODUCTION

On August 24, 2016, at 3:36 local time (1:36 UTC), most of the inhabitants of central Italy were woken up by a M_W 6.0 earthquake that occurred at the boundaries of Lazio, Umbria, Marche and Abruzzo regions. The epicenter was located by the Istituto Nazionale di Geofisica e Vulcanologia (INGV) seismic network [ISIDe 2016] at 42.70°N and 13.24°E, between the Municipalities of Accumoli and Amatrice, in the Lazio region. The Central Apennines sector is highly prone to seismic hazard: in recent years other devastating events occurred with epicenters located in a range of 30 km far from the actual one, like the April 6, 2009 (M_W 6.29) L'Aquila event and the 1997 Umbria seismic sequence, characterized by a M_W 5.97 mainshock. According to the Parametric Catalogue of Italian Earthquakes (CPTI15) [Rovida et al. 2016], historical information reveals that the seismic activity in the Monti Sibillini area is frequent and in the past centuries was characterized by highly destructive events: from the eighteen century a mean annual rate of about 0.25 events with magnitude M_W higher than 4.0 was observed. The first evidences of damage induced by earthquake occurrences in the area of Accumoli were related to the effects of the July 1627 Monti della Laga event (M_W 5.3, I_O 7-8 MCS) [Monachesi and Castelli 1992]. It was followed by the severe October 7, 1639 (M_W 6.21, I_O 8-9 MCS) [Castelli 2013] Amatrice earthquake, that seemed very similar to the actual seismic scenario. The Accumoli area suffered extensive damages also after the most destructive January 14, 1703 (M_W 6.92, I_O 10 MCS), and was re-struck by the May 12, 1730 Valnerina event (M_W 6.04, I_O 7 MCS) [Guidoboni et al. 2007]. After about 150 years these territories were hit again by the November 7, 1883 Monti della Laga earthquake (M_W 5.10, I_O 7 MCS) and in the twentieth century by other significant events with I_O MCS 7-8 in 1916, 1950 [Tertulliani et al. 2006] and 1979. In the days following the August 24 event, teams of the University of Padova organized a field survey of the damaged areas with the aim to develop an exhaustive macroseismic assessment of the

earthquake scenario, according to the European Macroseismic Scale (EMS98) [Grünthal 1998]. The survey was continuously updated until September 6, 2016 to better define the damage effects induced by the mainshock event.

II. Survey methodology

The teams surveyed 180 sites, assessing the intensity level on the basis of the structural damage suffered by the residential building stock and classifying it according to the European Macroseismic Scale (EMS98) [Grünthal 1998]. Industrial buildings were not taken into account due to their lack of representativeness for intensity assessment purposes in the region. Short interviews on the perception of the effects experienced by the inhabitants integrated damage data. A vulnerability class was identified for each analyzed building, and failures were classified according to the EMS98 damage grades. The most common residential building types in the area are: one-or-two-story old masonry buildings in stone and low quality mortar, with lack of connections (vulnerability class A and B); recently retrofitted masonry buildings (mostly renovated after the 1997 Umbria sequence, to which a vulnerability class D was assigned); and two-story seismically designed reinforced concrete frame structures (vulnerability class C). Historical buildings like churches, castles and towers were considered for the intensity assessment purposes only in sites where the building stock was undamaged or slightly affected.

III. Intensity assessment

Differently from the 2012 Emilia-Romagna seismic sequence, characterized by relevant aftershocks comparable to the May 20 mainshock, only one event was characterized by a magnitude M_W greater than 5.0, about one hour after the 1:36 UTC M_W 6.0 mainshock: for this reason, the intensity map can be reasonably viewed as the effects of the main event. Intensity values were defined on the basis of the damage grades detected on the different vulnerability classes observed in the analyzed villages. In some centers, difficulties in the intensity assessment were experienced mainly due to differences between damage levels observed in old centers and on recent reinforced concrete buildings: hence, teams surveyed such sites more times, to reduce subjectivity judgment. Figure 1 illustrates the intensity I_{EMS} distribution over the struck territories and Table 1 lists I_{EMS} values for each site surveyed. Major intensities were observed in Amatrice and Pescara del Tronto, which were mainly justified by a diffused level 5 of damage to several masonry buildings (Figure 2). Damages compatible with a I_{EMS} 8 were detected in villages in an area within a radius of about 12 km far from the instrumental epicenter: in these cases, most of the vulnerability class B residential masonry buildings suffered level 3 of damage. Some particular situations of very slight damage were observed close to the instrumental epicenter zone in the villages of Vezzano, Colle d'Arquata and Spelonga, probably due to beneficial site effects. The I_{EMS} 6 area instead extended asymmetrically northwards, about 30 km from the instrumental epicenter, whereas southwards effects seemed significantly attenuated. Some difficulties were encountered in the intensity evaluation of damage in the southeastern towns of the Abruzzo region, since many buildings were still presenting damage caused by the 2009 L'Aquila sequence, and the relatively slight level of ground shaking induced in these areas by the M_W 6.0 mainshock, if compared to the epicentral zones. Another challenging issue was related to the assessment in the Umbria towns, since most of them were seismically retrofitted after 1997 sequence: here the critical issue

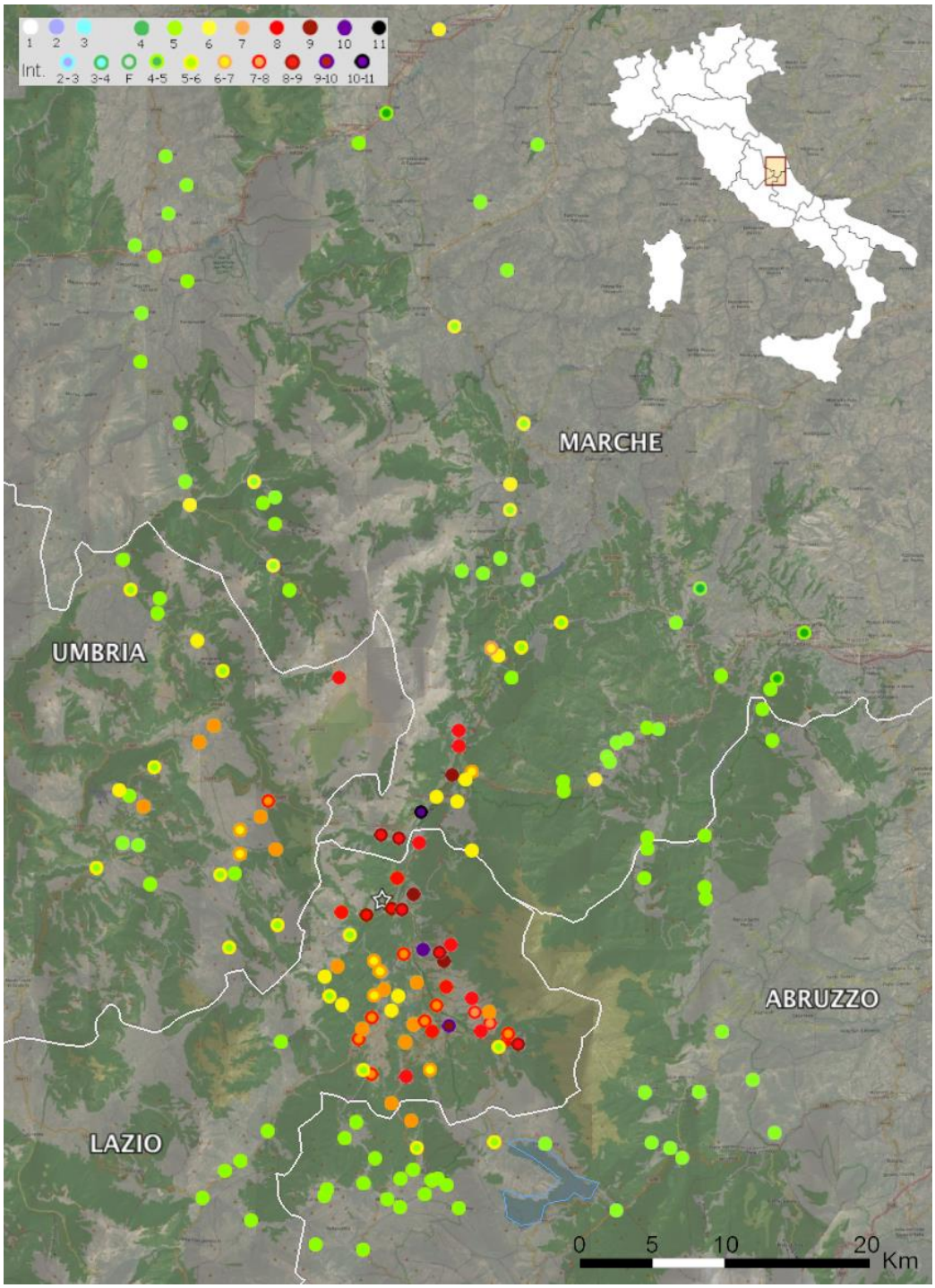

Figure 1: *Macroseismic intensities observed after the August 2016 seismic sequence (damage up to September 6, 2016).*

Table 1: *Localities surveyed after the August 2016 seismic sequence.*

D(*)	Municipality	Locality	I_{EMS}	D(*)	Municipality	Locality	I_{EMS}
AP	Arquata del T.	Pescara del T.	10-11	RI	Amatrice	Nommisci	6-7
RI	Amatrice	Saletta	10	PG	Norcia	Savelli	6-7
RI	Amatrice	Amatrice	9-10	PG	Norcia	Valcadara	6-7
RI	Accumoli	Illica	9	AP	Arquata del T.	Trisungo	6-7
RI	Amatrice	San Lorenzo Fl.	9	RI	Accumoli	Roccasalli	6
AP	Arquata del T.	Arquata del T.	9	RI	Amatrice	Pasciano	6
RI	Accumoli	Accumoli	8-9	RI	Amatrice	San Giorgio	6
RI	Accumoli	Fonte del Campo	8-9	RI	Amatrice	Santa Giusta	6
RI	Accumoli	Villanova	8-9	PG	Norcia	Agriano	6
RI	Amatrice	Casale	8-9	PG	Norcia	Campi	6
RI	Amatrice	Preta	8-9	AP	Acquasanta T.	Acquasanta T.	6
AP	Arquata del T.	Capodacqua	8-9	AP	Arquata del T.	Colle	6
AP	Arquata del T.	Tufo	8-9	AP	Arquata del T.	Faete	6
RI	Accumoli	Grisciano	8	AP	Arquata del T.	Spelonga	6
RI	Accumoli	San Giovanni	8	AP	Arquata del T.	Vezzano	6
RI	Accumoli	Tino	8	AP	Montegallo	Montegallo	6
RI	Amatrice	Casteltrione	8	FM	Montefortino	Montefortino	6
RI	Amatrice	Cornelle di Sotto	8	MC	Tolentino	Tolentino	6
RI	Amatrice	Cossito	8	MC	Visso	Visso	6
RI	Amatrice	Mosicchio	8	RI	Accumoli	Terracino	5-6
RI	Amatrice	Petrana	8	RI	Amatrice	Cornillo Nuovo	5-6
RI	Amatrice	Retrosi	8	RI	Amatrice	Forcelle	5-6
RI	Amatrice	Sommati	8	RI	Amatrice	Varoni	5-6
PG	Norcia	Castelluccio	8	PG	Cascia	Cascia	5-6
AP	Arquata del T.	Piedilama	8	PG	Cascia	Castel S. Maria	5-6
AP	Arquata del T.	Pretare	8	PG	Cascia	Civita	5-6
RI	Accumoli	Macchia	7-8	PG	Norcia	Ospedaletto	5-6
RI	Amatrice	Bagnolo	7-8	PG	Norcia	Pescia	5-6
RI	Amatrice	Capricchia	7-8	PG	Norcia	Piè la rocca	5-6
RI	Amatrice	Collepagliuca	7-8	PG	Preci	Preci	5-6
RI	Amatrice	Colli	7-8	AP	Montegallo	Bisignano	5-6
RI	Amatrice	Cornillo Vecchio	7-8	AP	Montegallo	Castro	5-6
RI	Amatrice	Moletano	7-8	AP	Montegallo	Uscerno	5-6
RI	Amatrice	Scai	7-8	FM	Amandola	Amandola	5-6
RI	Amatrice	Torrita	7-8	FM	Montefortino	Cerretana	5-6
PG	Norcia	San Pellegrino	7-8	MC	Castelsantangelo	Castelsantangelo	5-6
RI	Amatrice	Collegentilesco	7	MC	Sarnano	Sarnano	5-6
RI	Amatrice	Colleposta	7	MC	Ussita	Ussita	5-6
RI	Amatrice	Configno	7	AQ	Campotosto	Poggio Cancelli	5-6
RI	Amatrice	Patarico	7	AQ	Montereale	Aringo	5-6
RI	Amatrice	Poggio Vitellino	7	RI	Borbona	Borbona	5
RI	Amatrice	Roccapassa	7	RI	Cittareale	Cittareale	5
RI	Amatrice	San Benedetto	7	RI	Cittareale	Santa Croce	5
RI	Amatrice	Voceto	7	RI	Posta	Bacugno	5
PG	Cascia	Avendita	7	RI	Posta	Fontarello	5
PG	Norcia	Fontevena	7	RI	Posta	Posta	5
PG	Norcia	Frascano	7	PG	Norcia	Aliena	5
PG	Norcia	Norcia	7	PG	Norcia	Fogliano	5
PG	Norcia	Nottoria	7	PG	Norcia	Maltignano	5
AQ	Montereale	Santa Lucia	7	PG	Norcia	Puro	5
RI	Accumoli	Collespada	6-7	PG	Norcia	Sant'Andrea	5
RI	Amatrice	Collemoresco	6-7	PG	Preci	Collescille	5
RI	Amatrice	Domo	6-7	PG	Preci	Piedivalle	5

D(*)	Municipality	Locality	I_{EMS}	D(*)	Municipality	Locality	I_{EMS}
PG	Preci	Saccovescio	5	AQ	Capitignano	Capitignano	5
AP	Ascoli Piceno	Castel Trosino	5	AQ	Capitignano	Collenoveri	5
AP	Ascoli Piceno	Mozzano	5	AQ	Capitignano	Pago	5
AP	Acquasanta T.	Arli	5	AQ	Capitignano	Paterno	5
AP	Acquasanta T.	Centrale	5	AQ	Capitignano	Sivignano	5
AP	Acquasanta T.	Corneto	5	AQ	Montereale	Casale Bottone	5
AP	Acquasanta T.	Novele	5	AQ	Montereale	Castiglione	5
AP	Acquasanta T.	Paggese	5	AQ	Montereale	Cesaproba	5
AP	Acquasanta T.	Ponte d'Arli	5	AQ	Montereale	Cesariano	5
AP	Acquasanta T.	Quintodecimo	5	AQ	Montereale	Lonaro	5
AP	Acquasanta T.	San Martino	5	AQ	Montereale	Marana	5
AP	Acquasanta T.	Santa Maria	5	AQ	Montereale	Montereale	5
AP	Montegallo	Forca	5	AQ	Montereale	Piedicolle	5
AP	Montemonaco	Montemonaco	5	AQ	Montereale	San Vito	5
AP	Montemonaco	Pignotti	5	AQ	Montereale	Santa Vittoria	5
AP	Montemonaco	Rocca	5	AQ	Montereale	Verrico	5
AP	Montemonaco	San Giorgio Isola	5	AQ	Montereale	Ville	5
AP	Roccafluvione	Roccafluvione	5	TE	Cortino	Cortino	5
MC	Caldarola	Caldarola	5	TE	Crognaleto	Alvi	5
MC	Camerino	Camerino	5	TE	Crognaleto	Cesacastina	5
MC	Camerino	San Luca	5	TE	Crognaleto	Crognaleto	5
MC	Camerino	San Marcello	5	TE	Crognaleto	Nerito	5
MC	Castelsantangelo	Gualdo	5	TE	Crognaleto	Poggio U.	5
MC	Gualdo	Gualdo	5	TE	Crognaleto	San Giorgio	5
MC	Muccia	Muccia	5	TE	Crognaleto	Tottea	5
MC	Pieve Torina	Apennino	5	TE	Valle Castellana	Ceraso	5
MC	Pieve Torina	Capriglia	5	TE	Valle Castellana	Cerquito	5
MC	Pieve Torina	Pieve Torina	5	TE	Valle Castellana	Morrice	5
MC	Pievebovigliana	Pievebovigliana	5	TE	Valle Castellana	Pascellata	5
MC	Ripe S. Ginesio	Ripe S. Ginesio	5	TE	Valle Castellana	Pietralta	5
MC	San Ginesio	San Ginesio	5	TE	Valle Castellana	San Vito	5
MC	Ussita	Calcara	5	TE	Valle Castellana	Valle Castellana	5
MC	Ussita	Cuore di Sorbo	5	AP	Ascoli Piceno	Ascoli Piceno	4-5
MC	Ussita	Frontignano	5	AP	Ascoli Piceno	Casette	4-5
MC	Visso	Borgo S. Antonio	5	AP	Venarotta	Venarotta	4-5
AQ	Campotosto	Campotosto	5	MC	Belforte	Belforte	4-5
AQ	Campotosto	Ortolano	5	MC	Muccia	Maddalena	4-5

(*) Districts: Rieti (RI), Perugia (PG), Ascoli Piceno (AP), Fermo (FM), Macerata (MC), Aquila (AQ), Teramo (TE).

was to define the most reliable EMS98 vulnerability class, for properly derive the I_{EMS} degree. A review of the local strengthening techniques suggested to adopt, in such cases, a vulnerability class D for masonry structures. Unreinforced buildings, if present, were also considered in these localities to check the reliability of the assigned intensity value.

IV. CONCLUSIONS

Results of a macroseismic survey performed in the area struck by the August 24, 2016 Amatrice sequence were presented. A total number of 180 sites were surveyed and for each of them a I_{EMS} value was defined. According to the results shown in this work, it can be concluded that site effects

Figure 2: *Diffused collapses in Amatrice (left) and aerial view of Pescara del Tronto (right, retrieved on www.meteoweb.eu).*

significantly influenced the 2016 Central Italy sequence. Additionally, a key aspect of this work related the evaluation of the effects induced by the analyzed earthquake to pre-damaged and seismically retrofitted residential buildings, for a proper derivation of the a I_{EMS} value. Finally, a preliminary analysis based on statistical inference of the EMS intensities assessed was performed, evidencing how the macroseismic epicenter seems located 4 km southeastwards with respect to the instrumental one.

REFERENCES

Castelli, V. (2013). Revisione delle conoscenze sui terremoti del 1558 (Valdambra), 1561 (Campania-Basilicata), 1639 (Amatriciano) e 1747 (Nocera Umbra – Gualdo Tadino). Rapporto tecnico INGV-MI, Milano, 16 pp.

Grünthal, G., ed. (1998). European Macroseismic Scale 1998 (EMS-98). European Seismological Commission, Subcommission on Engineering Seismology, Working Group Macroseismic Scales. Conseil de l'Europe, Cahiers du Centre Européen de Gèodynamique et de Sèismologie, 15, Luxembourg, 99 pp.

Guidoboni, E., G. Ferrari, D. Mariotti, A. Comastri, G. Tarabusi and G. Valensise (2007) CFTI4Med, Catalogue of Strong Earthquakes in Italy (461 B.C. – 1997) and Mediterranean Area (760 B.C. – 1500). INGV-SGA. http://storing.ingv.it/cfti4med.

ISIDe Working Group (INGV) (2016). Italian seismological instrumental and parametric database: http://iside.rm.ingv.it, DOI: 10.13127/ISIDe, last accessed September 2016.

Rovida, A., M. Locati, R. Camassi, B. Lolli, P. Gasparini, eds. (2016). CPTI15, the 2015 version of the Parametric Catalogue of Italian Earthquakes. Istituto Nazionale di Geofisica e Vulcanologia. doi:http://doi.org/ 10.6092/ INGV.IT-CPTI15.

Tertulliani, A., F. Galadini, F. Mastino, A. Rossi and M. Vecchi (2006) Studio macrosismico del terremoto del Gran Sasso (Italia Centrale) del 5 settembre 1950: implicazioni sismotettoniche. Il Quaternario, 19, 2: 195-214.