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Observed damage database of past Italian earthquakes: the Da.D.O. WebGIS

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ABSTRACT Following major seismic events occurred in Italy over the last 50 years, a notable amount of data relevant to post-earthquake damage of ordinary buildings was collected. These data today represent an inestimable scientific heritage, useful for prevision and prevention purposes, including calibration of vulnerability models for seismic risk assessment and formulation of damage scenarios. However, the data sets resulting from different inspection tools developed over the years are not immediately comparable with each other. The need for enhancing the reliability of prevention models and more effectively support strategic decision-making has moved the Italian Civil Protection Department to undertake, since 2014, a specific project with this ambitious goal. Developed with the technological support of Eucentre Foundation, the web-gis platform, named Da.D.O. (Observed Damage Database), is meant to store and to share data from large post-earthquake damage campaigns occurred in the past. Da.D.O. is addressed to Civil Protection Department users, members of the scientific community and Regions, though its access could be further extended in the future to other stakeholders. The paper describes goals, contents and capabilities of the IT platform, which, at present, includes data sets relevant to nine seismic events (or sequences) occurred from 1976 (Friuli earthquake) to 2012 (Emilia-Romagna earthquake).

Key words: database, observed damage, damage surveys, seismic vulnerability.

1. Introduction

Over the last ten years, the Civil Protection Department (DPC) strongly supported seismic risk mitigation strategies, by underpinning prevision and prevention activities. The latter ones consist of structural interventions and non-structural activities, mostly relying upon knowledge improvement as a result of applied scientific research (Dolce, 2012a). More recently, the role of the scientific community within the frame of the Civil Protection National Service was strongly emphasized by the new Civil Protection Code, issued on January 2018 (Decree Law 2/1/2018, 2018), stressing the importance of the scientific world and relevant research work through different forms of participation (art. 19).

In fact, enhancement in scientific knowledge can reduce uncertainties in risk scenario modelling, so as to produce more reliable results and then support more effectively Civil Protection decision makers, at any territorial and administrative level. In this regard, past historical data represent a very important driver to increase knowledge among members of scientific community, as well as awareness among stakeholders, by means of data sharing.

Italy is a seismic prone country affected, over the last 50 years, by several events with magnitude between 5.5 and 6.9, causing monetary losses for over € 150 billion, due to recovery and reconstruction costs (Dolce, 2012a). This amount sensibly increases when considering the latest earthquakes following 2012.

From the Friuli 1976 onwards, the post-earthquake damage survey to ordinary buildings became a crucial need for the emergency management and following recovery phase. Since then, visual inspection methods, relying on specific operational tools, were subjected to several changes and upgrades, in accordance with the different uses of the surveys' outcomes and the growth of the technical and scientific knowledge in the field of seismic vulnerability and damage recognition of existing buildings. The AeDES survey form was early introduced in 1997 and, since 2002, it has become the official operational tool recognized by the DPC for the technical management of emergencies (Baggio *et al.*, 2002; Dolce *et al.*, 2014).

The huge amount of data collected since 1976, in past domestic emergencies, represents today an inestimable heritage decisive for increasing the capability of seismic risk models and make, in the end, their assessments more reliable. As a matter of fact, the likelihood of damage levels conditional to specific building types, analysed for each homogenous intensity of the shaking, enables the formulation and validation of damage models, such as damage probability matrices or observational fragility curves, largely used for loss scenarios and risk analyses since the 1980s.

Nevertheless, the lack of uniformity among different emergency campaigns hindered in the past the unification of all this information into a single data set. Given the important dissimilarities among them, in terms of amount and type of stored records, data sets were rather developed and analysed independently from each other. Examples are either provided by the Fr.E.D. database, specifically tailored to Friuli post-earthquake campaign (Di Cecca and Grimaz, 2008) or by the database obtained after the 1980 Irpinia earthquake. In the latter case, the large post-earthquake damage investigation carried out on almost 40,000 buildings, brought about the formulation of early damage probability matrices relevant to the Italian building stock (Braga *et al.*, 1982, 1983).

On the other hand, the difficulties in merging and comparing different informative formats resulting from previous post event campaigns were discussed in occasion of specific panels and applied researches coordinated by the Italian DPC (see e.g. CTS-DPC, 2002; Goretti *et al.*, 2008).

More recently, in 2014, the DPC promoted a new project specifically dedicated to the scientific community and to relevant stakeholders involved in civil protection research. The final goal was to create a solid and common ground, relying on data sharing, with the final purpose to strengthen seismic risk scenario modelling and enhancing their reliability. The project is leaded by the DPC with the support of Eucentre Foundation (European Centre for Training and Research in Earthquake Engineering) who developed a specific IT platform, accessible via web.

The Da.D.O. (Observed Damage Database) web-gis platform was conceived with the specific purpose to collect, catalogue, and compare data relevant to damage and structural characteristics of buildings inspected after severe earthquakes occurred in Italy from the Friuli 1976 earthquake to Emilia-Romagna 2012 event.

Compared to other international IT platforms with similar purpose, such as the one developed by the University of Cambridge (Cambridge Architectural Research Ltd, 2009) and further implemented into the Consequences Database World Map provided by the Global Earthquake Model (GEM), Da.D.O. provides a much higher level of detail of data sets, though for Italian earthquakes only. In fact, the information displayed by Da.D.O., rather than being clustered and pre-elaborated in terms of damage likelihood, is completely disaggregated, meaning that records point out georeferenced buildings, leaving the user free to customize his or her own analyses (Dolce *et al.*, 2017).

The paper describes the process according to which the different databases have been analysed, decoded from the original formats, in order to enhance their general understanding and mutual comparability. Moreover, it describes some elaborations aimed at comparing and unifying the different data sets, by formulating common metrics for seismic vulnerability classes and damage levels.

2. Contents and purposes of Da.D.O. data sets

2.1. General contents of Da.D.O.

Nine databases related to the following national seismic events are so far stored in Da.D.O.: Friuli 1976, Irpinia 1980, Abruzzo 1984, Umbria and Marche 1997, Pollino 1998, Molise and Puglia 2002, Emilia-Romagna 2003, L'Aquila 2009, and Emilia-Romagna 2012.

In terms of records processed, Da.D.O. includes in total more than 300,000 items, distributed among the above data sets, as shown in Table 1. The table specifies for each event, the year of occurrence, the number of records and the survey-form used. Fig. 1a outlines the percentage distribution of the nine data sets over the total amount of records. One can note that L'Aquila 2009, relevant to the sequence started in the Abruzzo region on 6 April 2009, is the largest data set, representing around 23% of the entire record population of Da.D.O., followed by Abruzzo 1984 (16%), Umbria and Marche 1997 (15%), and Friuli 1976 (13%). It is worth noticing that in case of the Umbria and Marche 1997 earthquake, data so far stored in Da.D.O. are those relevant to Marche region, while those relative to Umbria are not available at present. This is because the technical emergency at that time was carried out in the two regions according to two different inspection tools, with AeDES in Marche only, resulting in two independent data sets at the end of the emergency state. This is a clear example of the importance of a unified inspection tool and storage system, such as Da.D.O. is meant to be. Fig. 1b shows that records compliant to AeDES forms represent around 58% of the total amount of records, whilst the complementary percentage is characterized by databases using different survey-formats. These dissimilarities among data sets make their mutual comparability very complex and their total merge not feasible.

Each database can be displayed and downloaded by the user on a double version: the original version and a decoded version. While the former is the original release without any further manipulation, the latter has been obtained by converting the former into a more understandable and comparable version, on corresponding fields. In other words, information common to different data sets were decoded according to homogeneous labels, according to the criterion described in section 2.3.

Finally, for each database it is also possible to display and download a pdf version of the original inspection forms, listed on the last column of Table 1.

Table 1 - List of events and related data sets provided by Da.D.O., number of records and inspection forms associated.

Event	Year	N. of records	Survey form
Friuli 1976	1976	41,852	Friuli 1976
Irpinia 1980	1980	38,079	Irpinia 1980
Abruzzo 1984	1984	51,817	Abruzzo 1984
Umbria - Marche 1997*	1997	48,525	AeDES 09/1997
Pollino 1998	1998	17,442	AeDES 06/1998
Molise - Puglia 2002	2002	24,141	AeDES 05/2000
Emilia-Romagna 2003	2003	1,011	AeDES 05/2000
L'Aquila 2009	2009	74,049	AeDES 06/2008
Emilia-Romagna 2012	2012	22,554	AeDES 06/2008
Total		**319,470**	

*For the seismic event Umbria and Marche 1997, the available data refer to the region of Marche where the AeDES form was used.

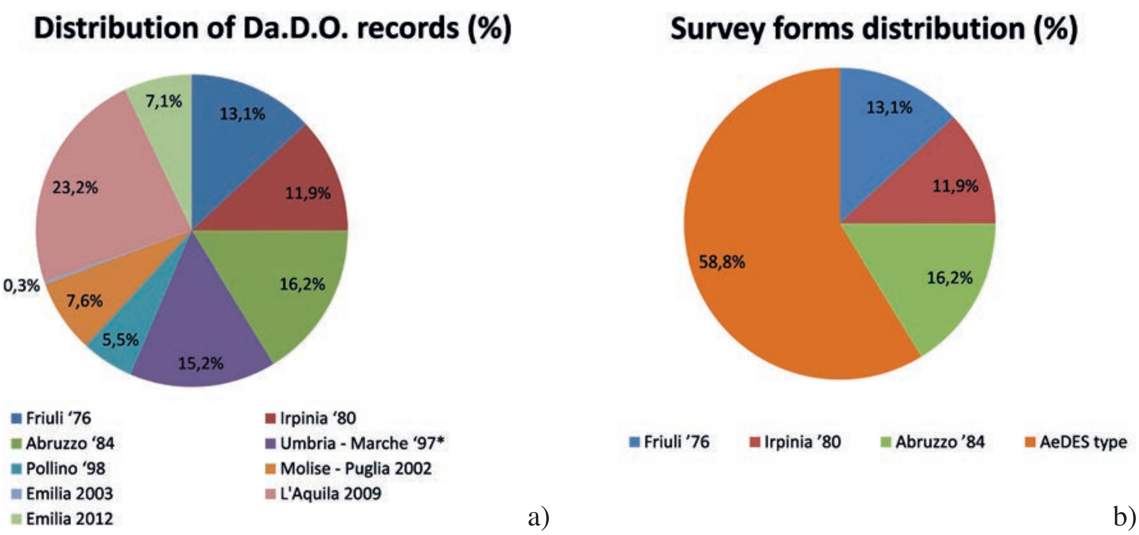


Fig. 1 - Distribution of Da.D.O. data sets (a) and related survey form used (b).

It is worth noticing that in both the database formats (original and decoded) any information considered misleading or unnecessary with respect to the final tasks of Da.D.O. was removed. First, information related to property or household identification was deleted in order to preserve personal data. Moreover, usability classification (defined as final judgment determining whether, following a seismic event, buildings affected by the earthquake can still be used with a reasonable level of life safety) was also removed at this stage, so as to let the user focus the attention on vulnerability and damage only, being usability classification provided just in few data sets, as outlined in section 2.2.

Moreover, records stored in the IT platform for each seismic event are all geo-referenced on a map in order to ensure their overlap with other data sources, such as characteristics of the seismic event and macroseismic intensity field. Fig. 2 shows the localizations of all the records related to the nine data sets so far processed by Da.D.O.

Note that the semi-automatic geo-referencing procedure, mostly relying on building addresses, is being associated to a given uncertainty rate of around 5-10%. This rate depends on several factors such as incomplete or mistaken addresses, shortcoming in the road graphs (of addresses), which hinder the precise identification of elements on the map. When the geo-decoding process completely fails, the marker is being positioned in the municipal geometric centre of the municipality. This accuracy level is, however, fairly satisfactory for the scientific purposes of the IT platform and at the same time it guarantees the protection of personal data, in compliance with Italian personal data regulations (Legislative Decree n. 196 20 June 2003, 2003).

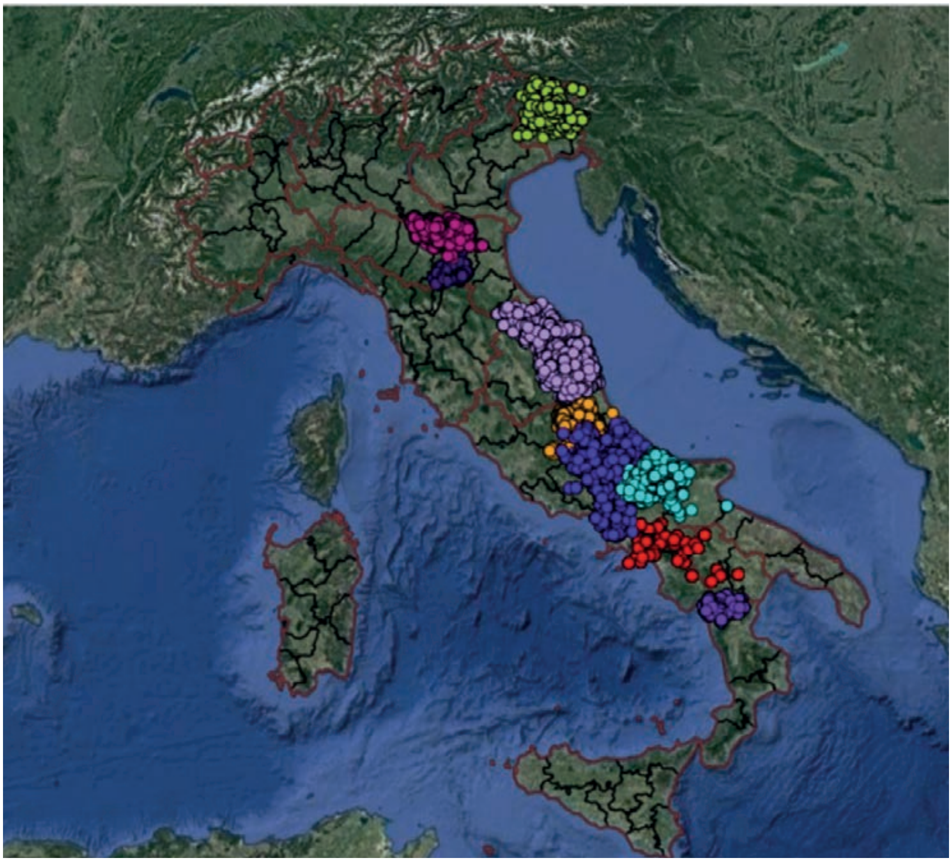


Fig. 2 - Localization map of all records relevant to the nine data sets of Da.D.O.

In case of seismic events characterized by several shocks or a seismic sequence, available records are those referred to the main event that triggered the emergency state, so that damage recorded could include also the effects of the aftershocks. Moreover, in case the building was subjected to more subsequent inspections, because of some increase of the damage, the most recent inspection is the one by default released by Da.D.O.. Consequently, information related to previous inspections on the same buildings are not recorded in the IT platform.

2.2. Operational inspection tools used in past seismic emergencies

From the seismic event of Friuli 1976 to the Emilia-Romagna 2012 one, over the years, post-earthquake survey methods have been developing on the basis of previous experience, civil protection targets and gradual upgrade of technical and scientific knowledge in the field of seismic vulnerability and damage recognition.

The final goal of the surveys was also subjected to sensible changes through the years: while the former inspections were aimed to investigate vulnerability and damage to buildings, subsequent ones, stemmed by early AeDES forms, were more specifically purposed to human life safeguard and hence focused on usability evaluation. This view is closest to post-earthquake international approaches (for an international review see www.world-housing.net/post-earthquake-building-damage-assessment-project), although, compared to these, Italian survey forms have been preserving attention to geometrical and structural features of buildings, namely seismic vulnerability, as fundamental cues enabling economical loss estimates and statistical elaborations.

At the same time, the definition of the physical object of the survey, i.e. the building, has been subjected to progressive specification. The building is today assumed as a minimal structural sky-ground unit, distinguishable from the adjacent ones for constructive techniques as well as geometrical features (Baggio *et al*., 2002; Dolce *et al*., 2014).

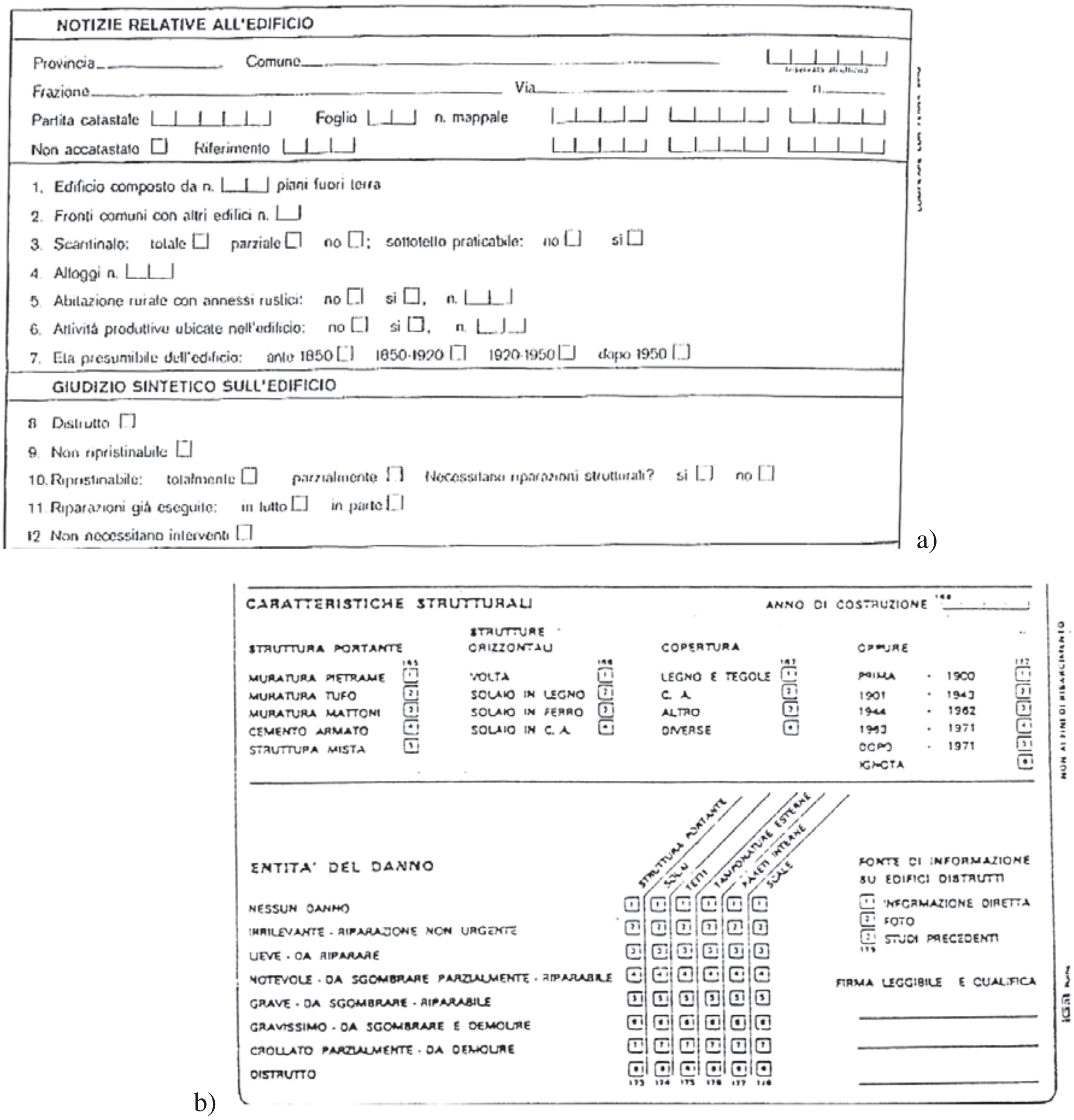
A brief review of the Italian post-earthquake survey forms can be helpful to better understand the differences among relative data sets.

Going back to the dramatic impact in terms of losses (around 1,000 victims and more than 100,000 homeless) of the 1976 event ($M_W = 6.5$), the Friuli-Venezia Giulia Region developed a simplified assessment report in order to detect structural damage to buildings. Damage was described through synthetic judgments referring to the building reparability, for a total of six distinct levels of judgments corresponding to specific cases [i.e. from “the building does not need any structural interventions” (NR) to “destroyed” (D)]. Construction period and structural classification of the building (Fig. 3a) completed its description (Giorgetti, 1976; Riuscetti *et al*., 1997).

Four years later, on 23 November 1980, Irpinia, in southern Italy, was stricken by a violent earthquake with magnitude 6.9 M_W, causing around 2,700 victims, 8,900 injured, and 280,000 homeless (Annuario Statistico Corpo Nazionale Vigili Fuoco, 1980). The damage inspection procedure used in that occasion introduced several elements of difference compared to the previous form. In particular, the damage was expressed in terms of damage levels quantitatively described in a field manual, rather than on descriptive judgements, and was detailed for each structural component of the building (Fig. 3b). Such information, relevant to all the buildings of 41 municipalities subjected to different macroseismic intensities, enabled the formulation of the first Italian Damage Probability Matrices (DPM) relative to the Italian building stock, still today representing a fundamental reference for risk scenarios modelling (Braga *et al*., 1982; Dolce, 1984).

Further post-earthquake surveys, including the one after the Abruzzo 1984 earthquake, were mostly focused on the assessment of the seismic vulnerability, as issued by the first level inspection form released by the National Group for the Defence against Earthquakes (GNDT), supporting in the 1980s scientific research in the field of civil protection (GNDT, Regione Emilia Romagna and Regione Toscana, 1986; GNDT, 1993).

The occurrence of the Umbria and Marche earthquake on 26 September 1997, speeded up the adoption of a new operational tool for ordinary buildings, more detailed in the damage assessment, and targeted to post-earthquake usability and short term countermeasures. A preliminary draft of the AeDES survey form (AeDES 09/97) was used in the Marche region during the earthquake emergency of 1997. As previously mentioned, the Umbria Region used in that occasion a different form. Since then, the AeDES survey form was adopted with minor changes in the subsequent seismic events which struck Italy, such as Pollino in September 1998 (AeDES 06/98), Patti and in the Frignano area in 1999, and Monti Tiburtini in 2000 (Baggio *et al.*, 2007). It was, then, adapted after the 2002 Santa Venerina and San Giuliano seismic events (AeDES 05/2000), and the same form was used following Emilia-Romagna earthquake in 2003. Further updates were carried out for the L'Aquila 2009 earthquake (AeDES 06/2008), while the same survey form was


NOTIZIE RELATIVE ALL'EDIFICIO

Provincia ____ Comune ____

Frazione ____ Via ____ n. ____

Partita catastale Foglio n. mappale

Non accatastato Riferimento

1. Edificio composto da n. piani fuori terra
2. Fronti comuni con altri edifici n.
3. Scantinato: totale parziale no ; sottotetto praticabile: no si
4. Alloggi n.
5. Abitazione rurale con annessi rustici: no si , n.
6. Attività produttive ubicate nell'edificio: no si , n.
7. Età presumibile dell'edificio: ante 1850 1850-1920 1920-1950 dopo 1950

GIUDIZIO SINTETICO SULL'EDIFICIO

8. Distrutto
9. Non ripristinabile
10. Ripristinabile: totalmente parzialmente Necessitano riparazioni strutturali? si no
11. Riparazioni già eseguite: in tutto in parte
12. Non necessitano interventi

a)

CARATTERISTICHE STRUTTURALI ANNO DI COSTRUZIONE

STRUTTURA PORTANTE	STRUTTURE ORIZZONTALI	COPERTURA	OPPURE
MURATURA PIETRAME 1	VOLTA 1	LEGNO E TEGOLE 1	PRIMA - 1900 1
MURATURA TUFO 2	SOLAIO IN LEGNO 2	C. A. 2	1901 - 1943 2
MURATURA MATTONI 3	SOLAIO IN FERRO 3	ALTRO 3	1944 - 1962 3
CEMENTO ARMATO 4	SOLAIO IN C. A. 4	DIVERSE 4	1963 - 1971 4
STRUTTURA MISTA 5			DOPO - 1971 5
			IGNOTA 6

ENTITA' DEL DANNO (STRUTTURA PORTANTE, SOLAI, TETTI, TAMPONATURE ESTERNE, PARETI INTERNE, SCALE)

NESSUN DANNO 1
IRRILEVANTE - RIPARAZIONE NON URGENTE 2
LIEVE - DA RIPARARE 3
NOTEVOLE - DA SGOMBRARE PARZIALMENTE - RIPARABILE 4
GRAVE - DA SGOMBRARE - RIPARABILE 5
GRAVISSIMO - DA SGOMBRARE E DEMOLIRE 6
CROLLATO PARZIALMENTE - DA DEMOLIRE 7
DISTRUTTO 8

FONTE DI INFORMAZIONE SU EDIFICI DISTRUTTI
1 INFORMAZIONE DIRETTA
2 FOTO
3 STUDI PRECEDENTI

FIRMA LEGGIBILE E QUALIFICA

b)

Fig. 3 - Building identification and damage inspection form used for Friuli 1976 (a) and Irpinia 1980 (b) earthquakes: sections related to damage description.

SEZIONE 2 - Descrizione edificio

Dati metrici			Età	Uso - Esposizione			
Superficie media di piano		*N° Piani*	*Costruzione e ristrutturazione*	*Uso*	*N° unità d'uso*	*Utilizzazione*	*Occupanti*
A ○ ≤ 50 m²	H ○ 800÷1000	○ 1 ○ 6	1 ○ ≤ 1919	A ○ Abitativo	1 ○ 1 ÷ 2	A ○ > 75%	1 ○ ≤ 10
B ○ 50 ÷ 100	I ○ > 1000	○ 2 ○ 7	2 ○ 19 - 45	B ○ Produttiva	2 ○ 3 ÷ 4	B ○ 10 ÷ 75%	2 ○ 11 ÷ 50
C ○ 100 ÷ 200		○ 3 ○ 8	3 ○ 46 ÷60	C ○ Commercio	3 ○ 5 ÷ 8	C ○ < 10%	3 ○ 51 ÷ 100
D ○ 200 ÷ 300		○ 4 ○ 9	4 ○ 61 ÷ 71	D ○ Uffici	4 ○ 9 ÷ 15	D ○ In costruzione	4 ○ ≥ 100
E ○ 300 ÷ 400		○ 5 ○ ≥10	5 ○ 72 ÷ 81	E ○ Serv. Pubb.	5 ○ 16 ÷ 30	E ○ Non finito	*Proprietà*
F ○ 400 ÷ 600	*Piani interrati*	A ○ Si	6 ○ 82 ÷ 91	F ○ Deposito	6 ○ > 30	F ○ Abbandonato	A ○ Pubblica
G ○ 600 ÷ 800		B ○ No	7 ○ > 91	G ○ Strategico			B ○ Privata

Istat Regione	Istat Prov. |__|__|__|	Istat Comune	Squadra / rilevat. |__|__|	N° scheda |__|__|__|__|__|

SEZIONE 3 - Tipologia (multiscelta[1])

Strutture verticali / Strutture orizzontali	Muratura					Cemento armato			
	Tessitura irregol. e cattiva qualità		Tessitura regol. e buona qualità						
	Pietrame, ciottoli... senza catene o cordoli	Pietrame, ciottoli... con catene o cordoli	Blocchi, mattoni, pietre squadrate senza catene o cordoli	Blocchi, mattoni, pietre squadrate con catene o cordoli	Pilastri isolati	Strutt. intelaiata con piano non tamponato	Strutt. intelaiata con piani tutti tamponati	Acciao	Non identificate
	A	B	C	D	E	F	G	H	I
1 Volte in muratura	○	○	○	○	SI				○
2 In legno	○	○	○	○	○				○
3 Acciaio voltine	○	○	○	○				○	○
4 Acciaio tavelloni	○	○	○	○				○	○
5 In c.a.	○	○	○	○	NO	○	○	○	○
6 Non identificate	○	○	○	○	○	○	○	○	○

(1- multiscelta: sono ammesse più scelte. Le caselle più evidenziate indicano situazioni peggiori)

Classificazione EMS-95

		TIPO DI STRUTTURA	CLASSI DI VULNERABILITA'						CLASSI DI DANNO				
			A	B	C	D	E	F	1	2	3	4	5
1	MURATURA	Pietrame irregolare	○										
2		Mattoni crudi o forati	○	--|									
3		Pietra regolare	|—	○									
4		Pietra squadrata		|—	○	--|							
5		cls	|—	○	--|								
6		Mattoni con solai in c.a.		|—	○								
7		Muratura confinata			|--	○	—	—|					
8	C.A.	Non antisismica	|--	—	○	—|							
9		Con norme della categ. 3		|--	—	○							
10		Con norme della categ. 2			|--	—	○						
11		Con norme della categ. 1					|—	○					
12		Legno		|--	—	○	—	—|					

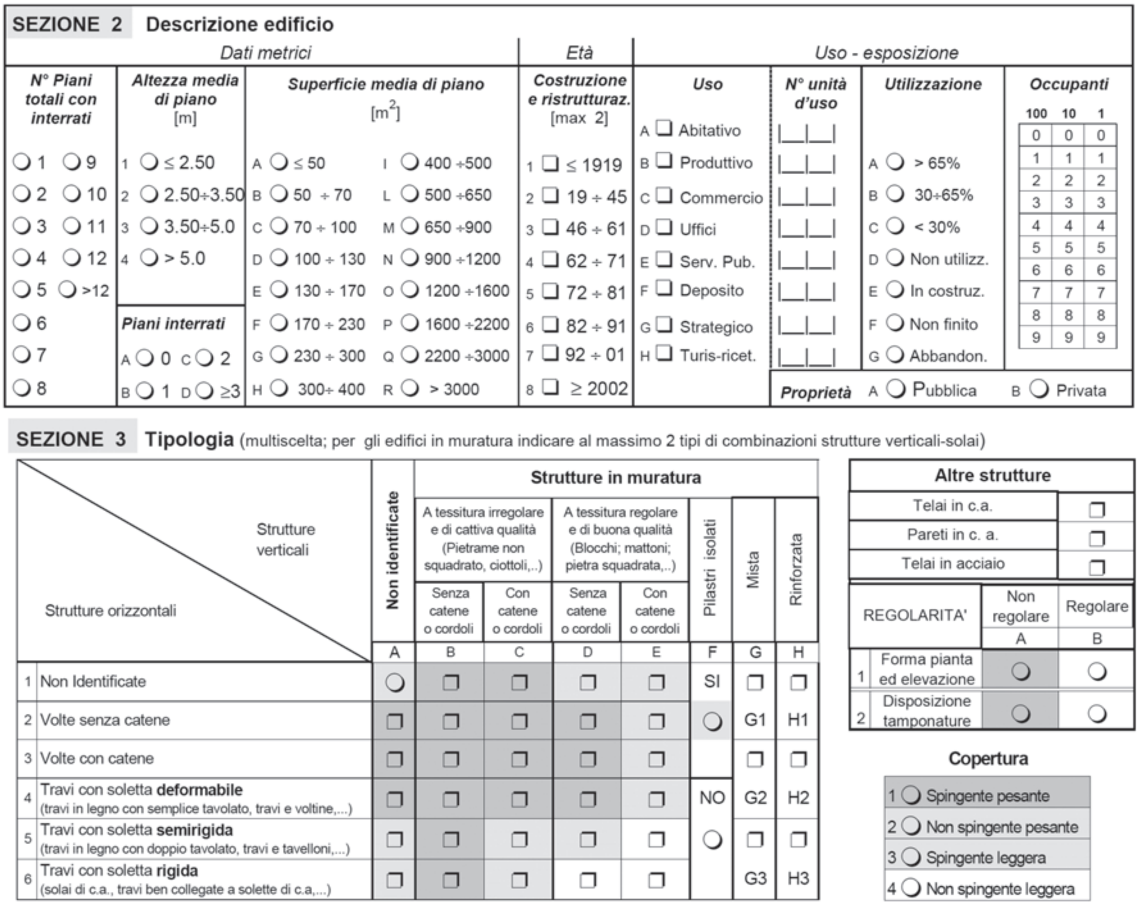
○ = Classe più verosimile
— = fascia probabile
--- = fascia meno probabile

Fig. 4 - Sections 2 and 3 of AeDES form used for Umbria and Marche 1997 earthquake (AeDES 09/97).

handled in 2012 for Emilia-Romagna seismic event. Major upgrades concerned sections 2 and 3 of the form, both relative to building geometry and structural characteristics (Figs. 4 and 5).

The AeDES 07/2013 is today the latest version which was also adopted for the recent seismic events occurred in central Italy starting from 24 August 2016 (http://www.protezionecivile.gov.it/resources/cms/documents/Scheda_AEDES.pdf) and in Ischia in August 2017.

An innovative approach introduced by AeDES concerns the way of classifying constructive and structural features of buildings (section 3), so as to identify their seismic vulnerability. In previous survey forms this task was achieved through a very detailed and time consuming identification process of all possible structural types, according to a descriptive approach. That means that the surveyor was required to find out which structural feature, among those listed in the form, was closest to the one observed in the building. However, this method showed significant limits when applied to situations different from the referenced one. As consequence, AeDES uses a different approach commonly defined as behavioural. In this case the surveyor is required to assess the expected performance of the structural features in terms of seismic response, implying that rather than being simply an observer he operates as evaluator. This radical change is one of the reasons hindering a straight comparison between pre-AeDES and post-AeDES data sets (Baggio *et al.*, 2002, 2007; Dolce *et al.*, 2014).



SEZIONE 2 Descrizione edificio

Dati metrici				Età	Uso - esposizione			
N° Piani totali con interrati	Altezza media di piano [m]	Superficie media di piano [m²]		Costruzione e ristrutturaz. [max 2]	Uso	N° unità d'uso	Utilizzazione	Occupanti (100 10 1)
1 / 9	1 ≤ 2.50	A ≤ 50	I 400 ÷500	1 ≤ 1919	A Abitativo	|__|__|	A > 65%	0 0 0
2 / 10	2 2.50÷3.50	B 50 ÷ 70	L 500 ÷650	2 19 ÷ 45	B Produttivo	|__|__|	B 30÷65%	1 1 1
3 / 11	3 3.50÷5.0	C 70 ÷ 100	M 650 ÷900	3 46 ÷ 61	C Commercio	|__|__|	C < 30%	2 2 2
4 / 12	4 > 5.0	D 100 ÷ 130	N 900 ÷1200	4 62 ÷ 71	D Uffici	|__|__|	D Non utilizz.	3 3 3
5 / >12		E 130 ÷ 170	O 1200 ÷1600	5 72 ÷ 81	E Serv. Pub.	|__|__|	E In costruz.	4 4 4
6	Piani interrati	F 170 ÷ 230	P 1600 ÷2200	6 82 ÷ 91	F Deposito	|__|__|	F Non finito	5 5 5
7	A 0 C 2	G 230 ÷ 300	Q 2200 ÷3000	7 92 ÷ 01	G Strategico	|__|__|	G Abbandon.	6 6 6
8	B 1 D ≥3	H 300÷ 400	R > 3000	8 ≥ 2002	H Turis-ricet.	|__|__|		7 7 7 / 8 8 8 / 9 9 9
						Proprietà	A Pubblica	B Privata

SEZIONE 3 Tipologia (multiscelta; per gli edifici in muratura indicare al massimo 2 tipi di combinazioni strutture verticali-solai)

Strutture orizzontali \ Strutture verticali	Non identificate	Strutture in muratura: A tessitura irregolare e di cattiva qualità (Pietrame non squadrato, ciottoli,..) – Senza catene o cordoli	A tessitura irregolare – Con catene o cordoli	A tessitura regolare e di buona qualità (Blocchi; mattoni; pietra squadrata,..) – Senza catene o cordoli	A tessitura regolare – Con catene o cordoli	Pilastri isolati	Mista	Rinforzata
	A	B	C	D	E	F	G	H
1 Non Identificate	○	❐	❐	❐	❐	SI	❐	❐
2 Volte senza catene	❐	❐	❐	❐	❐	○	G1	H1
3 Volte con catene	❐	❐	❐	❐	❐		❐	❐
4 Travi con soletta **deformabile** (travi in legno con semplice tavolato, travi e voltine,...)	❐	❐	❐	❐	❐	NO	G2	H2
5 Travi con soletta **semirigida** (travi in legno con doppio tavolato, travi e tavelloni,...)	❐	❐	❐	❐	❐	○	❐	❐
6 Travi con soletta **rigida** (solai di c.a., travi ben collegate a solette di c.a,...)	❐	❐	❐	❐	❐		G3	H3

Altre strutture	
Telai in c.a.	❐
Pareti in c. a.	❐
Telai in acciaio	❐

REGOLARITA'	Non regolare (A)	Regolare (B)
1 Forma pianta ed elevazione	○	○
2 Disposizione tamponature	○	○

Copertura

1 Spingente pesante
2 Non spingente pesante
3 Spingente leggera
4 Non spingente leggera

Fig. 5 - Sections 2 and 3 of AeDES form used for Molise and Puglia 2002 earthquake (AeDES 05/2000).

2.3. Data decoding and georeference

Significant dissimilarities among survey forms and relevant data sets are the main causes hindering the development of a unique database. This limitation brought about the need for enforcing, as much as possible, the comparability among databases.

Once non-pertinent pieces of information, such as personal data, were removed and manifest errors corrected, the further step was data decoding. First, corresponding fields were recognized in each database (i.e. number of storeys). Then, these were all decoded according to homogeneous labels, leaving unchanged numerical intervals associated to each of them. To make an example "brick masonry", one of the possible features associated to vertical structures, is labelled in original data sets in different ways: in the Irpinia one it is identified by number "3", in Friuli by label "LAT". The decoded format of this information is in both cases "brick masonry". In addition, decoded format includes the outcome of matrices (like section 3 of AeDES form) to be determined, avoiding repetition of "False" and "True" in the same row for all the existing matches of the matrix.

In this way, all common records have been made more recognizable, understandable and mutually comparable among different data sets. Furthermore, a re-organization of data order was carried out in order to store and display information in a more functional and homogenous way.

In particular, all information of each database was grouped in four macro sections (Identifiers, General characteristics, Building type, Damage levels) to make their interpretation easier when querying single records on the map. Despite the efforts, the articulation of each section presents significant variations between a database and another, not solely in terms of data ranges (i.e. possible intervals associated with number of storeys), but also in terms of existence itself of specific fields.

Table 2 provides an example relevant to macro section "General Characteristics". One can note important differences among contents of data sets under exam. While the number of floors is common to all of them, the inter-storey height is available just for AeDES survey forms.

Information concerning the structural characteristics, associated with "Building type" macro-section, presents even more dissimilarities. This is partially due to the above mentioned changeover from a descriptive to a behavioural approach, when passing from pre-AeDES form formats to AeDES ones (Baggio *et al*., 2002, 2007; Dolce *et al*., 2014). In fact, older data sets, rather than providing the structural performance (e.g. bad or good quality of masonry structures), provide detailed descriptive features (e.g. rubble masonry, ashlars, bricks). Consequently, the transformations of the latter information into the former is not always straightforward and require specific assumptions.

Table 2 - Comparison among all information contained in the macro section "General Characteristics".

Event	Number of Floors	Inter-storey Height	Floor Area	Construction age (C)/ Restructuring (R)
Friuli 1976	Yes	No	No	C
Irpinia 1980	Yes	No	Yes	C
Abruzzo 1984	Yes	No	Yes	C
Umbria - Marche 1997*	Yes	No	Yes	C/R
Pollino 1998	Yes	Yes	Yes	C/R
Molise - Puglia 2002	Yes	Yes	Yes	C/R
Emilia-Romagna 2003	Yes	Yes	Yes	C/R
L'Aquila 2009	Yes	Yes	Yes	C/R
Emilia-Romagna 2012	Yes	Yes	Yes	C/R

Table 3 shows a comparison across all data sets in terms of structural types. It is worth noticing that besides vertical and horizontal structures, some differences come out from "Type of roof" and "Construction details". The four roof types shown in the fourth column of the table come out from the 2×2 possible combinations resulting by matching roof weight (light/heavy) with thrusting effects (thrust / no thrust). However this information is missing in 3 out of 9 data sets, including Umbria and Marche.

Similarly, additional construction details (right column of Table 2) is just available in latest databases, including items such as structural strengthening's [Ring-beams or Tie roads (RB)], presence of Isolated Columns (Pi), Regularity (Reg), Mixed Structures (Mix), and localized reinforcements (Rinf).

Vertical structures are summarized in Table 4. Clearly, there is no straight correspondence from one database to another, except for Pollino and subsequent ones, including up to seven

Table 3 - Comparison among all information contained in the macro section "Building" type (Construction details: RB = Ring-beams or Tie roads, Pi = presence of Isolated Columns, Reg = Regularity, Mix = Mixed structures, Rinf = localized Reinforcements).

Event	Vertical Structure	Horizontal Structure	Type of Roof	Construction Details
Friuli 1976	4 Types	No	No	No
Irpinia 1980	5 Types	4 Types	4 Types	No
Abruzzo 1984	4 Types	4 Types	No	No
Umbria - Marche 1997*	4 Types	5 Types	No	RB, Pi, Reg
Pollino 1998	7 Types	5 Types	4 Types	RB, Pi, Reg, Mix
Molise - Puglia 2002	7 Types	5 Types	4 Types	RB, Pi, Reg, Rinf, Mix
Emilia-Romagna 2003	7 Types	5 Types	4 Types	RB, Pi, Reg, Rinf, Mix
L'Aquila 2009	7 Types	5 Types	4 Types	RB, Pi, Reg, Rinf, Mix
Emilia-Romagna 2012	7 Types	5 Types	4 Types	RB, Pi, Reg, Rinf, Mix

Table 4 - Comparison among structural types relevant to "Vertical Structures".

<table>
<tr><th>Friuli 1976</th><th>Irpinia 1980</th><th>Abruzzo 1984</th><th>Umbria-Marche 1997*</th><th>Pollino 1998, Molise-Puglia 2002, L'Aquila 2009, Emilia-Romagna 2003/12</th></tr>
<tr><td>Masonry (bricks)</td><td>Masonry (bricks)</td><td>Masonry (bricks)</td><td>Masonry (good quality)</td><td>Masonry (good quality)</td></tr>
<tr><td rowspan="2">Masonry (rubble+ashars)</td><td>Masonry (tuff)</td><td rowspan="2">Abruzzo Masonry (stone)</td><td rowspan="2">Masonry (bad quality)</td><td rowspan="2">Masonry (bad quality)</td></tr>
<tr><td>Masonry (rubble)</td></tr>
<tr><td rowspan="2">Mixed (R.C.+Masonry)</td><td rowspan="2">Mixed (R.C.+Masonry)</td><td rowspan="2">Mixed (R.C.+Masonry)</td><td>-</td><td>Mixed (R.C+Masonry bad quality)</td></tr>
<tr><td>-</td><td>Mixed (R.C+Masonry good quality)</td></tr>
<tr><td rowspan="2">Reinforced Concrete</td><td rowspan="2">Reinforced Concrete</td><td rowspan="2">Reinforced Concrete</td><td rowspan="2">Reinforced Concrete</td><td>Reinforced Concrete (frames)</td></tr>
<tr><td>Reinforced Concrete (walls)</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>Steel</td><td>Steel</td></tr>
</table>

structural types. Note that mixed structures (i.e. combination of masonry and reinforced concrete) are missing in Umbria and Marche database.

To sum up, databases realized in a format preceding AeDES are hardly comparable with each other and some troubles also exist with early version of AeDES (Umbria and Marche 1997 earthquake).

Similar comparative process can be carried out for damage description. Firstly, while for Friuli this relies on descriptive judgments, from Irpinia onwards, damage levels are used as replacement. These are set on eight levels (including no damage) for Irpinia 1980 survey form and on six levels (from D0 to D5) for Abruzzo 1998 according to European Macroseismic Scale (EMS'98)

(Grünthal, 1998). With the adoption of AeDES form, further changes are implemented. Firstly, the six damage levels become four levels, grouping D4 and D5 (D4-D5: Very severe damage), D2 and D3 (D2-D3: Moderate-Severe damage) and leaving D1 (Light) and D0 (Null) alone. In addition, damage is described by AeDES also with respect to the extent level. Besides, whilst in Friuli survey form the damage is cumulative for all structural elements, in subsequent forms this is referred to structural components, such as Vertical Structures (VS), Floors (F), Stairs (S), Roof (R) and Infill partitions (IP). However, the number of structural components described in terms of damage levels is also varying from one data set to another as far as AeDES formats, dealing with five structural components (Table 5).

Table 5 - Comparison among damage levels and structural components.

Event	Damage Levels from original DB	Number of structural components
Friuli 1976	6 Levels	No
Irpinia 1980	8 Levels	3 Components
Abruzzo 1984	6 Levels	2 Components
Umbria - Marche 1997*	4 Levels + extension	3 Components
Pollino 1998	4 Levels + extension	5 Components
Molise - Puglia 2002	4 Levels + extension	5 Components
Emilia-Romagna 2003	4 Levels + extension	5 Components
L'Aquila 2009	4 Levels + extension	5 Components
Emilia-Romagna 2012	4 Levels + extension	5 Components

3. First comparative processing: vulnerability and damage

For the reasons above explained, the merge of the nine data sets into one is not feasible so that they have been left independent on each other, although being provided by a decoded version that helps their mutual comparability. The main problem hindering their merge relies on the fact that the selected data sets have no common metrics, in terms of numerical range, formats, record labels and so on. This also does not allow information of different data sets being displayed on a map at the same time. To make an example, as shown in section 2.2., the damage metrics are different among most of the data sets, as shown in Table 5, so that they need additional comparative work in order to onset their full comparability and carry out thematic maps.

So far, two examples of thematic processing have been implemented in the IT platform, relevant to damage levels and seismic vulnerability classes respectively. These variables are particularly significant in scenario risk related activities, since their mutual combination, together with ground shaking, allows empirical damage probability matrices or fragility curves to be developed. Similar work is foreseen for other types of information of particular interest, such as geometric characteristics, structural types, and so on. The homogenization process used for the two mentioned variables enables the formulation of final outputs with the same metrics for all the databases.

However, it is worth noticing that the proposed common metrics adopted by Da.D.O. for the two mentioned variables should be considered as one of the possible existing methods. This means that the user is still free to process his or her own elaborations according to other methods.

In terms of vulnerability metrics, the approach pursued by Da.D.O. is very simplified and based on the formulation of vulnerability classes coherent with EMS'98 macroseismic scale (Grünthal, 1998).

In terms of damage levels, the homogenization was carried out limitedly to vertical structures, being these ones common to all databases considered.

3.1. Comparison by vulnerability classes

Seismic vulnerability relies on several factors, i.e. structural typology, design type, quality of materials, construction methods and maintenance level.

Among these, however, structural typology and design type are generally assumed to be the most significant parameters to allocate with a given margin of uncertainty, buildings into vulnerability classes characterized by average performance levels during earthquakes.

In fact, if the final goal of the analysis is the evaluation of the vulnerability at extensive scale, one of the most recognised methods for achieving this purpose is the use of vulnerability classes derived from macroseismic scales, such as MSK or EMS (Medvedev, 1965, 1977; Grünthal, 1993, 1998).

While the former was limited to three classes (i.e. A, B, C), related to masonry and reinforced concrete buildings, the EMS'98 scale defines in total six classes, ranging from A to F, with increasing levels of seismic performance and (seismic) design level.

It is worth mentioning that peculiarities of Italian building inventory determined the need, over the time, to adapt EMS'98 to the Italian context. In previous works carried out by the Italian National Seismic Service and DPC (Di Pasquale and Orsini, 1997; Di Pasquale *et al.*, 2000, 2005; Dolce *et al.*, 2000; Lucantoni *et al.*, 2001), four classes were defined: A, B, C1 and C2. The last two classes are related to masonry and reinforced concrete respectively. In other works two more classes (D1 and D2 respectively) were introduced for buildings complying with previous seismic codes (AA VV, 2000; Dolce *et al.*, 2012b, 2013), as listed in the following:

- A: high vulnerability masonry buildings;
- B: medium vulnerability masonry buildings;
- C1: low vulnerability masonry buildings;
- C2: non-seismically designed reinforced concrete buildings;
- D1: seismically designed masonry buildings;
- D2: seismically designed reinforced concrete buildings.

The need for processing sets of very different information required specific adaptations to the above methods and, consequently, simplification to the process.

The association of masonry and reinforced concrete buildings into vulnerability classes was related to structural characteristics of buildings and construction age respectively. Note that important but not homogenous data, like the number of storeys, were disregarded.

With reference to masonry buildings, vulnerability classes were defined through the reciprocal combination of vertical and horizontal structures. An exception was made for Friuli, missing any information on horizontal structures, whose classes were relevant just to vertical elements (Table 6).

In order to process vulnerability classes, vertical structures were ranked according to increasing quality of masonry fabric (from rubble stone to ashlars) and consequent seismic performance. Similarly, horizontal structures were ranked according to increasing stiffness levels. Vaulted systems, very common in the Italian building stock, were considered systematically vulnerable, unless strengthened by metallic ties. The resulting association into EMS'98 vulnerability classes was made by combining the above structural characteristics. In case of reinforcements in masonry

Table 6 - Vulnerability class association for data set related to Friuli 1976 earthquake (only masonry buildings).

Vulnerability Class	Vertical Structure Type
A	masonry (rubble)
B	masonry (tuff)

Table 7 - Vulnerability class association for data set related to Irpinia 1980 earthquake (only masonry buildings).

Vulnerability Class	Vertical Structure Type	Horizontal Structure Type
A	masonry (rubble)	vaults, wooden floors, steel slabs, n.a.
A	masonry (tuff)	vaults, wooden floors, n.a.
A	masonry (brickwork)	vaults system, wooden floors, n.a.
B	masonry (tuff)	steel beams, r.c. slabs
B	masonry (brickwork)	steel beams
B	masonry (rubble)	r.c. slabs
C1	masonry (brickwork)	r.c. slabs

Table 8 - Vulnerability class association for data set related to Abruzzo 1984 earthquake (only masonry buildings).

Vulnerability Classes	Vertical Structure Type	Horizontal Structure Type
A	masonry (rubble)	vaults, wooden floors, steel beams, n.a.
A	masonry (brickwork)	vaults, wooden floors, n.a.
B	masonry (brickwork)	steel beams
B	masonry (rubble)	r.c. slabs
C1	masonry (brickwork)	r.c. slabs

Table 9 - Vulnerability class association for data set related to Umbria and Marche 1997 earthquake (only masonry buildings).

Vulnerability Classes	Vertical Structure Type	Horizontal Structure Type	Ring beams/metallic ties
A	bad quality masonry	vaults, wooden floors, steel beams+lightweight vaults, r.c. beams beams+ lightweight slabs, n.a.	No
A	bad quality masonry	vaults, n.a.	Yes
A	good quality masonry	vaults, wooden floors, n.a.	No
B	bad quality masonry	r.c. slabs	No
B	bad quality masonry	wooden floors, steel beams+lightweight vaults, r.c. beams beams+ lightweight slabs	Yes
B	good quality masonry	steel beams+lightweight vaults, r.c. beams beams+ lightweight slabs	No
B	good quality masonry	vaults, wooden floors, n.a.	Yes
C1	good quality masonry	r.c. slabs	No
C1	good quality masonry	steel beams+lightweight vaults, r.c. beams beams+ lightweight slabs, r.c. slabs	Yes

walls, such as ring beams and metallic ties, lower vulnerability classes were assumed, compared to the same unreinforced constructive elements. It is worth noticing that information on strengthening devices is not present in all databases, but just in those from 1997 (Umbria - Marche earthquake).

According to the above process, resulting vulnerability classes relevant to masonry buildings range from class A to C1, whereas the latter one is averagely characterized by good masonry fabric and rigid horizontal structures. For the sake of clarity, buildings realized after the issue of 1974 seismic Italian Law (n. 64), being generally associated to class D1, were disregarded at this stage, given their very small percentage, and thus classified C1. Resulting vulnerability classes are summarized in tables from 6 to 10 for each data set.

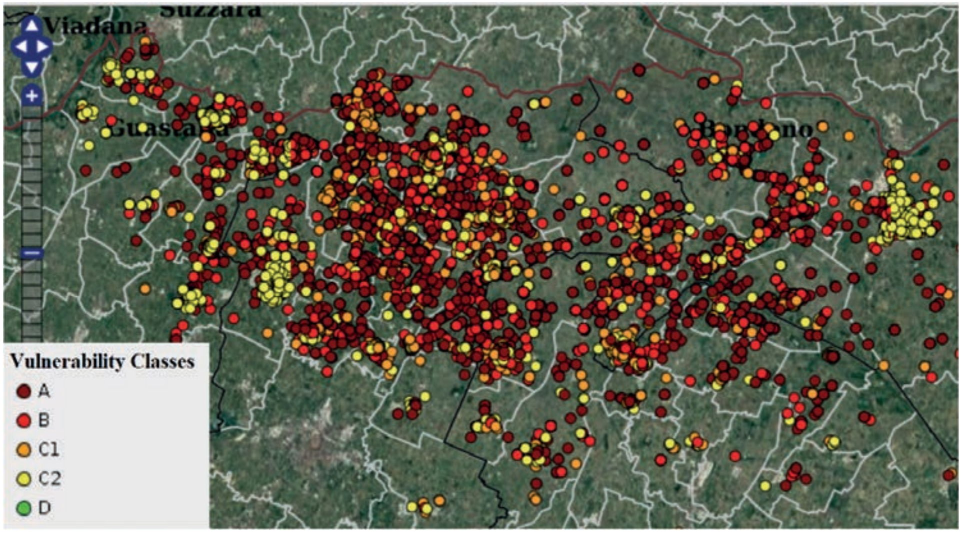
Table 10 - Vulnerability class association for data collected by means of AeDES form (Pollino 1998, Molise and Puglia 2002, Emilia-Romagna 2003, L'Aquila 2009, Emilia-Romagna 2012, only masonry buildings).

Vulnerability Classes	Vertical Structure Type	Horizontal Structure Type	Ring beams/metallic ties
A	bad quality masonry	vaults without ties, deformable slabs, semi-rigid slabs, n.a.	No
A	bad quality masonry	vaults without ties	Yes
A	good quality masonry	vaults without ties, vaults with ties, deformable slabs, n.a.	No
B	bad quality masonry	rigid slabs	No
B	bad quality masonry	vaults with ties, deformable slabs, semi-rigid slabs, rigid slabs	Yes
B	good quality masonry	semi-rigid slabs	No
B	good quality masonry	vaults without ties, vaults with ties, deformable slabs, n.a.	Yes
C1	good quality masonry	rigid slabs	No
C1	good quality masonry	semi-rigid slabs, rigid slabs	Yes

Vulnerability classes relevant to reinforced concrete buildings, as anticipated before, were defined solely on the basis of the construction age which, in turn, was compared with the year of the seismic classification of the municipality where the building is located. In particular, reinforced concrete buildings built after the seismic classification of the municipality were assumed by default class D, conversely buildings constructed before, were associated with class C2. The threshold between the two classes, represented by the first seismic classification, is implicitly determined by the compliance level to coeval seismic codes. Moreover, by assuming an irrelevant percentage of buildings constructed in compliance with most recent Italian codes NTC08, no further class was considered besides the above mentioned D.

The simplified method assumed for reinforced concrete is due to the need of being suitable to all data sets of the IT platform. Consequently, some important features such as number of floors and infills features, considered by the authors in other contexts (Dolce *et al.*, 2000, 2012b, 2013), could not be processed. Similarly, no specific class was considered for steel structures, due to the very low percentage in the Italian residential building stock.

Figs. 6a and 6b illustrate the buildings by vulnerability classes for Emilia-Romagna 2012 earthquake (Fig. 6a) and for all the building stock available in Da.D.O. (Fig. 6b), respectively. It is worth noticing that both the resulting distributions refer to buildings inspected during past emergencies, so that they do not include buildings that were not inspected.



a)

b)

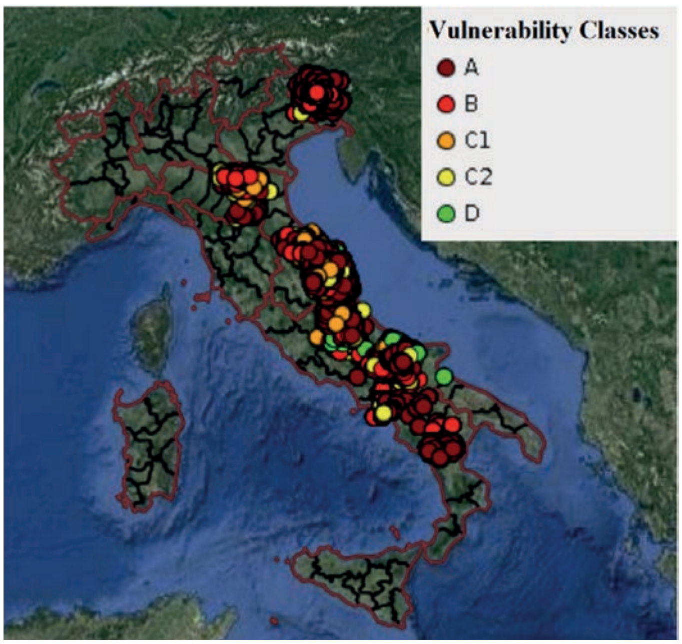


Fig. 6 - Output of resulting vulnerability classes for Emilia-Romagna 2012 earthquake (a) and for all building stock of Da.D.O. (b).

3.2. Comparison by damage levels

The comparison by damage levels required to turn all original damage metrics, as described in section 2.3., into the six damage levels provided by the EMS'98 scale (Grünthal, 1998). The homogenization process was applied just to the damage to vertical structural, being this component common to all data sets except for Friuli.

Damage levels provided by EMS‘98 scale are described for masonry and reinforced concrete respectively in Fig. 7. Note that D0 is conventionally associated with no damage, D1 corresponds to negligible or slight non-structural damage, D2 to moderate damage (slight structural damage and moderate non-structural damage), D3 to substantial to heavy damage (moderate structural damage and heavy non-structural damage), D4 to very heavy damage (heavy structural damage and very heavy non-structural damage), and D5 to total collapse (very heavy structural damage).

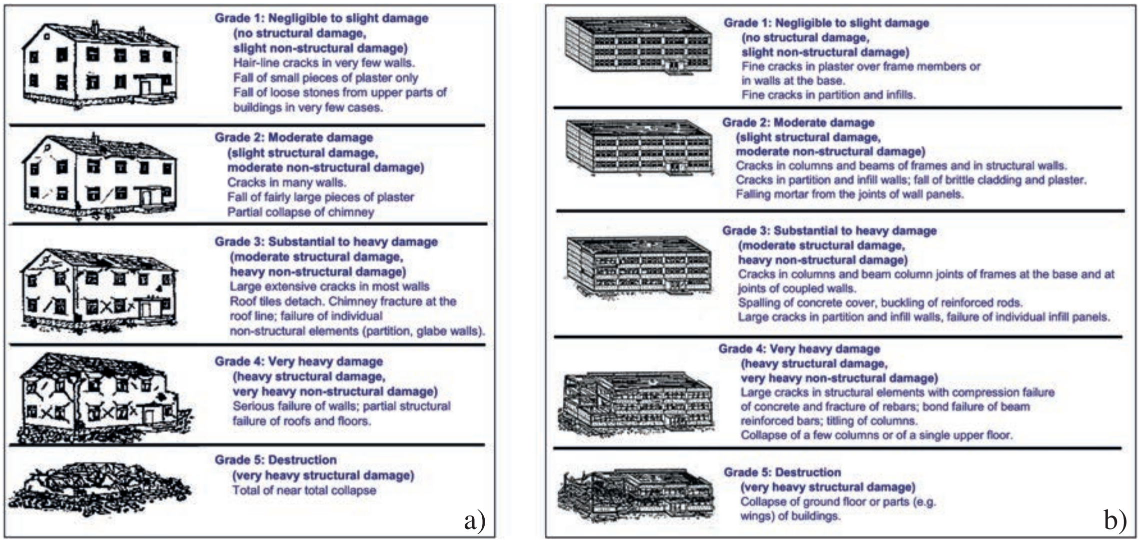


Fig. 7 - EMS’98 scale damage levels (Grünthal, 1998) for masonry (a) and reinforced concrete (b).

Specific criteria were tailored for each data set to convert damage descriptions into the above mentioned damage grades.

For Friuli, descriptive classification of reparability levels provided by the inspection form (NS = no intervention required, RT-NS = can be restored without structural interventions, RT-ST = restored with structural interventions; RP = partially reparable, NR = not repairable, and D = destroyed) (Giorgetti, 1976; Riuscetti *et al.*, 1997) was converted into EMS‘98 damage levels, as proposed in Table 11, coherently with the method implemented into the Fr.E.D. platform (Di Cecca and Grimaz, 2008).

For the Irpinia 1980 earthquake the eight damage levels initially recorded, (1 = no damage, 2 = irrelevant - non-urgent repair, 3 = slight - to be repaired, 4 = considerable - to be partially evacuated – repairable, 5 = serious - to be evacuated - repairable, 6 = very serious - to be evacuated and demolished, 7 = partially collapsed - to be demolished, and 8 = destroyed) were converted in previous works into six MSK‘67 levels by Braga *et al.* (1982). This same association was implemented in Da.D.O. by assuming a straight correspondence with EMS‘98 scale (Table 12).

Table 11 - Conversion of damage levels: from Friuli 1976 to EMS’98.

Friuli 1976	NS	RT-NS	RT-ST	RP	NR	D
EMS 98	D0	D1	D2	D3	D4	D5

Table 12 - Conversion of damage levels: from Irpinia 1980 to EMS'98.

Irpinia 1980	1	2	3	4	5	6	7	8
EMS-98	D0	D1		D2		D3	D4	D5

Table 13 - Conversion of damage levels: from Abruzzo 1984 to EMS'98.

Abruzzo 1984	1 Slight	2 Relevant	3 Serious	4 Very serious	5 Collapse
EMS-98	D1	D2	D3	D4	D5

Table 14 - Conversion of damage levels: from AeDES to EMS'98 damage levels.

	D4 - D5	D2 - D3	D1	No Damage	Level of Damage
				✓	0
			< 1/3		1
			1/3 - 2/3		1
			> 2/3		1
		< 1/3			2
		< 1/3	< 1/3		2
		< 1/3	1/3 - 2/3		2
		< 1/3	> 2/3		2
		1/3 - 2/3	< 1/3		3
		1/3 - 2/3	1/3 - 2/3		3
		1/3 - 2/3			3
		> 2/3			3
		> 2/3	< 1/3		3
Damage extension	< 1/3				3
	< 1/3		< 1/3		3
	< 1/3		1/3 - 2/3		3
	< 1/3		> 2/3		3
	< 1/3	< 1/3			3
	< 1/3	< 1/3	< 1/3		3
	< 1/3	1/3 - 2/3			4
	< 1/3	> 2/3			4
	1/3 - 2/3				4
	1/3 - 2/3		< 1/3		4
	1/3 - 2/3		1/3 - 2/3		4
	1/3 - 2/3	< 1/3			4
	1/3 - 2/3	1/3 - 2/3			5
	> 2/3				5
	> 2/3		< 1/3		5
	> 2/3	< 1/3			5

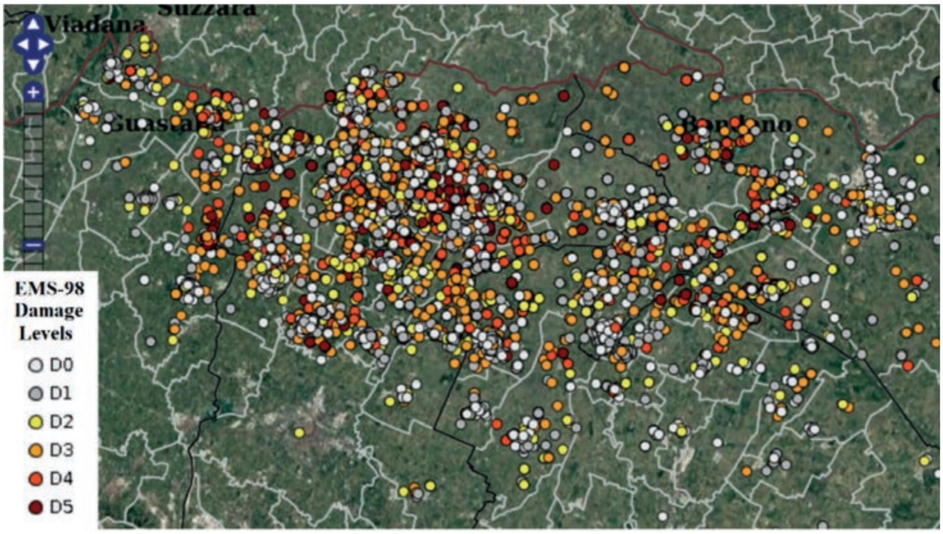
For the seismic event of Abruzzo 1984, the damage provided by the inspection forms is articulated in six levels, including no damage and five damage levels (1 = slight, 2 = relevant, 3 = serious, 4 = very serious, and 5 = collapse). These levels can be fairly associated with the corresponding five grades provided by EMS'98 scale (Table 13).

Finally, a more complex method was needed for level and extension of damage, according to the AeDES formulation, so as to be converted into single EMS'98 damage grades. In fact, according to section 4 of the AeDES survey form, the structural damage of each structural component of the building is being recorded according to a multi-choice criterion, where the crack pattern of the component is defined by damage grades (D4-D5; D2-D3; D1) and associated extension rates (<1/3; 1/3-2/3; >2/3). According to this approach, the sum of the damaged extensions cannot exceed 1 (it is not allowed, for example, to associate the damage extension >2/3 both to D1 and to D2-D3).

This method was developed by the Institute for Buildings Technology of the National Council of Research (CNR-ITC) within a working group coordinated by DPC aimed at analysing the damage distribution occurred following Abruzzo 2009 earthquake. The approach, shown in Table 14, attributes for each combination of damage and associated extension one single resulting damage level which is being assumed for vertical structures.

By implementing the above method in the IT platform it was possible to obtain homogenous metrics for all damage states resulting from all the databases.

Fig. 8a shows the final outputs relevant to Emilia-Romagna 2012 event, while Fig. 8b shows the results for all the nine databases at the same time. It is worth noticing that these results provide a picture of the damage distributions limitedly to buildings subjected to inspections. This means that a complete picture of the damage (and null damage) in a given area (e.g. a municipality), if needed by the user, should also take into account non-inspected buildings, presumably not significantly damaged. Note that according to the "standard" procedure, post-earthquake inspections are carried out according to the inspection requests from householders whose dwellings or buildings are supposed to be unusable due to damage. The strategy relevant to usability inspections is being defined during the emergency management, and mainly depends on the severity of the event and the territorial extension of the damage. Specific emergency decrees rule the procedure. However, in some cases, the strategy can entail the decision of investigating all the building stock of a given area or municipality, without requiring the request from householders. This is what happened, for instance, in the case of Abruzzo 2009 earthquake, where for some municipalities, essentially the ones with intensity greater than or equal to VII, including the L'Aquila centre, the surveys were extended to all the urban settlement. Total investigations of the building stock were carried out also in municipalities affected by Irpinia 1980 earthquake, which allowed the previously mentioned damage probability matrices to be evaluated. These two approaches, bring about direct consequences on resulting survey completeness. While in the former case (on request), the resulting databases are progressively less populated by proceeding from epicentre areas outwards, in the latter case (total survey) they show the advantage of a complete inventory of buildings and relevant damage levels, which is extremely helpful for processing damage probability matrices or vulnerability functions. Generally speaking, incompleteness of surveys relevant to undamaged buildings is usually being complemented by means of data census (in Italy provided by ISTAT), by difference with building stock subjected to inspections. This procedure needs particular care and skilled users since the



a)

b)

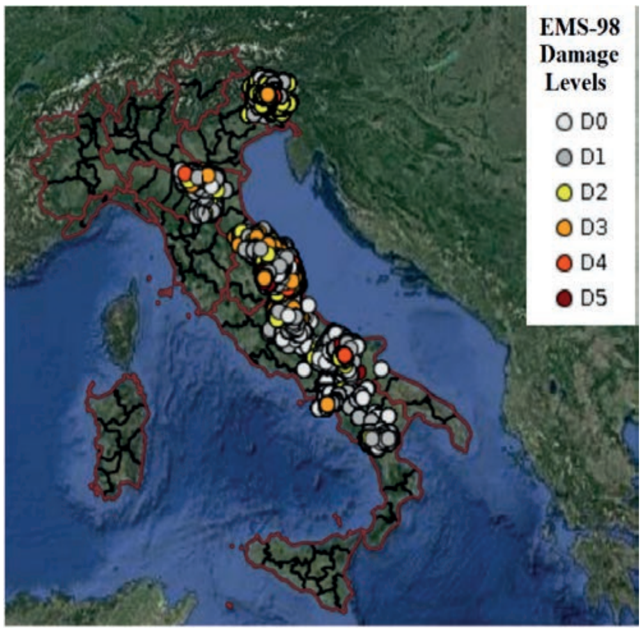


Fig. 8 - Output of resulting damage levels for Emilia-Romagna 2012 earthquake (a) and for all the nine databases (b).

number of items recognized by data census does not always match with the one observed during emergency investigations. So far Da.D.O. does not make any processing of ISTAT census data, which, if needed, must be achieved by Da.D.O.'s users independently.

4. Overlapping with other types of data

Besides information concerning constructive features and damage levels, further information is being delivered by Da.D.O. on different layers, providing the user with additional elements of analysis.

For each event of interest, among those introduced in section 2.1., most relevant information about the characteristics of the main shock and possible aftershock with $M \geq 5$ can be displayed by turning on the pertinent layer. The seismic event (or events) are georeferenced and can be overlapped to the building inventory. The information source is the Earthquake National Centre of the National Institute of Geophysics and Volcanology (INGV) (http://cnt.rm.ingv.it/) which is coherent with the parametric catalogues of the Italian earthquakes CPT11 and CPT15 (Rovida *et al*., 2011, 2016).

Event characteristics include the day and the time of the event (in local format and UTC), magnitude (provided when available both in M_L and M_W), geographical coordinates of the epicentre and corresponding hypocentre depth. The location of each event is identified on map by a red star (Fig. 9). All this information can be downloaded by the user by selecting the event of interest. In addition to the main geophysical information, Da.D.O. provides further information about the total number of casualties, in terms of victims, injured and homeless, mostly provided by the institutional website of the DPC (http://www.protezionecivile.gov.it/jcms/it/emerg_it_sismico.wp) and occasionally complemented by additional data available on other institutional sites.

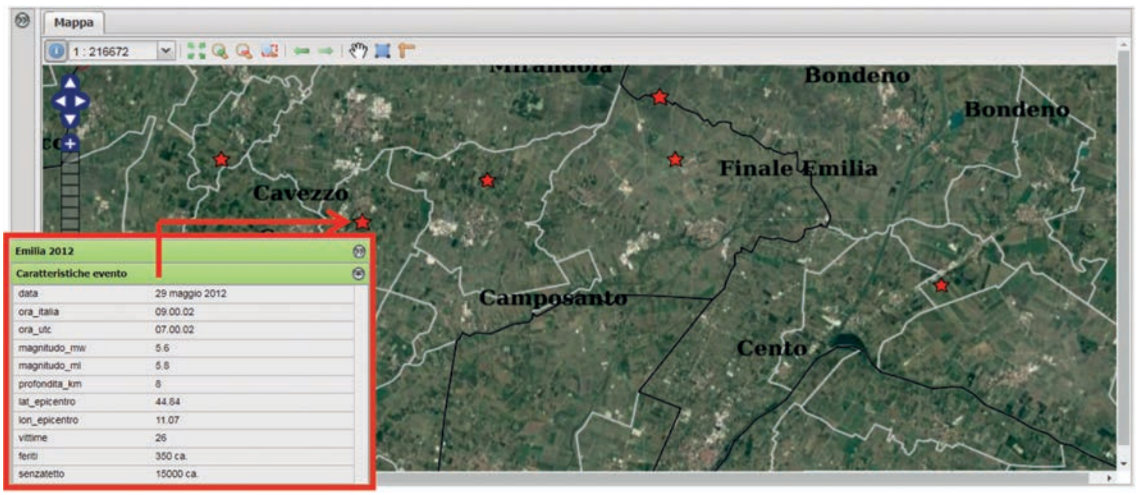


Fig. 9 - Characteristics of the event: localization and information provided to the user.

Besides the above characteristics, for all the earthquakes of interest, Da.D.O. provides the macroseismic field carried out by the INGV. Macroseismic field is described by a set of homogeneous MCS intensities [Mercalli Cancani Sieberg Scale (Sieberg, 1930)] which are being associated with all municipalities stricken with I (MCS) ≥ V (Rovida *et al*., 2016). For seismic events following 1997, macroseismic intensities are also displayed for localities, besides those for municipalities, with a more detailed information. Macroseismic fields can be onset by selecting relevant layers, such as "Macroseismic" and "Macroseismic by locality" according to the level of detail required. Fig. 10 illustrates the macroseismic field related to the seismic event of L'Aquila 2009. Similarly to other pieces of information, these data can be downloaded for each event of interest.

Further types of maps, such as shake maps representing ground motion by means of peak acceleration (PGA), peak velocity (PGV) or spectral ordinates are not being delivered by

Da.D.O. since they are available for events from 2008 onwards. At this stage, priority was given to information levels common to all the data sets and postponing possible upgrades to further developments of the IT platform.

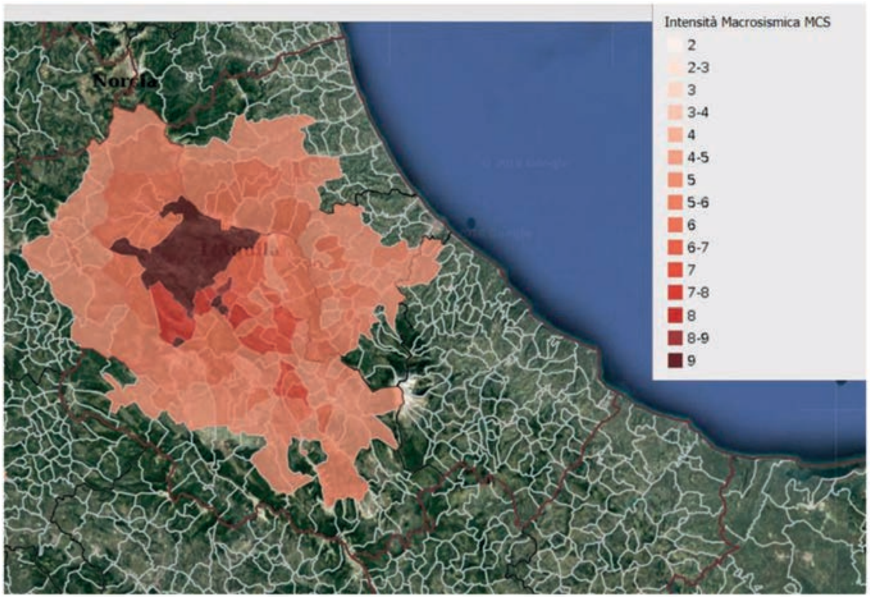


Fig. 10 - Macroseismic field for L'Aquila 2009 earthquake.

5. Conclusions

Da.D.O. (http://egeos.eucentre.it/danno_osservato/web/danno_osservato) is a web-gis platform developed by the Italian DPC, with the technological support from Eucentre Foundation. It is aimed at enhancing the reliability of risk scenario models and more effectively support Civil Protection decision making. It is addressed to users belonging to the Italian DPC, the scientific community represented by the relevant Competence Centres, and further stakeholders of the National Service of Civil Protection such as Regions. Access to the platform requires prior acceptance of the platform regulation, providing restrictions to the use and dissemination of Da.D.O. data sets. More specifically, users and institutions applying to Da.D.O. are responsible for any improper use or dissemination of data sets, when different from the scientific purposes of the platform.

Because of some substantial differences in the contents and structures among data sets, it was not possible to convert all of them into a unique database. Rather, data sets so far implemented in Da.D.O. are kept separated from each other and are provided to users in the original and decoded format, in order some comparison among corresponding fields to be tackled. Specific paragraphs of the paper are devoted to the illustration of the decoding process of each database. The paper also deals with the issue of common metrics. An exemplification of the homogenization process for seismic vulnerability classes and damage levels has been developed in the IT platform and summarised in the paper.

Da.D.O. is continuously maintained and some improvements and implementation of other significant data sets is envisaged in the next future.

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