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Rapid estimation of the seismic impact through the active contribution of the Civil Protection volunteers

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ABSTRACT Immediately after an earthquake, a rapid estimation of the seismic impact is crucial to carrying out a prompt and appropriate Civil Protection response. This is particularly important in districts characterized by frequent and moderate-to-high seismicity, as is the case in the north-eastern part of Italy. In this paper, the authors illustrate an innovative approach developed in the Friuli Venezia Giulia Region (in north-eastern Italy), based on the active contribution of Civil Protection volunteers. The methodology is based on the rapid and pre-codified communication of the earthquake effects, focusing on two main aspects: (i) the observed effects on people and buildings in the urban areas, and (ii) the structural and non-structural damage observed on pre-identified buildings. In particular, this paper illustrates the methodology and its integration into the seismic emergency plans of the municipalities in the Friuli Venezia Giulia Region and discusses the first test, which occurred during a full-scale exercise and on the occasion of recent minor earthquakes affecting the area.

Key words: civil protection, volunteers, questionnaires, “sentinel” buildings, Friuli Venezia Giulia, NE Italy.

1. Introduction

After an earthquake, the prompt estimation of the seismic impact is fundamental to establishing the appropriate countermeasures for dealing with the emergency scenario. A rapid and reliable identification of the earthquake effects is essential to planning the Civil Protection response from the first phases of the emergency. Recent Italian earthquakes, such as L’Aquila (April 6, 2009) and Emilia (May 20 and 29, 2012), underlined the importance of quickly defining the boundaries of the area with damage as a support for the contextual organization of the Civil Protection forces. For this purpose, nowadays, mathematical and numerical models are generally used; these models adopt simplified hypotheses concerning the propagation and the attenuation of the seismic waves. Starting from instrumental records, they permit the delineation of approximated shakemaps simulating where and how intensely the earthquake was felt, as well as the expected damage. These maps are routinely produced for Italy by the National Institute of Geophysics and Vulcanology (Michelini *et al.*, 2008) and are available at the webpage http://shakemap.rm.ingv.it. The application, however, of these models to the recent aforementioned earthquakes showed that the estimated damage distribution was significantly different from the actual one (Pettenati *et al.*, 2011), thus reducing the benefits of prompt action. Therefore, rapid feedback from field surveys becomes crucial to the integration and improvement of the emergency maps, especially for defining the damaged and non-damaged areas.

The Friuli Venezia Giulia (FVG) Civil Protection system includes a broad presence of volunteers within the territory. The Civil Protection volunteers can carry out an active and strategic role in the very first phases of earthquake response, if they are involved in simple and rapidly accomplished procedures. The purpose of this paper is to describe how the active contribution of the FVG Civil Protection volunteers can help outline a preliminary map that identifies different seismic impacts, especially distinguishing between damaged and non-damaged areas. The authors illustrate a methodology for assessing the seismic impact based on two types of rapid and pre-codified communication about the perceived and observed earthquake effects in the territory. The two types of communication can be used (preferably together) to assess the seismic impact: one communication is based on the reporting of the earthquake effects on population and buildings by filling in simple questionnaires; the other is based on a quick visual survey of the so-called “sentinel” buildings (i.e., pre-identified and pre-characterized buildings). Both methodologies were tested for the first time during a full-scale exercise in FVG and the Veneto Region (also in north-eastern Italy) in 2013. The results were positive, and encouraged the integration of the procedures directly into the seismic emergency plans of the FVG municipalities. The results also evidenced that the methodology is a valid practice for taking advantage of the active and systemic contribution of volunteers and that, with appropriate arrangements, the procedures can be extended to other regions and areas inside or outside of Italy.

2. Background

The FVG Region has a system of Regional Civil Protection (in Italian “Protezione Civile Regionale”, hereinafter PCR) with an organized network of volunteer teams in each municipality. The teams are coordinated by the Civil Protection Operative Centre (in Italian, “Sala Operativa Regionale”, hereinafter SOR), situated in Palmanova (province of Udine, north-east Italy). The PCR has over the years promoted the development of strong collaborations with local scientific institutions [the National Institute of Oceanography and Experimental Geophysics (OGS), the University of Trieste, and the University of Udine] to support the prevision, prevention, and management of earthquake emergencies. This synergistic arrangement provided the ideal conditions for the conception, development, and experimentation of innovative procedures for earthquake response. The management of earthquake emergencies can leverage the organized volunteers’ active contribution to such activities as the quick field survey, optimized to provide a preliminary definition of the observed seismic scenario. In particular, the efforts that have served as a foundation are:

- the agreement between PCR-FVG and OGS, for seismometric network management and seismic monitoring in the FVG territory (Priolo *et al.*, 2005);
- the ASSESS project, aimed at knowing, as a preventive measure, the level of seismic risk in school buildings for the definition of decision-making tools for the development and management of strategies for seismic risk mitigation (Grimaz *et al.*, 2016b);

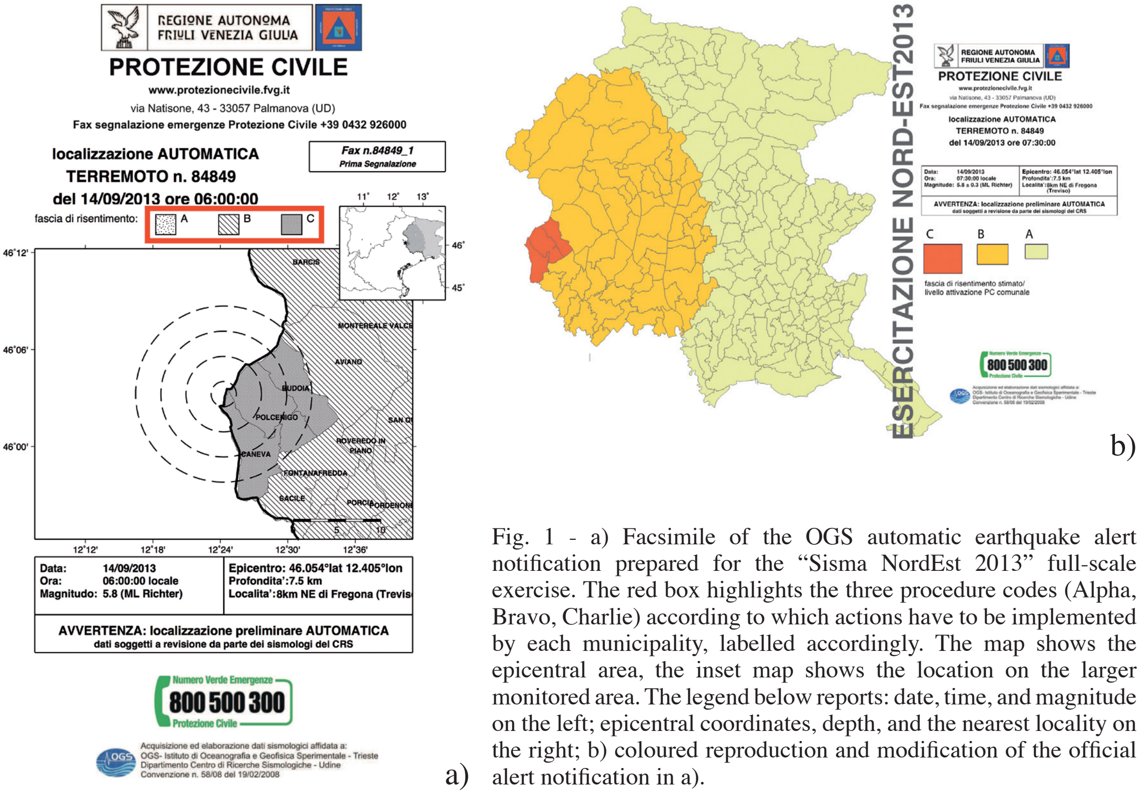
- the formulation of a procedure for a coordinated and organized response in case of an earthquake, and its integration into municipal emergency plans (Sandron *et al.*, 2012);
- the experience acquired by the SPRINT-Lab researchers of the University of Udine in the scientific coordination of the Short-Term Countermeasures System of the Italian National Fire Service, on the occasion of recent earthquakes on the Italian territory (L'Aquila, 2009; Emilia, 2012; Garfagnana e Lumigiana, 2013), and during international missions after strong earthquakes (Nepal, 2015) (Grimaz and Maiolo, 2010; Grimaz, 2011; Grimaz *et al.*, 2016a);
- the development of dissertations and prototypal studies at the University of Udine for the realization of municipal emergency plans and for the production of cartography relevant to the emergency, with management of the emergency directly tuned to municipal Civil Protection procedures (Comisso, 2013; Marzin, 2015).

3. Earthquake alert and emergency system

The Italian government established the Seismological Research Centre (hereinafter CRS) of OGS after the destructive 1976 Friuli earthquake. The CRS manages an integrated seismic network, expressly designed and developed to monitor the regional seismic activity of north-eastern Italy and its surroundings. The OGS seismic network includes 15 very sensitive digital broadband seismometers and 20 short-period stations, all of which are telemetered to and acquired in real time at the OGS-CRS data centre in Udine. Real-time data exchange agreements in place with other Italian, Slovenian, Austrian, and Swiss seismological institutes provide data in real time for a total number of about 100 seismic stations.

The OGS-PCR agreement for network management and seismic monitoring in the FVG territory requires the daily check of the remote stations' operating state and that of the acquisition and processing equipment. The alert system is guaranteed in the event of an earthquake, through the automatic transmission in real time of the parametric data of the earthquake and by the on-call service of the CRS rapid-response team. Alert messages report the magnitude and the location of an earthquake (Fig. 1a) along with information about the municipalities where the shaking might be felt by the population or might produce moderate or strong damage. Such preliminary fast and rough estimation is designed to help the Civil Protection authorities to activate the appropriate level of response. The classification of the municipalities, highlighted in the red box in Fig. 1a, (three alarm levels, along with no alarm), is based on an empirical predictive equation that relates the Mercalli-Cancani-Sieberg (MCS) intensity values in the municipalities to the magnitude of the earthquake (M_L, magnitude "Richter") and the distance from the source. The full list of municipalities is also attached, with the corresponding alarm level (in the case of generalized non-alarm level, the list reports the municipalities within an epicentral distance of 15 km). This estimation was calibrated (Bragato *et al.*, 2011) for the monitored area using a nonparametric regression on data from the CPTI04 (Gruppo di Lavoro CPTI, 2004) catalogue for north-eastern Italy.

At the municipal level, those involved in the early stages of the emergency in the case of an earthquake are: i) the mayor; ii) the Regional Civil Protection; iii) the group of municipal Civil Protection volunteers; iv) safety officers in relevant buildings.



REGIONE AUTONOMA FRIULI VENEZIA GIULIA

PROTEZIONE CIVILE

www.protezionecivile.fvg.it

via Natisone, 43 - 33057 Palmanova (UD)

Fax segnalazione emergenze Protezione Civile +39 0432 926000

localizzazione AUTOMATICA

TERREMOTO n. 84849

del 14/09/2013 ore 06:00:00

Fax n.84849_1

Prima Segnalazione

fascia di risentimento: A B C

Data: 14/09/2013

Ora: 06:00:00 locale

Magnitudo: 5.8 (ML Richter)

Epicentro: 46.054°lat 12.405°lon

Profondita':7.5 km

Localita':8km NE di Fregona (Trevis

AVVERTENZA: localizzazione preliminare AUTOMATICA

dati soggetti a revisione da parte dei sismologi del CRS

Numero Verde Emergenze 800 500 300 Protezione Civile

Acquisizione ed elaborazione dati sismologici affidata a:

OGS- Istituto di Oceanografia e Geofisica Sperimentale - Trieste

Dipartimento Centro di Ricerche Sismologiche - Udine

Convenzione n. 58/08 del 19/02/2008

a)

ESERCITAZIONE NORD-EST2013

REGIONE AUTONOMA FRIULI VENEZIA GIULIA

PROTEZIONE CIVILE

localizzazione AUTOMATICA

TERREMOTO n. 84849

del 14/09/2013 ore 07:30:00

C B A

fascia di risentimento stimato/ livello attivazione PC comunale

800 500 300

b)

Fig. 1 - a) Facsimile of the OGS automatic earthquake alert notification prepared for the "Sisma NordEst 2013" full-scale exercise. The red box highlights the three procedure codes (Alpha, Bravo, Charlie) according to which actions have to be implemented by each municipality, labelled accordingly. The map shows the epicentral area, the inset map shows the location on the larger monitored area. The legend below reports: date, time, and magnitude on the left; epicentral coordinates, depth, and the nearest locality on the right; b) coloured reproduction and modification of the official alert notification in a).

The general scheme in the case of an earthquake is: the SOR is alerted in real time by OGS; the SOR forwards the alarm notification to all the authorities and organizations involved in emergency activities (such as prefectures, Fire Brigade (VVF), Carabinieri (CC), etc.) and to the mayors of the region. The mayor, who is responsible for the emergency procedures for the municipality, has to identify the actions to be implemented according to the Civil Protection emergency plans. The level of alarm "A" (areas in "A" class, Fig. 1) requires the activation of the procedure code, named "Alpha". In this case, the worst expected effect is the simple awareness of the shock. The level of alarm "B" (areas in "B" class, Fig. 1) requires the activation of the procedure code "Bravo". In this case, the range of potential expected effects goes from the simple awareness of the shock to the occurrence of minor damage. The level of alarm "C" (areas in "C" class, Fig. 1) requires the activation of the procedure code "Charlie". The range of expected effects goes from the simple awareness of the shock to the occurrence of moderate damage. Typical alarms in the epicentral area are: level A of alarm for earthquakes with magnitude up to $M_L<3$; level B of alarm for earthquakes with magnitude in the range $3.0\leq M_L<4.5$; level C of alarm for earthquakes with magnitude in the range $4.5\leq M_L\leq 5.5$. Earthquakes with higher magnitude could be associated with higher damage in the epicentral and surrounding areas, and therefore a super-regional response could be required. In this case, the procedure is managed within the national response plan. Table 1 summarises the whole procedure.

From the emergency management perspective, the notification form constitutes the "signal in code" for activating a predefined procedure within a set of three levels of coordinated response. The simple operative estimation of the potential post-event scenario and its association with a level of alarm (A, B, C levels) triggers the activation of specific response procedures (Alpha, Bravo,

Table 1 - Procedure of rapid response of local PCR-FVG subjects and volunteers in the case of an earthquake.

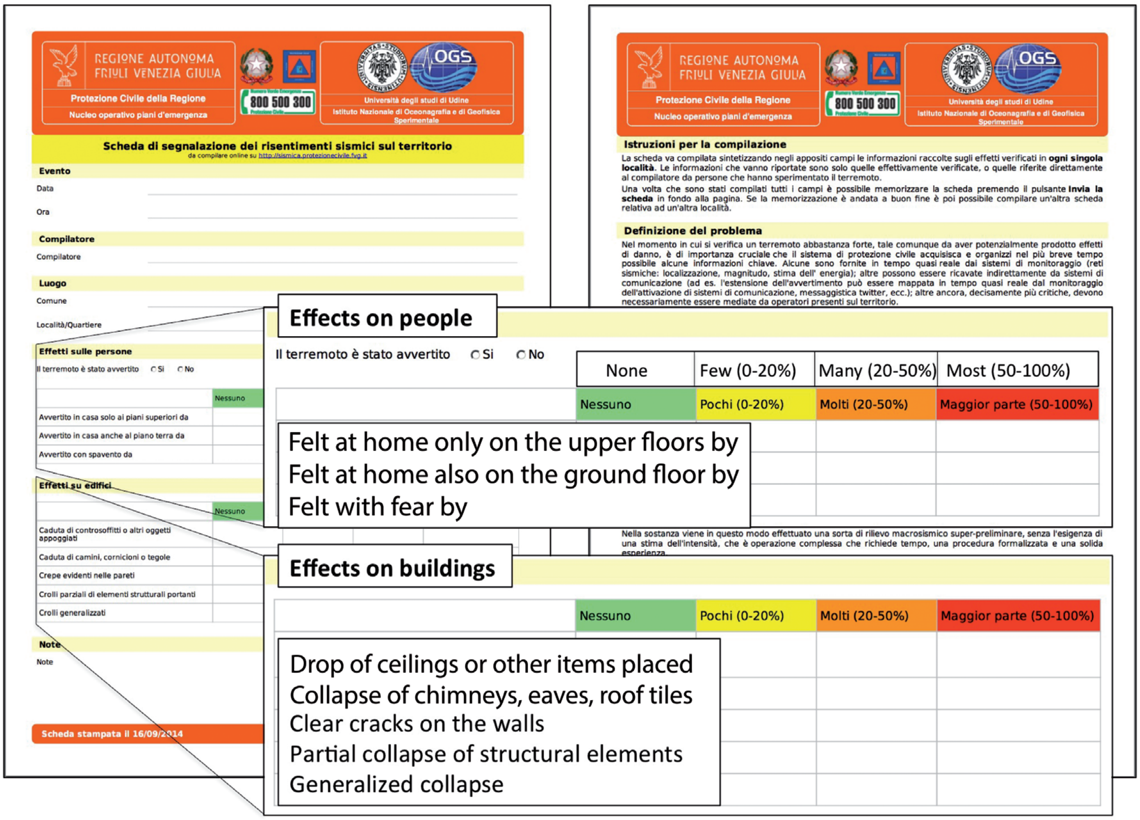
Magnitude from automatic elaboration	Level of allarm from automatic elaboration	Procedure code	Description of tasks
$M_L \leq 5.5$ or $M_L > 5.5$ epicentre out of the FVG region	A	Alpha	• *Open radio communications with SOR;* • *Compile and transmit the seismic impact questionnaire to the SOR*
	B	Bravo	• *Tasks of Alpha procedure* • *Give support to school or other relevant buildings' staff in the event of evacuation until the recovery of the normal activities.* • *Check-up of the "sentinel" buildings with the specific form.*
	C	Charlie	• *Tasks of Alpha and Bravo procedures* • *Give assistance to people in areas of shelter; if requested by SOR and activated by the mayor, support other nearby local municipalities.*
$M_L \leq 5.5$ within the FVG region			Coordination with national response plan

Charlie). This approach has multiple advantages: it avoids false alarms, mainly for the media, generates a clear and unique request for activation of predefined procedures, and, especially, reduces organizational noise, always present in the first phase of emergency response, thus minimizing the time for obtaining a systemic and coordinated response among all the actors involved.

4. Data from the field acquired through the impact data form

The initial "Seismic Impact on the Territory Report" (SITR) form was developed by OGS in close collaboration with SPRINT-Lab of University of Udine and the PCR-FVG. The form was conceived to be simple and easy to fill in by the PCR volunteers. The form is divided into two principal sections (Fig. 2): the first one aims to describe the different increasing levels of people's awareness of an earthquake; the second one is dedicated to the impacts on buildings. Therefore, while the former section of the form can be compiled after non-damaging earthquakes that have merely been perceived by the population, the latter can be filled in only after an earthquake which generated some damage to buildings. The entire system was designed to quickly provide to the PCR crucial data about the impact of an earthquake useful to emergency management and rescue coordination. The acquired information has to be sent to the SOR through web, email, or fax (not recommended), but in the case of a strong earthquake and the consequent failure of the Internet and telephone lines, the PCR-FVG volunteers group can communicate with the SOR through a proprietary radio system dedicated specially to the emergency communications. A dedicated smartphone application is under development by PCR-FVG. The use of this device will simplify and speed the procedure of acquisition of observational data by the SOR.

The procedure of collecting and transmitting information after a strong earthquake has the purpose of defining, directly and reliably, the extension of the hit area in the shortest possible time. The PCR volunteers have the task of roughly estimating the damage (simply distinguishing between light or severe) and its extension (limited to the historical centres, few buildings, or many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Protezione Civile della Regione
Nucleo operativo piani d'emergenza
800 500 300
Università degli studi di Udine
Istituto Nazionale di Oceonagrafia e di Geofisica Sperimentale

Scheda di segnalazione dei risentimenti sismici sul territorio
da compilare online su http://sismica.protezionecivile.fvg.it

Evento
Data
Ora

Compilatore
Compilatore

Luogo
Comune
Località/Quartiere

Effetti sulle persone
Il terremoto è stato avvertito ○ Si ○ No

	Nessuno
Avvertito in casa solo ai piani superiori da	
Avvertito in casa anche al piano terra da	
Avvertito con spavento da	

Effetti su edifici

	Nessuno
Caduta di controsoffitti o altri oggetti appoggiati	
Caduta di camini, cornicioni o tegole	
Crepe evidenti nelle pareti	
Crolli parziali di elementi strutturali portanti	
Crolli generalizzati	

Note
Note

Scheda stampata il 16/09/2014

REGIONE AUTONOMA FRIULI VENEZIA GIULIA
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Nucleo operativo piani d'emergenza
800 500 300
Università degli studi di Udine
Istituto Nazionale di Oceonagrafia e di Geofisica Sperimentale

Istruzioni per la compilazione

La scheda va compilata sintetizzando negli appositi campi le informazioni raccolte sugli effetti verificati in **ogni singola località**. Le informazioni che vanno riportate sono solo quelle effettivamente verificate, o quelle riferite direttamente al compilatore da persone che hanno sperimentato il terremoto.

Una volta che sono stati compilati tutti i campi è possibile memorizzare la scheda premendo il pulsante **Invia la scheda** in fondo alla pagina. Se la memorizzazione è andata a buon fine è poi possibile compilare un'altra scheda relativa ad un'altra località.

Definizione del problema

Nel momento in cui si verifica un terremoto abbastanza forte, tale comunque da aver potenzialmente prodotto effetti di danno, è di importanza cruciale che il sistema di protezione civile acquisisca e organizzi nel più breve tempo possibile alcune informazioni chiave. Alcune sono fornite in tempo quasi reale dai sistemi di monitoraggio (reti sismiche: localizzazione, magnitudo, stima dell' energia); altre possono essere ricavate indirettamente da sistemi di comunicazione (ad es. l'estensione dell'avvertimento può essere mappata in tempo quasi reale dal monitoraggio dell'attivazione di sistemi di comunicazione, messaggistica twitter, ecc.); altre ancora, decisamente più critiche, devono necessariamente essere mediate da operatori presenti sul territorio.

Nella sostanza viene in questo modo effettuato una sorta di rilievo macrosismico super-preliminare, senza l'esigenza di una stima dell'intensità, che è operazione complessa che richiede tempo, una procedura formalizzata e una solida esperienza.

Effects on people

Il terremoto è stato avvertito ○ Si ○ No

	None	Few (0-20%)	Many (20-50%)	Most (50-100%)
	Nessuno	Pochi (0-20%)	Molti (20-50%)	Maggior parte (50-100%)
Felt at home only on the upper floors by				
Felt at home also on the ground floor by				
Felt with fear by				

Effects on buildings

	Nessuno	Pochi (0-20%)	Molti (20-50%)	Maggior parte (50-100%)
Drop of ceilings or other items placed				
Collapse of chimneys, eaves, roof tiles				
Clear cracks on the walls				
Partial collapse of structural elements				
Generalized collapse				

Fig. 2 - "Seismic Impact on the Territory Report (SITR) form" (both sides in background). The form (front page) is divided into two principal sections (enlargement): the first one (top panel) describes the different levels of people's awareness; the second one (bottom panel) is dedicated to the impacts on buildings. The user guide is on the second page of the questionnaire.

buildings). It is likely that the area of the most damage will be defined through information arriving from surrounding areas with less damage. In fact, it is reasonable that a delay in acquiring and collecting information has to be expected from the most affected areas due to the PCR volunteers' physical and psychological implication there.

The data collected through the form in ordinary conditions, that is in the case of moderate or small earthquakes felt by the population, represent a valid tool for the validation and the calibration of the simulation of the A, B, or C seismic impact areas (Sandron *et al.*, 2012) in the territory. Also, this is also useful in keeping people's attention to the earthquake issue at high levels and the municipal Civil Protection system continuously trained. In fact, people forced to live with earthquakes of low magnitude, generally just perceived by the population, may lower their safety threshold.

5. Data from the field from rapid observations of "sentinel" buildings

In addition, to facilitating the communication collected through the SITR forms, this methodology engages the PCR volunteers in a more detailed procedure for the acquisition of information concerning the observable structural and non-structural damage on pre-identified buildings (hereinafter, "sentinel" buildings). The procedure foresees how to rapidly transmit observations to the SOR through pre-codified communications. The "sentinel" buildings procedure aims at obtaining a more realistic delimitation of the zones with different impact categories (A, B, C), taking advantage of prompt feedback from trained PCR volunteers in the affected area, who are rapidly activated by the emergency plans.

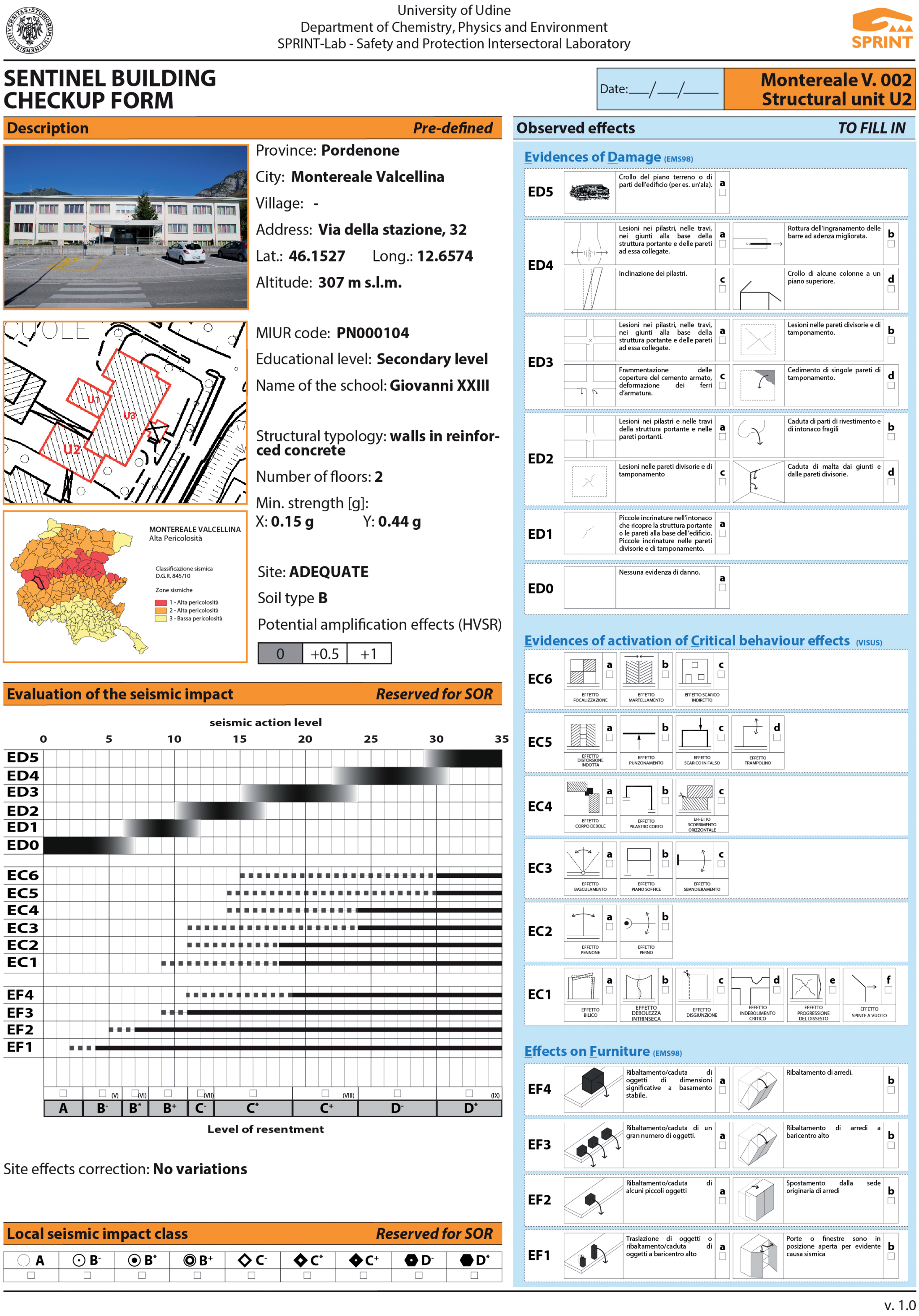
The core idea of this proposal is to quickly obtain basic information about the effects provoked by an earthquake on pre-identified and well-known buildings located in the affected area. The buildings are preliminarily identified in order to establish a sort of "detectors" mechanism for the impact scenario. If the buildings are adequately spread over the territory, the observations of damage provide a rapid indication of the actual earthquake effects at different locations. For this reason, the buildings are called "sentinels". The "sentinel" buildings methodology relies on the assumption that it is possible to make a preliminary estimate of the seismic effects at a site by comparing the condition of a building before and after an earthquake. In other words, the "sentinel" buildings operate as "informers", and the different levels of impact can be associated with the level of ground shaking at the sites in which the buildings are located, thus permitting us to infer the effects on other structures in the same location. Installing instrumentation in the "sentinel" buildings (to acquire data on environmental or seismic vibrations) can also provide an immediate (real-time) assessment of the earthquake effects on the buildings (Ponzo *et al.*, 2010; Grimaz *et al.*, 2013), which should be confirmed by a visual survey of the building.

The "sentinel" buildings procedure allows the collection of geo-localized information that facilitates a preliminary and prompt delimitation of the non-damaged area (zone A) and permits an adjustment of the estimated impact levels defined through the automatic procedure illustrated in section 3. In particular, the effects observed on "sentinel" buildings permit, through the pre-codified procedure, to assign the levels B-, B, or B+ and C-, C, or C+ in the area of major impact (with damage evidence). This assignment can confirm the preliminary estimation, or determine an adaptation, while allowing a more realistic definition of the boundaries of the affected areas.

The "sentinel" buildings methodology relies on the identification and characterization of the buildings and structures spread throughout the territory which could act as an informer of the impact scenario after an earthquake. Each "sentinel" building is characterized in advance, assessing the potential seismic response considering both structural and non-structural seismic behaviours.

The results of this characterization permit the preparation of a "sentinel" building check-up form" for each "sentinel" building. The form is designed for guiding, immediately after an earthquake, a quick visual survey of the "sentinel" building by trained technical personnel of the local Civil Protection group. The form pre-codifies the information and permits a rapid and simple communication of the observed effects. Fig. 3 illustrates the form prepared and used in the full-scale exercise "Sisma NordEst 2013", as a first example of a "sentinel" building check-up form". The form includes a short description of the "sentinel" building, in order to identify its main features, such as the structural typology, the estimated strength, and the description of site and soil type. The characterization of the seismic response of the building permits the estimation of its vulnerability and therefore the association of the seismic impact level with the expected damage.

Surveyors fill in the blue sections of the form, while the orange sections are reserved for specialists at the SOR. In order to collect the information, the surveyor has to recognize the



University of Udine
Department of Chemistry, Physics and Environment
SPRINT-Lab - Safety and Protection Intersectoral Laboratory

SENTINEL BUILDING CHECKUP FORM

Date:___/___/_____

Montereale V. 002
Structural unit U2

Description *Pre-defined*

Province: **Pordenone**
City: **Montereale Valcellina**
Village: **-**
Address: **Via della stazione, 32**
Lat.: **46.1527** Long.: **12.6574**
Altitude: **307 m s.l.m.**

MIUR code: **PN000104**
Educational level: **Secondary level**
Name of the school: **Giovanni XXIII**

Structural typology: **walls in reinforced concrete**
Number of floors: **2**
Min. strength [g]:
X: **0.15 g** Y: **0.44 g**

Site: **ADEQUATE**
Soil type **B**
Potential amplification effects (HVSR)

0	+0.5	+1

Evaluation of the seismic impact *Reserved for SOR*

A	B⁻	B*	B⁺	C⁻	C*	C⁺	D⁻	D*
☐	☐	☐	☐	☐	☐	☐	☐	☐

Site effects correction: **No variations**

Local seismic impact class *Reserved for SOR*

○ A	⊙ B⁻	◉ B*	◎ B⁺	◇ C⁻	◈ C*	◆ C⁺	⬢ D⁻	⬢ D*
☐	☐	☐	☐	☐	☐	☐	☐	☐

Observed effects *TO FILL IN*

Evidences of Damage (EMS98)

ED5	Crollo del piano terreno o di parti dell'edificio (per es. un'ala).	**a** ☐		
ED4	Lesioni nei pilastri, nelle travi, nei giunti alla base della struttura portante e delle pareti ad essa collegate.	**a** ☐	Rottura dell'ingranamento delle barre ad adenza migliorata.	**b** ☐
	Inclinazione dei pilastri.	**c** ☐	Crollo di alcune colonne a un piano superiore.	**d** ☐
ED3	Lesioni nei pilastri, nelle travi, nei giunti alla base della struttura portante e delle pareti ad essa collegate.	**a** ☐	Lesioni nelle pareti divisorie e di tamponamento.	**b** ☐
	Frammentazione delle coperture del cemento armato, deformazione dei ferri d'armatura.	**c** ☐	Cedimento di singole pareti di tamponamento.	**d** ☐
ED2	Lesioni nei pilastri e nelle travi della struttura portante e nelle pareti portanti.	**a** ☐	Caduta di parti di rivestimento e di intonaco fragili	**b** ☐
	Lesioni nelle pareti divisorie e di tamponamento	**c** ☐	Caduta di malta dai giunti e dalle pareti divisorie.	**d** ☐
ED1	Piccole incrinature nell'intonaco che ricopre la struttura portante o le pareti alla base dell'edificio. Piccole incrinature nelle pareti divisorie e di tamponamento.	**a** ☐		
ED0	Nessuna evidenza di danno.	**a** ☐		

Evidences of activation of Critical behaviour effects (VISUS)

EC6	**a** ☐ EFFETTO FOCALIZZAZIONE	**b** ☐ EFFETTO MARTELLAMENTO	**c** ☐ EFFETTO SCARICO INDIRETTO			
EC5	**a** ☐ EFFETTO DISTORSIONE INDOTTA	**b** ☐ EFFETTO PUNZONAMENTO	**c** ☐ EFFETTO SCARICO IN FALSO	**d** ☐ EFFETTO TRAMPOLINO		
EC4	**a** ☐ EFFETTO CORPO DEBOLE	**b** ☐ EFFETTO PILASTRO CORTO	**c** ☐ EFFETTO SCORRIMENTO ORIZZONTALE			
EC3	**a** ☐ EFFETTO BASCULAMENTO	**b** ☐ EFFETTO PIANO SOFFICE	**c** ☐ EFFETTO SBANDIERAMENTO			
EC2	**a** ☐ EFFETTO PENNONE	**b** ☐ EFFETTO PERNO				
EC1	**a** ☐ EFFETTO BILICO	**b** ☐ EFFETTO DEBOLEZZA INTRINSECA	**c** ☐ EFFETTO DISGIUNZIONE	**d** ☐ EFFETTO INDEBOLIMENTO CRITICO	**e** ☐ EFFETTO PROGRESSIONE DEL DISSESTO	**f** ☐ EFFETTO SPINTE A VUOTO

Effects on Furniture (EMS98)

EF4	Ribaltamento/caduta di oggetti di dimensioni significative a basamento stabile.	**a** ☐	Ribaltamento di arredi.	**b** ☐
EF3	Ribaltamento/caduta di un gran numero di oggetti.	**a** ☐	Ribaltamento di arredi a baricentro alto	**b** ☐
EF2	Ribaltamento/caduta di alcuni piccoli oggetti	**a** ☐	Spostamento dalla sede originaria di arredi	**b** ☐
EF1	Traslazione di oggetti o ribaltamento/caduta di oggetti a baricentro alto	**a** ☐	Porte o finestre sono in posizione aperta per evidente causa sismica	**b** ☐

v. 1.0

Fig. 3 - Example of sentinel building check-up form, used during the "Sisma NordEst 2013" full-scale exercise, for a school made of reinforced concrete. The form is a part of the seismic emergency plan of the municipality where the building is located. When the procedure Bravo or Charlie is activated by the preliminary alarm, the surveyors fill out only the right part of the form (blue) with a tick on the observed effect. If the surveyor can observe structural and/or non-structural damage from the outside, the procedure stops, in order to avoid the exposure of the surveyors to dangerous situations.

presence of pre-codified scenarios. In particular, the procedure distinguishes three groups of potential observable scenarios, concerning:

a) evidence of damage (ED group). The scenarios of this group depend on the structural typology of the building; the scenarios derive from the damage scenarios of EMS98 (Grünthal, 1998);
b) evidence of activation of critical behaviour effects (EC group). Potential observable critical behaviour effects are illustrated; the effects depend on the structural typology of the building. The effects derive from VISUS methodology (Grimaz and Malisan, 2016);
c) effects on the furniture (EF group). The effects on furniture are determined only in low-impact areas; their observation implies that the surveyor has to enter in the building, and therefore, to ensure the surveyor's safety, these should be determined only in the cases in which the building has no damage. The scenarios derive from EMS98 (Grünthal, 1998).

The graph in the section "Evaluation of the seismic impact" links the observed effects with the level of seismic impact. The graph is tailored to the structural typology and the seismic response of the building, and it also considers the definitions in the EMS98 macroseismic scale (Grünthal, 1998).

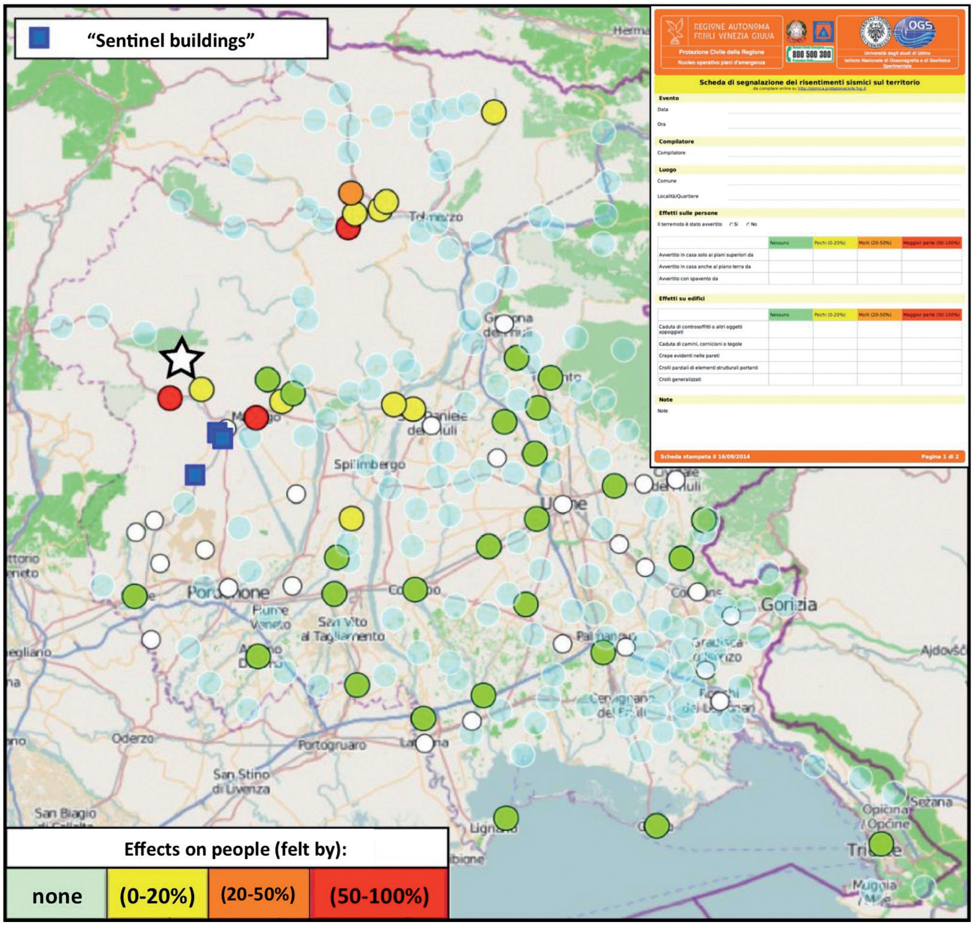
By considering the observed effects, SOR specialists can assess the level of seismic impact. In particular, the formulation of the judgement relies on the observed damage (ED and EC groups) and eventually it is refined through evidence concerning the effects on furniture (EF group). The final judgement is determined by the upper limit of the damage. This makes applying the procedure application extremely fast if performed by trained surveyors and if the SOR is organized for analysing the data immediately after the reception of the observed effects (blue column of the form). SOR specialists could do further refinements on the judgement, based on expert evaluations after the analysis of eventual pictures sent together with the data.

In order to assign the local seismic impact class, experts also take into account the site effects correction, neglecting, at this phase, the eventual near-field effects (Grimaz and Malisan, 2014). The table in the "Local seismic impact class" section of the form summarizes the outcome of the procedure. The icon near the class name is the icon that will be used on maps to represent the final judgement.

6. First applications

The fundamental requirement for the proposed procedures is quick response. The PCR volunteers' contribution is significant and its usefulness can be exploited if performed in the first hours after an earthquake. To meet such a time frame, the volunteers must be able to observe and collect the requested information and to transfer it to the SOR almost in real time. This is not easy to achieve in difficult environmental and emotional conditions, which often characterize the first hours after an earthquake.

On September 14, 2013, during the "Sisma NordEst" simulation, the municipal teams of PCR volunteers filled in the questionnaire for the first time. The teams were asked to complete the form describing the M_L=3.5 earthquake that hit Barcis (PN) on August 24, 2013 (white star on Fig. 4), which was clearly perceived by the population and caused no damage. The seismic impact degree attributed to the single localities, according to the one reported on the format



REGIONE AUTONOMA FRIULI VENEZIA GIULIA
Protezione Civile della Regione
Nucleo operativo piani d'emergenza
800 500 300
Università degli studi di Udine
Istituto Nazionale di Oceanografia e di Geofisica Sperimentale

Scheda di segnalazione dei risentimenti sismici sul territorio
da compilare online su http://sismica.protezionecivile.fvg.it

Evento
Data
Ora

Compilatore
Compilatore

Luogo
Comune
Località/Quartiere

Effetti sulle persone
Il terremoto è stato avvertito ○ Si ○ No

	Nessuno	Pochi (0-20%)	Molti (20-50%)	Maggior parte (50-100%)
Avvertito in casa solo ai piani superiori da				
Avvertito in casa anche al piano terra da				
Avvertito con spavento da				

Effetti su edifici

	Nessuno	Pochi (0-20%)	Molti (20-50%)	Maggior parte (50-100%)
Caduta di controsoffitti o altri oggetti appoggiati				
Caduta di camini, cornicioni o tegole				
Crepe evidenti nelle pareti				
Crolli parziali di elementi strutturali portanti				
Crolli generalizzati				

Note
Note

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Fig. 4 - Seismic impact on the FVG territory following the M_L=3.5 Barcis earthquake (August 24, 2013) (star) on the individual municipalities (coloured dots) collected during the "North-East 2013 Training" (September 14, 2013). The white dots are for data compiled incorrectly and considered invalid. The blue squares indicate the location of "sentinel" buildings.

questionnaire the volunteers filled in, is shown in Fig. 4 with coloured circles. The data should be delivered through the web, but only a few municipalities (12 in total) were able to send the questionnaires through this medium. Most of the questionnaires were instead sent to the SOR via fax, due to computer glitches (inadvertently producing a situation that could occur during a seismic crisis). Overall, 65 report forms were collected, 35 of which were considered to be valid. Previous to this first experiment, it was not possible to perform an efficient training campaign on the form's compiling purposes and procedures. Also, the coincidence of the test with the official larger Civil Protection simulation focused on a 5.8 magnitude earthquake in Tambre (Veneto) (Fig. 1) generated confusion about the earthquake on which the simulation was focused. In any case, SOR staff judged the general behaviour of the Civil Defence Volunteer Groups during the "Sisma NordEst" to be satisfactory.

With regard to the "sentinel" buildings, the procedures carried out in the affected area quickly permitted a definition of the seismic impact class in correspondence to three sites (blue squares in Fig. 4). The PCR volunteers carried out a rapid evaluation of the physical effects observed on three

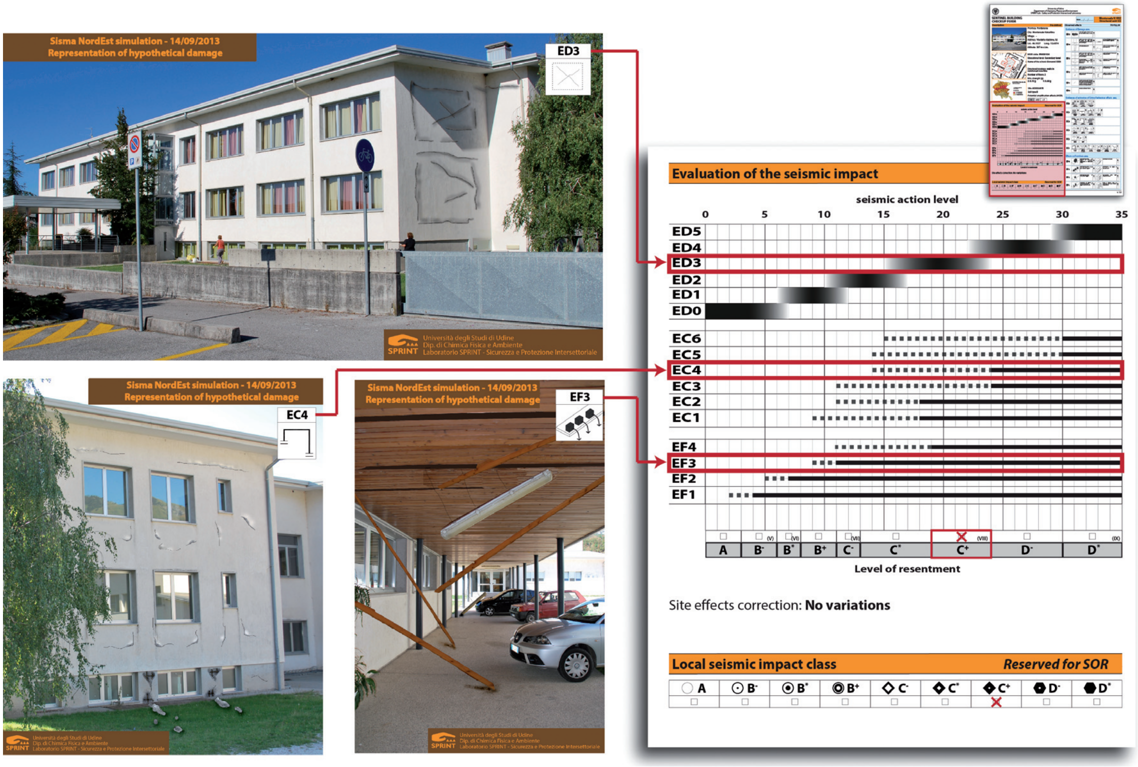

Fig. 5 - Example of the application of the “sentinel” building methodology. The application was prepared in order to show to surveyors some hypothetical seismic scenarios.

predefined “sentinel” buildings. In particular, the buildings were assessed through the evaluation of pictures representing collapses and failures on the “sentinel” buildings, in conjunction with preliminary scenarios defined by experts during the preparation of the exercise. These pictures were shown to surveyors during the on-site assessments.

The data acquired through the SITR and “sentinel” building forms allowed the integration and adaptation of the shake map, originally estimated by OGS according to isotropic models of supposed shake attenuation and related impact in terms of potential damage. The SITR data improved the delimitation between damaged and non-damaged areas with reference to the municipalities. The “sentinel” buildings observations refined the delimitation with reference to the specific sites within the municipalities. Fig. 5 shows an example of impact assessment using the data collected by the volunteers through the “sentinel” building check-up form.

On January 30, 2015, a M_L=4.1 earthquake occurred 4 km WSW of Moggio Udinese (Udine) at 01:45:49 AM (white star in Fig. 6a). At that time, half of the municipalities, unfortunately mainly in the southern part of the region, had participated in the training course, and this is the main reason why only a few municipalities in the mountains filled out the questionnaires. In total, 45 questionnaires were collected, and the level of the seismic impact was in accord with the trend of the peak ground velocity contour lines obtained by the recorded values from the stations of the FVG seismometric network. In fact, the shakemap shows a second relative maximum NW of the epicentre in correspondence with the Lauco, Zuglio and Enemonzo municipalities, where the questionnaires reported the highest level of seismic impact as well.

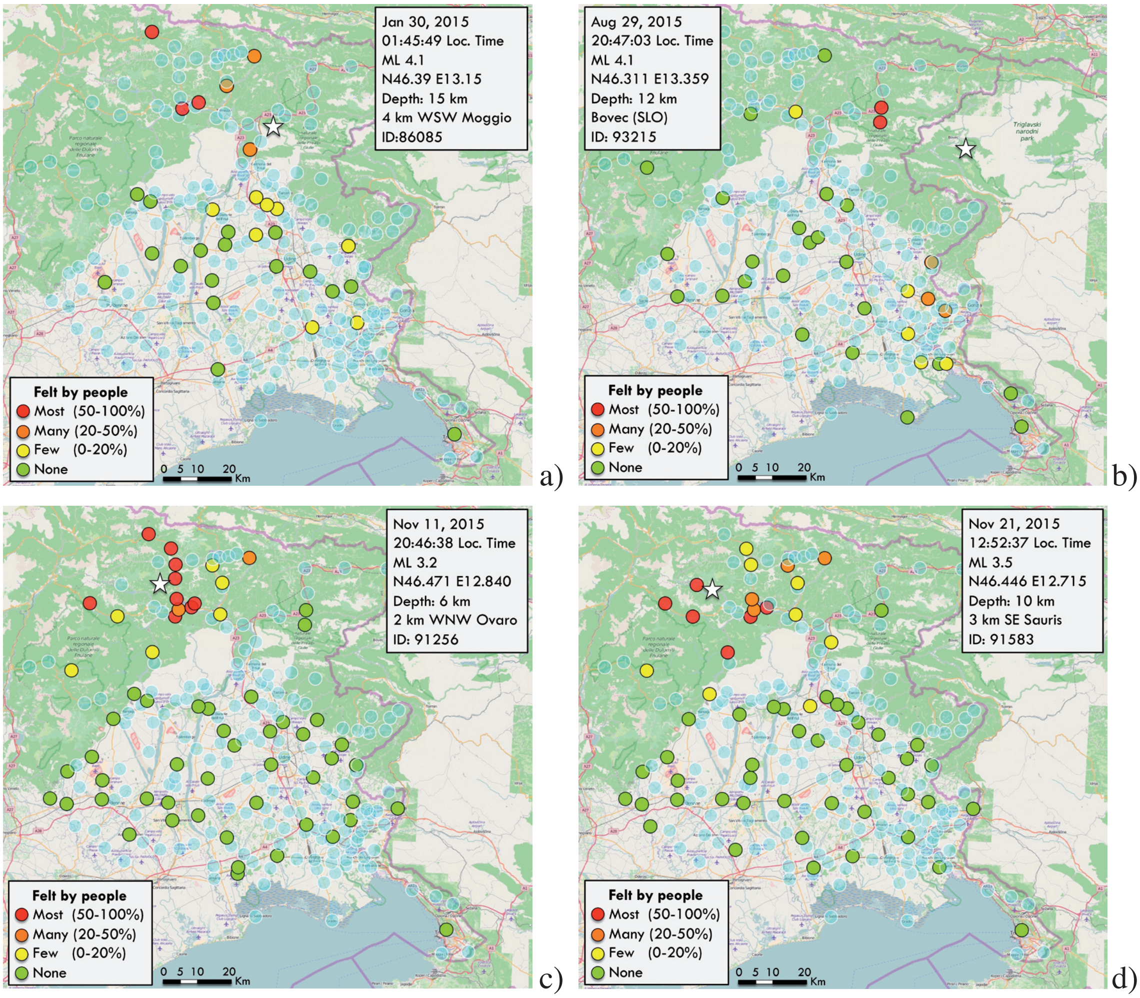

Fig. 6 - Examples of regional seismic impact obtained via the questionnaires after the: a) January 30, 2015 M_L=4.1 Moggio Udinese (Udine) earthquake; b) August 29, 2015 M_L=4.1 Bovec (Slovenia) earthquake; c) November 11, 2015 M_L=3.2 Ovaro (Udine) earthquake; d) November 21, 2015 M_L=3.5 Ovaro (Udine) earthquake.

Among the earthquakes felt by the local population during 2015, there is the August 29, 2015 M_L=4.1 earthquake, located in Slovenia at Bovec (Fig. 6b). Most of the municipalities near the border filled the questionnaires with 45 collected data points.

Most of the municipalities in the epicentral area of the earthquake of Ovaro, M_L=3.2, on November 11, 2015 compiled the report form, highlighting how even an earthquake of small magnitude but quite superficial (6 km depth) can be clearly felt by people (Fig. 6c). During 2015, OGS personnel performed several training courses, and as a consequence the amount of data sent to the SOR increased and reached, in this case, 90 filled questionnaires.

Another earthquake hit the area of Ovaro on November 21, 2015. The magnitude was similar, M_L=3.5 (Fig. 6d), but the seismic impact pattern (80 points) shows slight differences with respect to the previous case, probably due to source or directivity effects.

In the above cases, the procedure involving the “sentinel” building check-up was not activated.

7. Observations

Up to now, the illustrated methodology was tested only on small-magnitude earthquakes, but the described examples prove how organized volunteering represents a Civil Protection system element that can guarantee rapid post-event feedback, performing a strategic and functional role if integrated in a coded and tested procedure. The engagement of non-expert volunteers calls for great attention towards two other requirements of the procedure, which are simplicity and safety. The recognition of damage evidence, easy to detect from the outside, must be the aim of these procedures, in order to avoid risks. In fact, the PCR volunteers are non-experts in structural conditions and cannot protect themselves from severe loss of bearing capacity, incipient collapse, etc. In the inspections, it is not necessary to identify the damage in detail but only the maximum level of suffered damage attributed to the maximum impact at the site, considering a direct relation between intensity and damage. This explains why, if there is clear evidence of external damage, the filling in of the forms must omit the section concerning the internal elements (for example, partitions or furniture) because it is potentially dangerous and unnecessary for the goal of the survey.

The choice of the buildings is a crucial point in the "sentinel" buildings procedure. The choice shall take into account that the simpler the seismic behaviour, the better the characterization of the link between the damage and the severity of the seismic effects on the site. Furthermore, to define a map of the seismic impact, it is necessary to choose a number of "sentinel" buildings that guarantees an adequate coverage of the territory. In order to better identify the level of shaking at the site, structural units with different structural behaviours should be selected. Also, in order to rapidly perform the survey, it is necessary that the building be inspected by trained technical volunteers (or public technical personnel, such as technical office personnel of the municipality), i.e., without waiting for the authorization to enter. Strategic and relevant public building spread on the territory can be considered as the main candidate as "sentinel" buildings.

The proposed procedures are not intended to replace the macroseismic surveys that are performed in the days after the earthquake. Therefore, in the choice of the "sentinel" buildings, it is not necessary to consider if and when those are representative of the construction typologies (i.e., vulnerability classes) existing in the building heritage. That aspect would have been necessary in order to define the macroseismic intensity, which, as is known, requires an estimation of the quantity of buildings that suffered a certain damage degree (e.g., few, many, most in the EMS98). On the contrary, it appears important to pre-identify the foundation soil conditions, in order to consider the potential existence and extension of site effects that may affect the estimation of the maximum intensities. In the same way, the observation of the "sentinel" building performance is not intended to replace, even partially, the practicability inspections based on the damage and usability assessment forms (AeDES, Baggio *et al.*, 2007). That procedure has different implications in regard to people protection. Currently, it involves surveys that are performed in the days and weeks immediately after the earthquake, adopting a temporary and preliminary procedure essentially based on an expert judgement. Therefore, it has to be performed by experts in the seismic engineering field.

8. Final considerations

The procedure of compiling the "seismic impact on the territory report form" was tested for the first time in the "Sisma NordEst" context and activated after the M_L=4.1 January 30, 2015 earthquake. Municipality PCR volunteer teams were activated by the automatic notification of the seismic event, and were asked to follow the municipal emergency plan procedures. The training of the PCR volunteers assigned to the filling in of the forms is a crucial part of the entire process. Not only do they have to be adequately instructed in order to fill in the questionnaires correctly, but it is also necessary to increase awareness that filling in the forms is an important contribution to the emergency management and must be realized in a very short time. This allows, through a quick mapping, an evolutionary representation of the impacts, to be made available to the Civil Protection system.

The emergency plans and the report forms should become instruments for training during the non-emergency periods. The "sentinel" building system, if thought of as an element that can be integrated into the municipal emergency plan, would allow training during "white" simulations, with the aim of gaining confidence in accomplishing the tasks requested by the procedure.

The first experiences in Friuli Venezia Giulia region highlight the importance of the contribution of the PCR volunteers. That contribution can be used and taken advantage of only if the specific tasks and roles are well defined in the emergency plans and tested in advance. The experience also shows that the collaboration with and among the scientific institutions is fundamental to the definition and implementation of the comprehensive framework and the tools necessary for managing the entire process. Considering that Civil Protection volunteers are helpful, capable, and numerous in the entire national territory, it is the authors' belief that the procedure can be exported to other regions.

The Civil Protection of the Veneto and Trentino Regions expressed a concrete interest in developing the methodology. Furthermore, the FVG Civil Protection is planning to export the methodology during the next European Projects with Austria and Slovenia. In Friuli Venezia Giulia, earthquakes are often near the border. Therefore, sharing the procedures and the tools could improve the cross-border interoperability in the case of an earthquake for the rapid estimation of the seismic impact..

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