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Note Articles

THE UNIVERSITY OF MALTA (SEISMIC MONITORING AND RESEARCH UNIT), UNIVERSITY OF BASILICATA AND IMAA-CNR (ITALY) OPERATIONS DURING THE 2012 EMILIA SEISMIC SEQUENCE

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Abstract. On 20th May 2012 (02:03 UTC), and on 29th May 2012 (07.00 UTC) two major earthquakes occurred in Northern Italy. The two earthquakes caused 27 people to be killed (7 on 20th May and 20 on 29th May), at least 400 injured, and up to 45,000 homeless in total, with initial estimates placing the total economic loss at several billion Euros. The main goal of this communication is to describe the operations and efforts of several researchers and Institutions during the seismic crises of the Emilia sequence. The acquired data can provide tools to reduce the impact of future earthquakes on the local communities.

Keywords Seismic crises, HVSR, Data Acquisition during emergency

1 Introduction

On 20th May 2012 (02 : 03 UTC) May 2012, and on 29th May 2012 (07.00 UTC) two major earthquakes occurred in Northern Italy (Anzidei et al. 2012). They were felt throughout northern Italy, 27 people were killed (7 on 20th May and 20 on 29th May), at least 400 injured, and up to 45,000 homeless in total, with initial estimates placing the total economic loss at several billion Euros. The two earthquakes struck in the Emilia-Romagna region, about 40 kilometres north of the city of Bologna.

The epicentre (depth of 9 km) of the first one was located between Finale Emilia and San Felice sul Panaro; while the second one was in Medolla at a depth of about 10 kilometres. Both earthquakes were followed by thousands of aftershocks, which were detected and located by the Istituto Nazionale di Geofisica e Vulcanologia (INGV) using a portable network of seismometers installed a few hours after the earthquake, which detected even the smallest events. The Po Plain is part of the active front of the Northern Apennines fold and thrust belt. The area is characterized by a series of active thrust faults and related folds. These faults are roughly WNW-ESE trending, parallel to the mountain front, and dip shallowly towards the south-southwest (Toscani et al. 2008). Several damaging historical earthquakes, such as the 1570 Ferrara earthquake (Boschi et al. 2000), have occurred in the area of the 2012 seismic sequence.

Both the 20th May and 29th May events caused extensive damage. After the two large events of the seismic sequence, inspections were underway to determine

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which buildings were safe to re-enter. Total and partial collapses were observed in the old and monumental buildings in the historical centres (Fig. 1). At least 100 structures of historical significance were damaged or destroyed. Many churches and towers in towns around the epicentre suffered damage. Half of a clock tower in one of the small villages in the epicentral area dating from the 13th century (known as the torre dei modenesi) fell down in the mainshock and the remaining part collapsed completely during an aftershock later that day. The 15th-century cathedral of Mirandola, already damaged on 20th May, collapsed after the 29th May shock. Heavy damage to industrial bases and farmhouses, and also the collapse of numerous barns, was observed through the whole epicentral area. There was also significant damage to factories and agricultural land in the region. Some of the deaths were caused by the collapse of recently constructed factory buildings. Old traditional brick houses suffered widespread cracks in the walls, detachment of tiles, and chimney falls. In general, it has been observed that reinforced-concrete buildings suffered minor damage. However, a few reinforced-concrete buildings collapsed or suffered a partial collapse (for instance in the village of Cavezzo and Rovereto sulla Secchia). In some cases, the damage was increased due to the huge liquefaction phenomenon that affected the deposits below the buildings (Galli et al. 2012; Tertulliani et al. 2012).

Right after the first shock the Italian Civil Protection Department arranged 35 reception camps set up in Emilia-Romagna and 10 in Lombardia. Other structures able to host people affected by the quake were also made available (tensioned structures, train carriages, covered structures and hotels). One of the reception camps in Mirandola (Fig. 1f) was able to host the group of scientists conducting the field work briefly presented in this note.

2 Instrumentation Installed, Data Acquired, Processing, and Preliminary Results

The main goal of this communication is to describe the operations and efforts of several researchers and Institutions during the seismic crises of the Emilia sequence. The acquired data can provide tools to reduce the impact of future earthquakes on the local communities as well as to contribute to the installation of seismic networks In fact, rapid-response seismic networks are an important element in the response to seismic crises. They temporarily improve the detection performance of permanent monitoring systems during seismic sequences. The improvement in earthquake detection and location capabilities can be important for decision makers to assess the current situation, and can provide invaluable data for scientific studies related to hazard, tectonics and earthquake physics (Moretti et al. 2012). The day after the mainshock, the Istituto Nazionale di Geofisica e Vulcanologia (INGV) rapid response network for site effects, called EMERSITO, deployed three linear arrays with a total of 22 sites instrumented, 16 of them equipped with both velocimeters and accelerometers (Bordoni et al. 2012)

Our team of scientists installed 3 accelerometers (ETNA-Kinemetrics) in the hospital of Mirandola and in the urban area of the same village (Fig. 1g: Fig. 2). They were placed in order to evaluate the variability of the seismic site response and they have been continuously functioning from May 23rd to June 7th recording about 700 earthquakes including the magnitude 5.8 which occurred on May 29th. Some examples of earthquake recordings are shown in Figure 2.

During the campaign we also recorded ambient noise at 57 sites (Fig. 1e-g; Fig. 2) using a 3- component portable seismometer (Tromino, www.tromino.eu). Time series of ambient noise, having a length of $10-20$ min, were recorded following the guidelines suggested by the SESAME project (2004) in order to compute the Horizontal to Vertical Spectral Ratio (HVSR) which will contribute to investigate the shallow geological structures in the study area. A direct estimate of the polarization angle (Fig. 2) at all the recording sites was also achieved by using the Time- Frequency (TF) polarization method based on the combination of complex polarization analysis (Vidale 1986) and the continuous wavelet transform (CWT) (Burjánek et al. 2010; Burjánek et al. 2012).

The passive array data was collected using a 24 vertical 4.5 Hz Geospace geophones, arranged in an L-shaped array with an inter-distance ranging from 1 to 60 meters and the longest arm 250 meters long. The data were collected using a 24 bit A/D digitiser (Geode Geometrics) with a 125 μs sampling rate. In order to process and interpret the seismic array results we used the ESAC (Extended Spatial Autocorrelation) procedure (Okada, 2003; Ohori et al. 2002; Parolai et al. 2006).

HVSR analyses, at the investigated sites, show a resonance peak frequency at about 0.9 Hz, while results using earthquake recordings show a much more complex behaviour that that one observed by ambient noise. The array measurements show a quite uniform Vs profile (Fig. 2). At a first instance, the differences observed between the HVSR obtained by using noise and earthquake data may be due to source effects or to complex propagation at depths larger than the one presently investigated (see e.g. Malagnini et al. 2012 for the possible role of crustal propagation). However, on-going studies will try to shade light on this.

Figure 1: Panels a to e show some examples of damage caused by the strongest earthquakes of the seismic sequence. Panel f shows one of the Mirandola camps set by the Italian Civil Protection Department, Panel g reports an example of the installation of the temporary seismic instruments. Panel e shows also the installation of the Tromino® during the measurements in the vicinity of one building severely damaged during the maninshock. The children drawing presented in panel h has the aim to illustrate the effects of earthquakes on society (the word "PRIMA" stands for before while the word "DOPO" stands for after). The drawing has been realized by one the children hosted in the Mirandola camp in which also the research team has stayed.

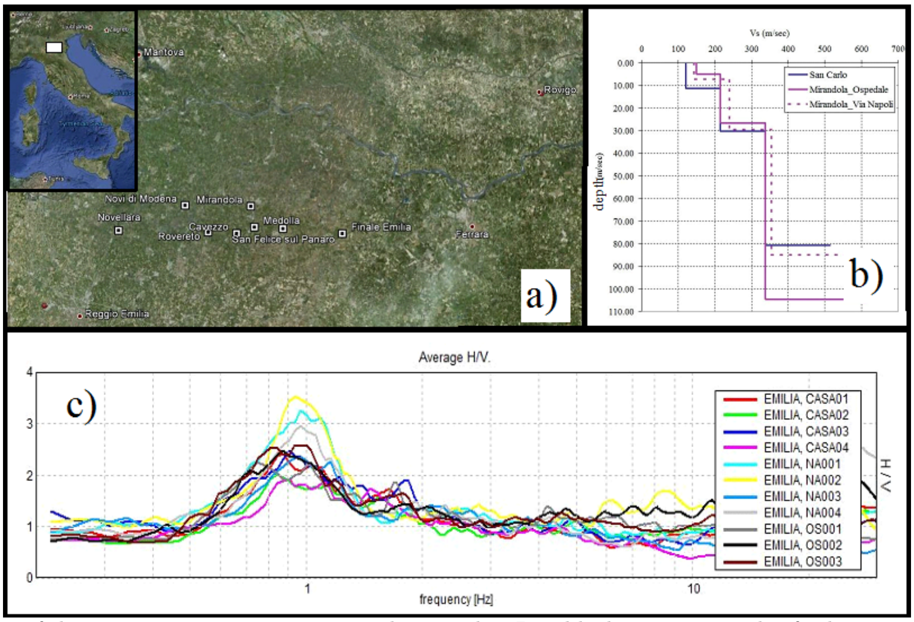

Figure 2: The location of the site measurements are reported in panel a. Panel b shows an example of velocity profile derived by using the ESAC technique. Panel c reports some example of HVSR analysis.

3 Concluding Remarks

Rapid earthquake response by scientists is very challenging and requires a high degree of preparedness.

In recent years the acquisition, transmission, exchanges and archiving of data have succeeded in vastly improving real-time monitoring systems and are widely available to the scientific community. Many improvements have been achieved through several international projects (e.g. Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation). Such kind of approach represents an important first step towards being prepared. The data collected during emergency response consist of a remarkable quantity of high-quality data that spans the entire range of ground motion and is usually recorded under near-field conditions. However, several further improvements are foreseen and needed. For example, in this context, the organization of regular seismic-risk emergency simulation can play a key role, and surely would help and contribute to improve technical and scientific exchange among the different research groups, institutions, and governments.

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