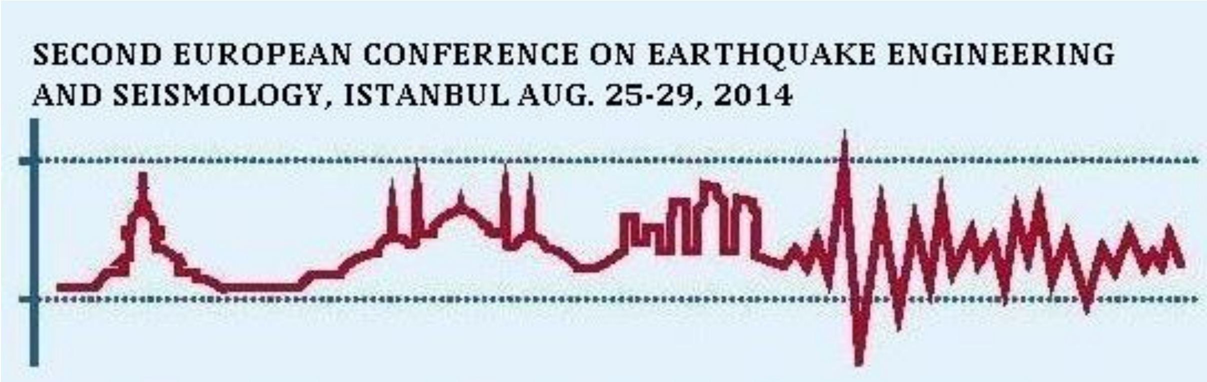

A LARGE SCALE AMBIENT VIBRATION SURVEY IN THE AREA DAMAGED BY MAY-JUNE 2012 SEISMIC SEQUENCE IN EMILIA ROMAGNA, ITALY

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An intensive passive seismic measurements survey was carried out in the whole area damaged by May-June 2012 seismic sequence in Emilia-Romagna (Northern Italy). In particular, 194 single station acquisitions (analyzed with the HVSR technique) and 34 multiple station measurements (seismic arrays) have been performed within the areas characterized by effects corresponding to or larger than VI MCS (Figure 1).

The aims of this survey were the characterization of possible seismic resonance phenomena in the area and investigate the depth of the relevant resonance interfaces by estimating the local shear wave velocity profiles.

Acquisitions were carried out by a team of University of Siena (UNISI), University of Basilicata (UNIBAS), University of Malta (UM), Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS) and Servizio geologico, sismico e dei suoli of Regione Emilia Romagna (RER). Some preliminary results from measurements from OGS and UNIBAS are discussed in Priolo et al. (2012).

Except as concerns OGS measurements, single station acquisitions were performed by a three-directional digital tromograph Tromino Micromed (www.tromino.eu) with a sampling frequency of 128 Hz and an acquisition time of 20 minutes; HVSR curves (SESAME, 2005; Albarello & Castellaro, 2011) were obtained following the procedure described in Picozzi et al. (2005).

At seismic arrays, ambient vibrations were recorded for 20 minutes at a 128 Hz sampling rate by using vertical geophones (4.5 Hz) and a digital acquisition system (BrainSpy 16 channel acquisition system by Micromed for UNISI and RER and Geode 24-channel modular acquisition system by Geometrics for UNIBAS). These acquisitions were analyzed by Extended Spatial AutoCorrelation (ESAC) technique (Okada, 2003) with the purpose to obtain the effective dispersion curve of Rayleigh wave phase velocities.

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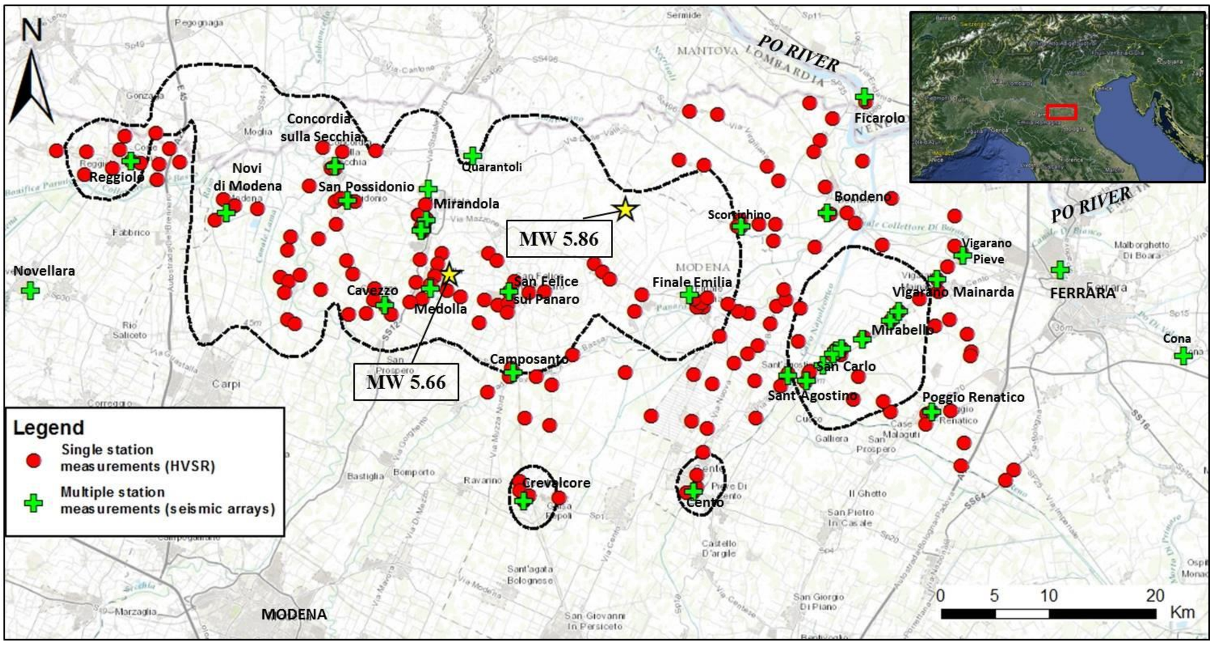

Figure 1. Localizations of the passive seismic measurements: green crosses are related to the seismic arrays, red dots to the single stations. Dashed black lines indicate 6 MCS isoseismal (modified from Galli et al., 2012), the stars are the epicenters of two mainshocks (May 20 and 29, 2012).

Examining the overall trend of the HVSR curves, two main patterns were identified. The first one (mainly in the area of the Mirandola Municipality) is characterized by a single sharp main peak in the range 0.9-1.0 Hz that is possibly the effect of a sharp seismic impedance contrast. The second pattern is widespread and is characterized by the presence of two main peaks: a main broad peak in the frequency range 0.6-1.2 Hz (occasionally accompanied by a slight "hump" in the range 1.5-2 Hz) and a secondary peak in the range 0.25-0.3 Hz. Within the broad peak, no systematic lateral variations of the maxima have been identified and this suggests that it is the result of a relatively broad transition in the seismic impedance values at depth. Both these HVSR "maxima" present significant erratic variations in amplitude. This suggests that at some extent this amplitude could be driven more by the structure of the ambient vibration wavefield than of the subsoil structure. To explore this possibility, these amplitude values were correlated with the sea-wave activity in the seas surrounding the area (Tyrrhenian and Adriatic seas). In particular, data provided by ISPRA – Servizio Mareografico "Rete Ondametrica Nazionale" (Bencivenga et al., 2012) were considered on purpose. This analysis enlightens the presence of a statistically significant correlation between sea-wave activity and maxima only in the low frequency range (0.25-0.3 Hz). This feature leads to conclude that the amplitude of the main peaks in the range 0.6-1 Hz mainly depends on the actual nature of the impedance contrast responsible for the observed resonance phenomenon.

Effective dispersion curves obtained at the arrays are very similar each to the others (differences in the effective Rayleigh wave phase velocities are lower than 100 m/s) revealing the sedimentary cover is homogeneous for the whole area (about 2500 Km^2) at least as concerns its upper portion (several tens of meters). This implies that differences observed in the HVSR patterns in the band 0.6-1.2 Hz mainly depend on the different depths of the broad transition at depth.

To assess the depth of this transition a "fast and dirty" inversion procedure (Albarello et al., 2011) was used. In particular, it has been assumed that the average S-wave velocity up to a depth *h* roughly corresponds to the effective Rayleigh wave velocity corresponding to a fraction of the relevant wavelength. In particular, by considering available information provided from down-hole and cross-hole measurements available in the area, it was established that the depth *h* roughly corresponds to 80% of the relevant wavelength. The depth profiles of the average Vs values determined in this way, were then modelized by considering a power law pattern in the form $Vs(z) = V_0 \cdot z^x$, where Vs is the S-wave velocity at the depth z; the parameters V_0 and x obtained in this way were used to attribute to the frequency f_0 of the HVSR maxima a depth H of the relevant resonant interface following the formula

$$H \cong \left[\frac{V_0\,(1-x)}{4f_0}+1\right]^{\frac{1}{1-x}}-1$$

(Ibs-Von Seht and Wohlemberg, 1999). In this way one can attribute a depth around 60-130 m to the transition responsible for the main peak (0.6-1.2 Hz). As concerns the lower frequency peak, the suggested depth is of the order of several hundreds of meters.

From the geological point of view, the nature of these surfaces is the same of those detected near the river Po zone (Martelli et al., 2014): the shallowest one is possibly related with a sub-horizontal unconformity within the Quaternary alluvial sequence (Middle Pleistocene), while the deepest one could correspond to the upper part of Quaternary marine succession (Lower Pleistocene). This last interface was involved in the most recent tectonic processes and presents long range depth variations. In particular, in the Mirandola zone, the above interfaces coincide due the rising of the Pliocenic geological substratum caused by the presence of a buried thrusts and folds ridge: this can explain the sharpness of the single HVSR maximum detected in this area.

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