SECOND EUROPEAN CONFERENCE ON EARTHQUAKE ENGINEERING
AND SEISMOLOGY, ISTANBUL AUG. 25-29, 2014

COMPARATIVE STUDY OF SPAC AND MASW METHODS TO OBTAIN THE V_S^{30} STRUCTURE FOR SEISMIC SITE EFFECT EVALUATION IN ALMERIA TOWN, SE SPAIN

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The city of Almeria is located in Andalusian region (SE Spain), belonging to the eastern part of the Betic Cordillera (Figure 1). This is the most hazardous seismic region of Spain, characterized by frequent earthquakes of small and moderate magnitude (generally smaller than 5.5). Historical seismicity data (Vidal, 1986) reveal that Almeria city has been affected, in the past, by some local or nearby damaging earthquakes (e.g. 1487, 1522, 1658, 1804 and 1910) with epicentral macroseismic intensities ranging from VIII to X (EMS scale). Some events have shown the special relevance of site effects in the city for explanation the degree and spatial distribution of building destruction (Vidal et al., 2013).

Since the NEHRP soil classification in 1994, the mean shear-wave velocity in the first 30 m (V_S^{30}) has been adopted as a representative site characteristic parameter in several official seismic codes (e.g. NCSE-02; Eurocode-8 (EC8)). The relation between surface wave dispersion curves and elastic parameters of the ground has been extensively used in geophysical prospecting, using earthquakes or controlled sources for derivation of 1-D layered ground models. The Spatial Autocorrelation method for ambient noise analysis (SPAC method), based on the early work of Aki (1957), and the Multichannel Analysis of Surface Waves method (MASW method) introduced in early 1999 (Park et al. 1999) have been proved as innovative and convenient techniques for determining the elastic properties of shallow sedimentary deposits in this kind of studies (e.g. García-Jerez et al., 2008; Navarro et al., 2013; Cox et al., 2011; Martinez-Pagan et al., 2013). Both methods are characterized by a rapid data acquisition and minimal impact on the urban environment.

In order to evaluate the site effect in Almeria town, the shallow shear-wave velocity structure of urban area has been explored from SPAC and MASW methods. Ambient noise measurements were carried out at ten open spaces located on different soil conditions (Figure 1a) by using regular pentagonal arrays. Different radii were used at each point depending on the expected thickness of sediments and on the available spatial dimension, ranging from 1.5 to 94 m (Table1). Cross correlations between records on the circle and on the central station were calculated in frequency domain, to obtain the correlation coefficient $\rho(f,R)$. Dispersion curves were calculated in different wavelength ranges depending on the radius used and these segments were subsequently combined in a single dispersion curve $c_R(\omega)$ for each site. The frequencies of the obtained curves ranged from 2.0 to 30.0 Hz and the phase velocity values varied between 191 and 904 m/sec (Table 1).

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Two profiles along the directions EW and SN, for a total length of 3.0 and 4.1 Km, respectively were analyzed by means of the active seismic MASW method (Figure 1b). A system for continuous measurements or land-streamer system was used that allowed the recording of high-performance surface wave data. 12 geophones of 28 Hz and 12 geophones of 4.5 Hz interposed were used. The selected separation between the impact point and the first geophone (offset) was 4 m and the spacing between geophones was 2 m. To generate enough energy to explore 30-m depth, a vibratory rammers was used. The study has been carried out over 24 sections (Figure 1b), maximizing the number of lithologies analysed.

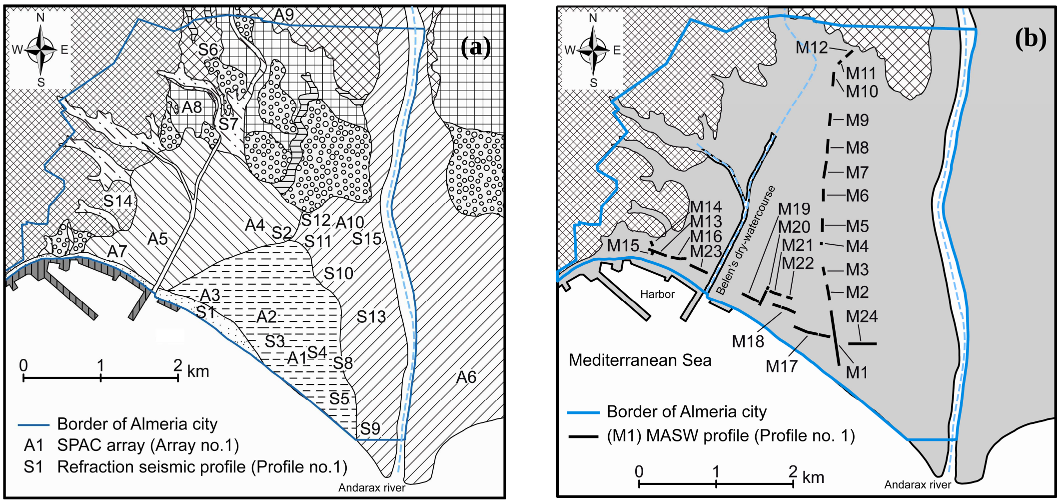

Figure 1. (a) Location of the SPACs arrays (from A1 to A9) and refraction seismic profiles (from S1 to S15); (b) Location of the MASW profiles (from M1 to M24)

Table 1. Results of array ambient noise measurements into account in this study. Frequency intervals (Δf), Phase velocity range (Δc_R) and V_S^{30} for each site located in Figure 1.

Site	Name	Landform	Radii (m)	Δf (Hz)	Δc_R (m/sec)	V_S^{30} (m/sec)
A1	Vega de Acá	Flood plain	5-10-20-40	4,8 – 17,0	215 - 412	293
A2	Nicolás Salmerón	Flood plain	2,5-5-10-20	3,0 – 21,8	191 – 419	317
A3	Rafael Alberti	Flood plain	5-10-20	3,0 – 13,9	312 – 554	359
A4	Adela Díaz	Holocene alluvial fan I	2,5-5-10-20	6,4 – 29,8	471 – 674	595
A5	Compañía de María	Holocene alluvial fan I	2,5-5-10-18	7,0 – 20,0	288 – 701	490
A6	Desaladora	Holocene alluvial fan II	6-12-25-50-94	2,0 – 18,0	257 - 904	368
A7	Gobierno Militar	Holocene alluvial fan I	1,5-3-5-10	10,5 – 30,0	397 - 775	596
A8	Colegio Goya	Hill with gentle slope	2-4-7,5-15	10,0 – 25,0	362 - 882	513
A9	H. Torrecardenas	Hill with steep slope	3-6-12-25	10,0 – 19,9	495 - 707	564
A10	Estadio J.M.	Holocene alluvial fan II	5-10-20	4,2 –13,0	288 - 589	365

Shallow shear-wave velocity structure has been calculated in different soil conditions by means of inversion of Rayleigh wave dispersion data. The results obtained by both methods (SPAC and MASW methods) reflect high similarity and they are consistent with the type of geology which underlies Almería city (Navarro et al. 2001).

Finally, a microzonation map of ground conditions of Almería town has been obtained according with Eurocode-8 (EC8) soil classification considering the average shear-wave velocity for the top 5, 10, 15, 20, 25, and 30 m depth (Figura 2). The results show the presence of lithologies whose V_S^{30} values range from 290 m/s to 770 m/s. The more extended EC8 soil class in Almería urban area is type B, although an important urban area of the town is over soil class C. These results will be applicable to seismic risk management of Almería town.

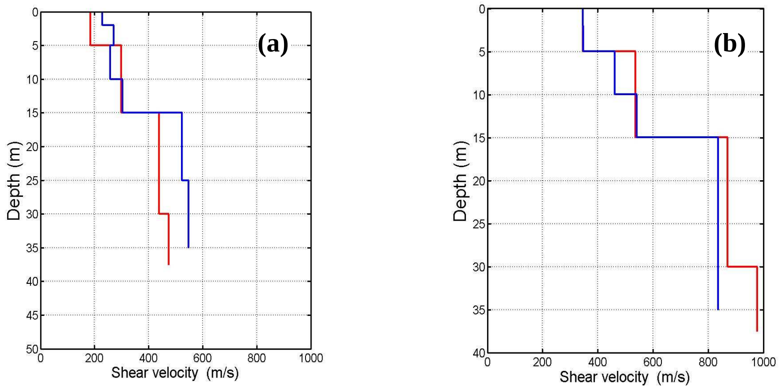

Figure 2. Comparative example V_S profiles: a) V_S profile at A2 point from SPAC method (red colour, V_S^{30} = 317 m/sec) and Vs profile in M22 section from MASW method (blue colour, V_S^{30} = 358 m/sec); b) V_S profile at A7 point from SPAC method (red colour, V_S^{30} = 596 m/sec) and Vs profile in M13 section from MASW method (blue colour; V_S^{30} = 573 m/sec)

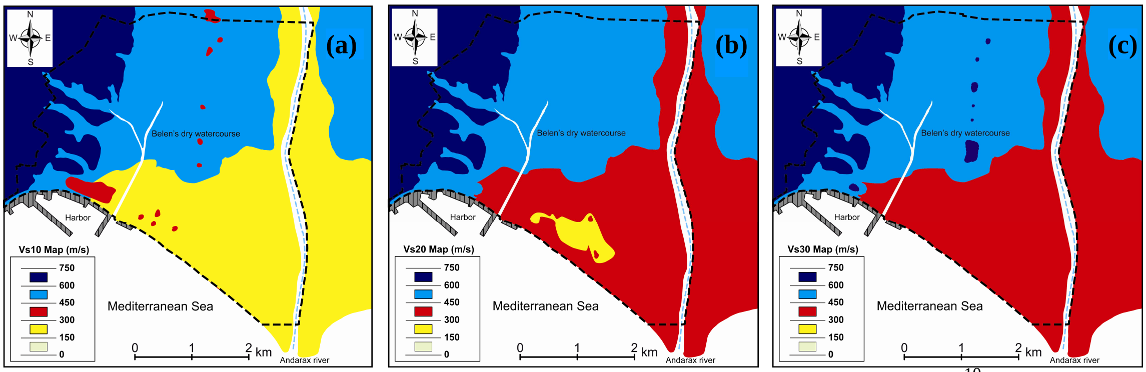

Figure 3. Average shear wave velocity distribution maps of Almería town down to: a) 10 (V_S^{10}) meters depth; b) 20 (V_S^{20}) meters depth; c) 30 (V_S^{30}) meters depth.

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