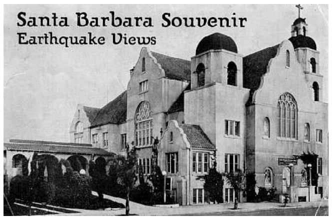

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SURFACE WAVE ANALYSIS FOR SITE EFFECT EVALUATION

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ABSTRACT

Shear-wave velocity is an important parameter for evaluating the dynamic behaviour of soil in the shallow subsurface. Determination of the near surface shear-wave velocity values is a crucial task in most of the civil and earthquake engineering, environmental and earth sciences applications. Therefore, in the study, an integrated and also a systematic geophysical approach will be introduced based on the surface wave analysis to obtain the shear wave velocity profiles. In this regard, this study can be divided by two main parts. In the first stage, The dispersion data of the recorded Rayleigh waves from the MASW experiment were inverted using a Genetic Algorithm (GA) method to obtain shear wave velocity profiles of the investigated site. A new interactive based inversion algorithm will be introduced including both GA and surface wave inversion scheme used in the MASW study. Thereafter, a special type source will be presented which is very effective not only in near-surface seismic reflection studies but also in the surface wave studies. In the last step of the first stage, MASW data were used to derivate the standard penetration data (SPT) and then compared with the borehole results. A shear modulus distribution map was plotted for the geotechnical purpose based on the MASW experiments results. The results were used to create Vs30 soil classification maps for geotechnical, seismic site effect and hazard evaluation purposes.
In the second stage of the study, The microtremor survey was carried out parallel to the MASW experiment to determine the resonance frequencies and depths of the sedimentary layers using a broadband seismometer. The shear-wave velocity profile of the basin sediments was estimated from the inversion of the microtremor horizontal-to-vertical (H/V) spectrum based on surface waves from seismic noise at each site using a genetic algorithm. The average shear-wave velocities estimated from the multichannel analysis of surface waves experiments were given as constraints in the inversion process that will be presented as a new developed algorithm scheme. Then the lateral variations of the sedimentary basin depths up to the bedrock were mapped and a new relationship between the resonance frequency (f_0) and the thickness of the overlaying layer (H) was derived.

INTRODUCTION

The Dinar earthquake (M_S = 6.1) of 1995 October 1in South-western Turkey killed 90 people and destroyed more than 4000 buildings. Despite the moderate size of the earthquake, the level of damage was extremely high, which led to many studies that were carried out in the region. The majority of these studies concluded that the main reasons for the damage were the construction errors and the poor soil conditions. However, at that time no appropriate soil condition map based on extended, high density measurements was available. Shear wave velocity is an important parameter for evaluating the dynamic behaviour of soil in the shallow subsurface. Thus site characterization in calculating seismic hazards is usually based on the near surface shear wave velocity values. The average shear wave velocity for the top 30 m of soil is referred to as V S 30. For earthquake engineering design purposes, both the Uniform Building Code (UBC) and Eurocode 8 (EC8) codes use V S 30 to classify sites according to the soil type. The V s 30 values calculated by using multichannel analysis of surface waves (MASW) were used to create a new soil classification map of the Dinar region (figure 3). Surface seismic measurements were carried out at several locations mostly in Dinar city and its surroundings. The dispersion data of the recorded Rayleigh waves were inverted using a Genetic Algorithm (GA) method to obtain shear wave velocity profiles of the investigated sites. Thus the derived V s30 map of the Dinar region was transformed to the UBC and EC8 standards. Soil classification results show that most parts of the region, located in alluvial basin, have low shear wave velocity values. These values are within the range of 160–240 m s^{-1} and thus fall into the *S*D and *S*E categories according to the UBC and the C and D categories according to EC8. Within the region, some parts located on the hill zone and the transition zone have better soil conditions [corresponding to *S*C (UBC) and B (EC8) categories] and have comparatively high shear wave velocities in the range of 500–740 m s^{-1} and 350–450 m s^{-1}, respectively. V_{S30} and soil classification maps were compared with the damage distribution associated with the earthquake. In possession of a detailed shear wave velocity map of Dinar City, in general, the results show that there is a correlation between the V_{S30} values and the damage distribution of the region (Kanlı et al., 2006).

Fig. 1. A. SR-II (kangaroo) source (a special type source which is very effective not only in near-surface seismic reflection studies but also in the surface wave studies), B. SR-II is jumping(After Kanlı et. al. 2008a and Kanlı, 2010).

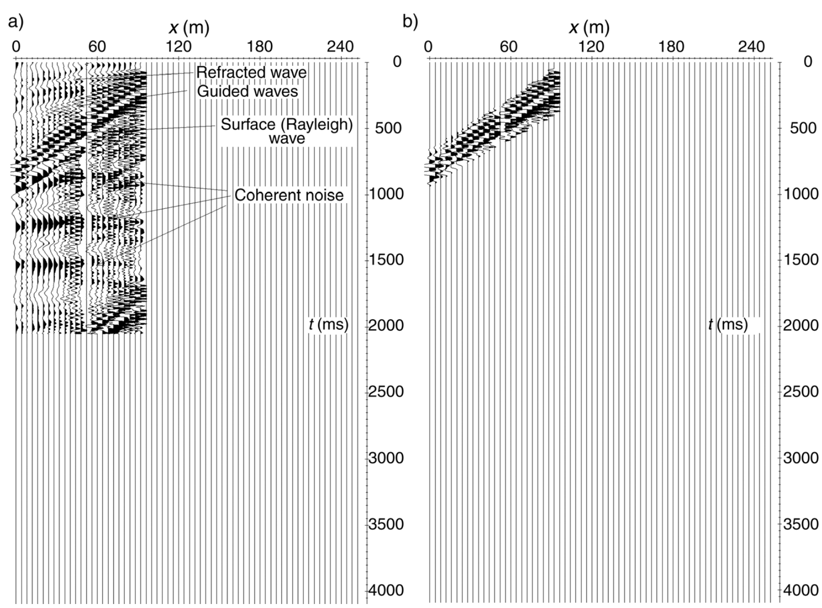


Fig. 2. (a) Zero-padded record showing different waveforms. (b) The data used for the analysis (Kanlı, 2010).

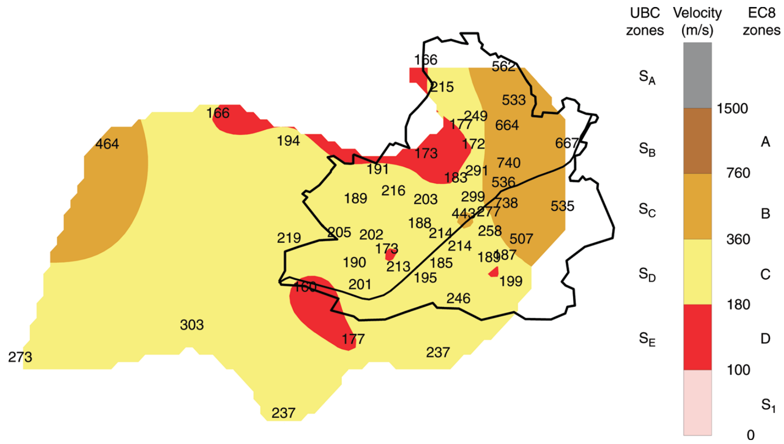


Fig. 3. Soil-classification map overlaid by the calculated average shearwave velocity distribution down to 30 m (VS30), from MASW surveys according to UBC(NEHRP) and Eurocode-8 standards (After Kanlı et al., 2006 and Kanlı, 2010).

MICROTREMOR SURVEY

Parallel to MASW study, the effects of geological conditions on the localized damage patterns were investigated by using microtremor survey. The microtremor survey was carried out in and around the Dinar basin to determine the resonance frequencies and depths of the sedimentary layer at several different locations using a broadband seismometer. The shear-wave velocity profile of the basin sediments was estimated from the inversion of the microtremor horizontal-to-vertical spectrum based on surface waves from seismic noise at each site using a genetic algorithm. The average shear-wave velocities estimated from the multichannel analysis of surface waves experiments were given as constraints in the inversion. A new relationship between the thickness of basin sediment and the main peak frequency in the horizontal-to-vertical spectral ratios was derived as $H = 110 f_0^{0.392}$. This relationship allows a zonation of the Dinar region, which is consistent with previous studies and can be importantly used for the seismic hazard evaluation of the region (Kanlı et. al. 2008b).

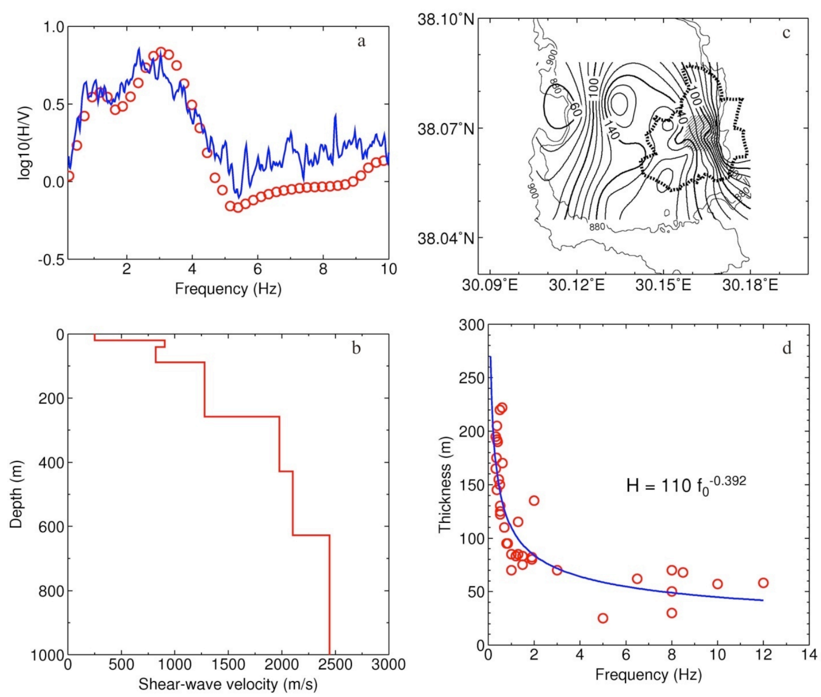
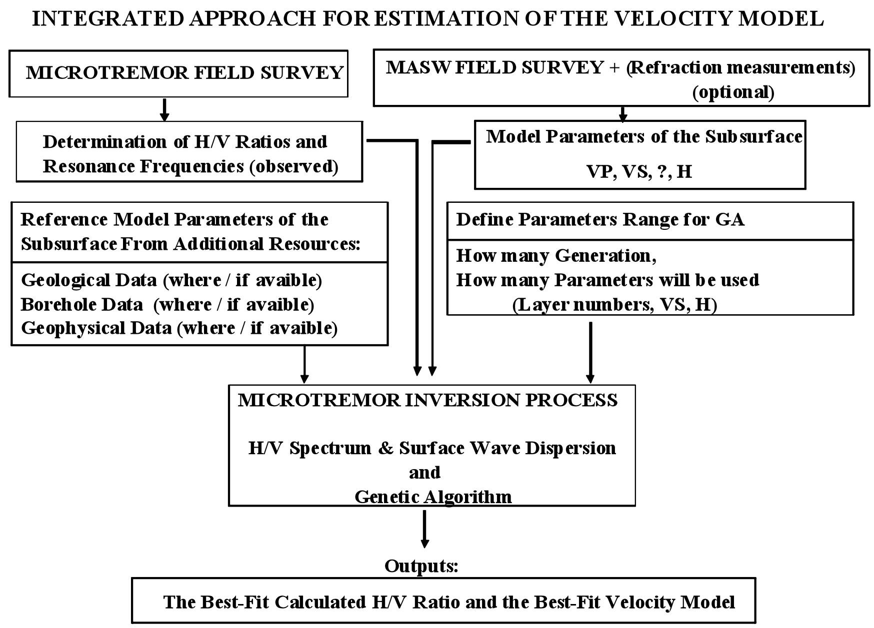


Fig.4. a) Comparison of the H/V spectrum of the microtremor (solid line) with synthetic data (open circles) for the inverted shear-wave velocity profile in (b), c) Lateral variation in the sediment thickness (contour intervals are 10m) d) The relationship between the resonance frequency and sediment thickness (After Kanlı et. al. 2008b and Kanlı, 2010).

Table 1. Flowchart of the integrated approach for MASW and the microtremor survey to obtain best-fit velocity model and H/V ratios (After Kanlı, 2010).



CONCLUSIONS

It is advised to use the MASW method with suitable source and data acquisition parameters especially in near surface characterization, geotechnical and seismic hazard assessment studies (eg. shear wave velocity mapping (VS30), soil classification, microzonation). Due to MASW method stabilization in near surface characterization and the known source geometry, the share wave velocity estimation from the MASW experiments are more robust compared with the passive source based methods in near surface geotechnical studies. On the other hand in most of the sites where the MASW method penetrations are limited and not enough to obtain related information, passive source surface wave methods are advised to be used. To increase the stability of the microtremor based studies, MASW data can also be used as constraints in the inversion stage. Similarly refraction data usage can improve the inversion stability of MASW analysis and can yield to obtain further geotechnical parameters. In the inversion process of microtremor data, the MASW results were used as a constraint for the topmost layer of the resulting shear-wave velocity profile. These constraints play an important role in stabilizing the inversion process as a priori information. But it should be kept in mind that the different measurements reflect a different aspect and/or property of the medium irrespective of whether active source or passive source since each technique capture a different size of volume from each other. MASW experiment considers information from any limited volume by a single source while the microtremor experiment captures information from wider volume by uncertain multiple sources.

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