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Determination of Soil Characteristic Using SPAC Method in Karsiyaka-Izmir, Turkey

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Abstract: *All surface waves, with the exception of Rayleigh waves which are in an isotropic, half-infinite and homogeneous environment, in spite of showing a certain distribution of velocity (depends on frequency) through the surface, act in a different phase waves.In this study, for the purpose of determining the S wave velocity structure, utilizing from the property of dispersion of surface waves, has been used Spatial Autocorrelation Method (SPAC) and microtremor method which doesn't require any source and measures the natural noise of surface with seismometers. Spatial auto-correlation method is used and passive sources have been used in this study as the source. S-wave velocities were obtained from a circular seismometer placed in the array. In addition, in order to determine the period of the floor of the dominant cycle values were obtained for each point. Settlements in the northern part of Izmir at the beach, it has a slower Vs velocity and period than the distant point.*

Keywords: *Engineering Seismology, SPAC, Izmir, soil characteristic*

I. Introduction

The Spatial Autocorrelation Method (SPAC) was proposed by Aki [1] on the basis of the assumption that microtremors are a space & time stationary scholastic process. It was based on the relationship between the signals recorded with an array of receivers equally located on a circle or a semi-circle and the signal recorded with the receiver located at the center of the array. Information about the wave types forming a complex wave field, their contributions to the complex wave field and their polarization can be acquired with the SPAC method. The SPAC is widely applied for the studies with the engineering purposes. Information about the velocity structure of the area between the receivers recording the wave field propagation is acquired from the microtremors recorded with the circular array. Thus, the method has also started to be used to determine the seismic ground response [2-4].

In a broad sense, the study area is located in Izmir Ankara zone [5], which extends from the Sakarya area in the north to the Menderes Massif in the southwest. Most of the area consists of Plio-Quaternary terrestrial-marine sediments and the remaining part consists of Miocene-period volcanic rocks. One of the current structures in the west edge of the Western Anatolia, Izmir Bay is a marine basin bordered with NE, NW, NS and EW extended faults. The Konak-Guzelbahce area located in the southern edge of the bay is bordered with the Izmir Fault. The Bayrakli-Karsiyaka area in the northern edge of the bay, the study area, is bordered with the Karsiyaka fault, which is the anti-trigger of the Izmir Fault (Fig. 1). Karsiyaka Fault in this area has the oblique-slip normal fault features with an almost E-W extension and a slope to the south. The fault is lied between Karsiyaka and Bostanli with an NW-SE extension. Miocene period volcanic units and units belonging to the Bornova Complex in the rising block of the fault were cut with NE and NW extended strike-slip faults. A large part of the falling block of Karsiyaka Fault is under the waters of Izmir Bay [6].

In order to determine the S wave velocity structure, the microtremor method, which measures the natural noise of the soil by using the dispersion of the surface waves and does not require any source, has been used in the study. The aim of this study is to determine the S-waves velocity by using SPAC method in Karsiyaka, Izmir region, which has a complex geology and active tectonics (Fig. 1).

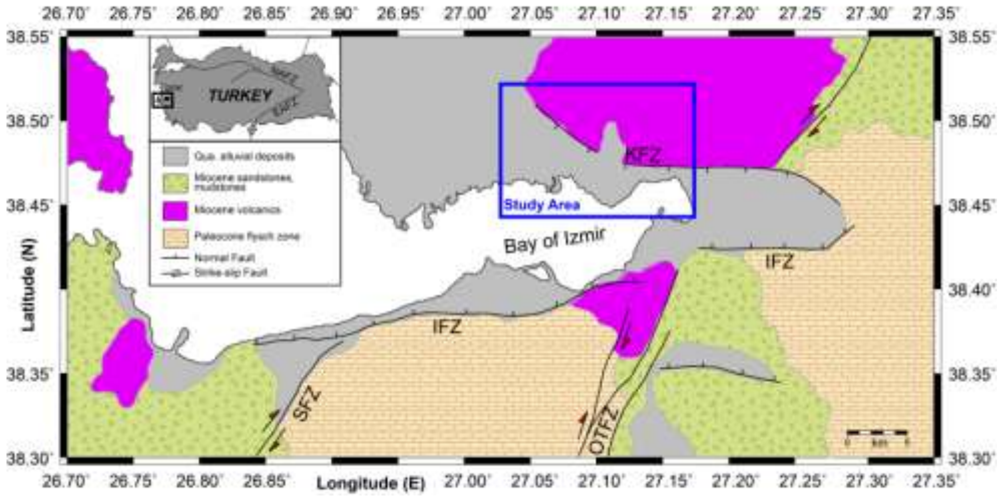

Fig. 1: Geological and principal tectonic unit map around Izmir, Turkey. EAFZ: East Anatolian Fault Zone, KFZ: Karsiyaka Fault Zone, NAFZ: North Anatolian Fault Zone, IFZ: Izmir Fault Zone, SFZ: Seferihisar Fault Zone, OTFZ: Orhanli-Tuzla Fault Zone [compiled from 7-13].

II. Data And Method

The SPAC method has two important advantages over the other passive source method (i.e.; f-k method). The first one produces similar results using smaller arrays and fewer stations than the wave number method. The arrays dimensions are important in tremor studies.Because large arrays increase the number of trials and reduce the accuracy and influence, the result of the microtremor method for the horizontal layers underneath the array. The second advantage is that not only the Rayleigh wave but also the Love waves can be determined by recording the vertical and horizontal components of the tremor signal [14-15].

In SPAC, the array geometry is circular. This array can be formed by the receivers located equally around the circle or semi-circle while the reference receiver is at the center (Fig. 2). The correlation coefficients are obtained by calculating the azimuthal averages of the correlation functions of the signals recorded by the receivers around the array. It is not possible to distinguish between the high modes of the surface waves via the spatial auto-correlation method. This is because the initial acceptance as a result of this method is that the microtremors consist from the fundamental model of the surface waves [1].

The data is collected via using a three-component seismometer array whose one component is vertical while its other two components are horizontal in the SPAC method. Since the received record has three-component structure, Love or Rayleigh waves can be examined. Since the applications within this study are focused on the Rayleigh waves, the vertical components of the data collected have been used for the evaluation of the SPAC data. The most important factor when applying the SPAC method is to make a decision about how the instruments recording the resonance will be placed in the survey. In the survey, the receivers can be placed on the circle in different combinations (Fig. 2). For the SPAC method, the receivers should be located at equal distances from one another. The most well-known survey pattern is the array type that records from four points at least. One of these is located at a certain point. This point is accepted as the center of the circle. Via taking the center as the basis, the other three instruments are placed at points with the distances of a certain radius value away from the center. If the instrument at the center is accepted as the center of gravity, these points are the locations corresponding to the corners of the equilateral triangle that is formed [3, 15].

The microtremor instruments used in the survey are Guralp CMG-6TD seismometers that are sensitive to the ground motions with medium strength. The selected sampling interval is 100 Hz. The average ground recording time of each recording is at least 30 minutes. The measurements were taken at four SPAC points (Fig. 3). The natural noise of the soil around the center point was recorded for the radii of 17, 52 and 100 m.The theoretical data to be used in the inverse solution process of the modeling of the dispersion curve is required. The digitized values have been given as separate input values for each SPAC points on the DispCurve program, which is written on MATLAB. Moreover, the S waves velocity based on the layers have been created to be used on the program to acquire the velocity profile of the Shear waves. The program tries to reach the coherence of the curve acquired with the SPAC result and the initial model. When the coherence reaches the desired level, the iteration is released and the velocity model of the S waves is created. After the start-up of the program, the dispersion curves calculated for different modes are monitored. When we have the basic mode drawn, the theoretical data calculated with the modeling program for the given model is acquired.

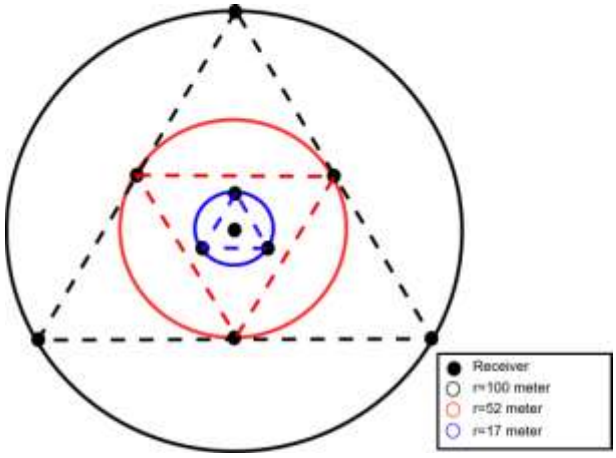

Fig. 2: Survey plan of SPAC measurement

Fig. 3: Distribution of SPAC measurement point, Karsiyaka, Izmir.

III. Discussion

The real soil parameters have been tried to be found by using the dispersion curve acquired with the help of the SPAC method applied to the resonance data collected in the survey and the theoretical dispersion curve calculated as a result of the modeling in the inverse solution process. The 1-D S- wave velocity model is acquired as a result of the inverse solution. It is not possible to achieve exact results with 1D inverse-solution because the underground is 3-D and the measured values also belong to a 3-D space. The inverse solution for the damped least squares method has been applied with a program coded on MATLAB. In the study, the modeling was not formed separately for each radius but they were formed as a result of the joint evaluation of the three radius values for the SPAC measurement performed at a single point. The reason for choosing three different radii is to examine how deeper depths can be proceeded with the arrays having different radii. Calculations were made for each radius value, and three seismometers have been located at the edges of the equilateral triangle consisting of the circular array. The last one has been located at the center of the circle. Location of central seismometer never changes even others move for different radius. After whole array is prepared for specified radius, recordings of natural resonance of ground start immediately by switching on all seismometers.

Figures 4 to 7 show the frequency based phase velocity (dispersion) curve for the K-1, K-2, K-3 and K-4 SPAC points, respectively. Plots for the vertical velocity profiles of the coherence change with the iteration and sliding wave.When the S-wave velocities at 100th meter has been observed for all points, it has been observed that velocities at the K-1 on the coastline are 250 m/s (Fig. 4). They are around 400 m/s at K-2 (Fig. 5) and K-3 (Fig. 6), and above 1000 m/s at K-4 (Fig. 7). When the velocities at 200th meter have been considered, it has been determined that they have mean velocity near 400 m/s on the coast, 600 m/s in the middle part and 2000 m/s at the farthest parts. The calculations have been performed for fifteen layers and for each thickness to calculate S-wave velocity. To get information from the deeper points, the measurements should be taken in the study area with wider expansions. However, the process could not be repeated for the expansions with the wider radii since the study area was a residential area. Wireless connection was almost impossible at more distances. Figure 8 shows the S-wave vertical velocity models for all points as a summary. When the evaluations have been made via SPAC points, there are twelve different microtremor records at each point since the measurements have been performed for four different seismometers and three different radii at each point. The coherence of these records has been examined within the scope of the study. The H/V (horizontal/vertical) ratios change depending on the frequency plots for the K1 measurement point are given in Figure 8. It is seen that the average frequency is around 1.5 Hz on the graph and accordingly it can be calculated that the dominant period is 0.66 s.

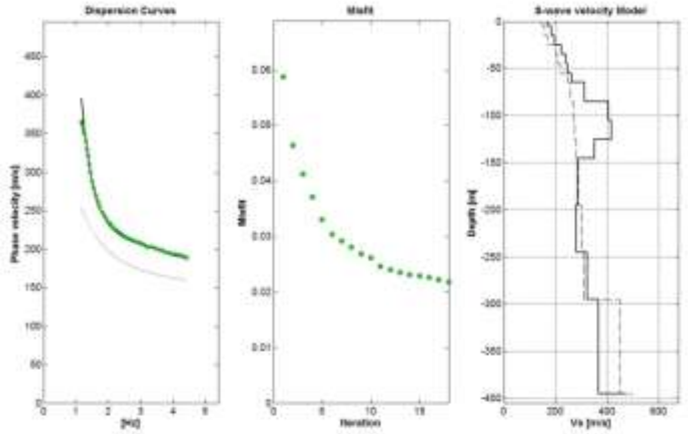

Fig. 4: Dispersion curve, misfit and vertical S-wave velocity structure for K1 measurement point.

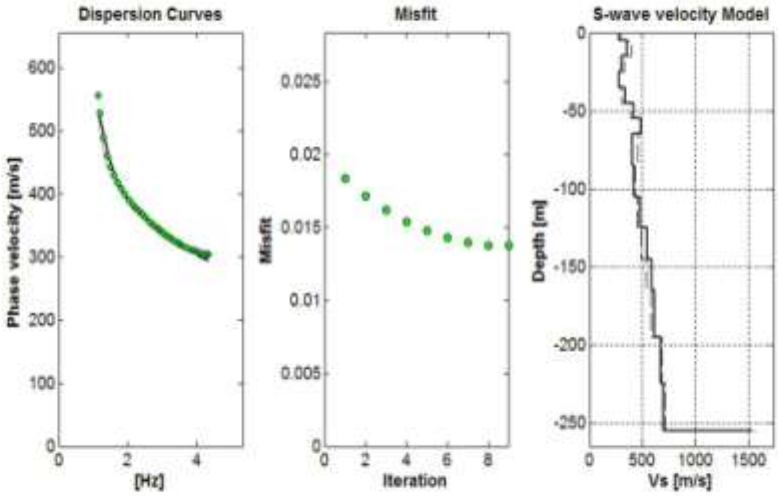

Fig. 5: Dispersion curve, misfit and vertical S-wave velocity structure for K2 measurement point.

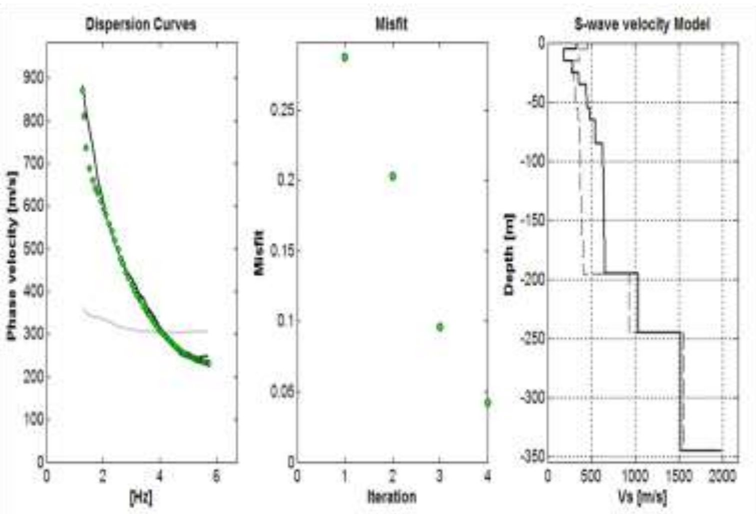

Fig. 6: Dispersion curve, misfit and vertical S-wave velocity structure for K3 measurement point.

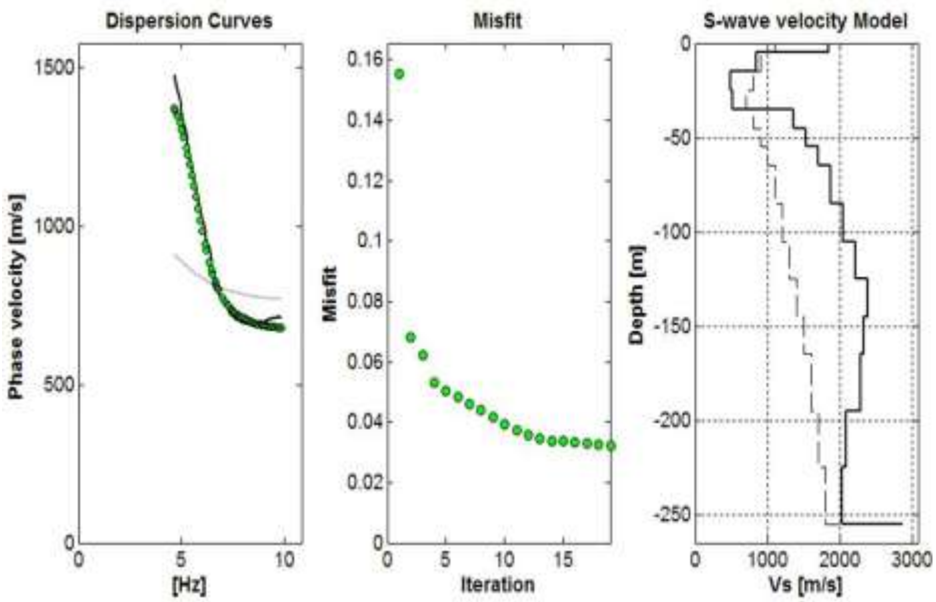

Fig. 7: Dispersion curve, misfit and vertical S-wave velocity structure for K4 measurement point.

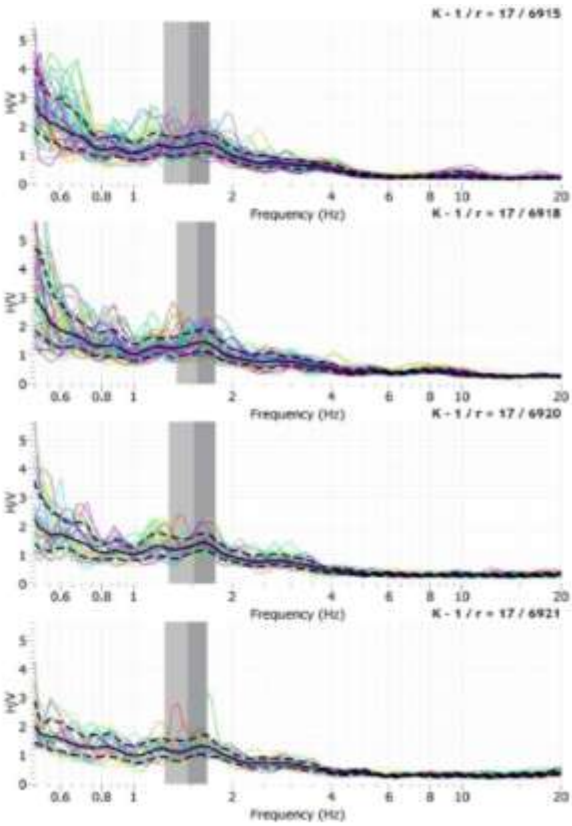

Fig. 8: Horizontal to vertical spectral ratio (HVSR) result for Karsiyaka at K1 SPAC point using 17 m criteria.

According to the results of the passive source SPAC method in Izmir Karsiyaka, it has been seen that the thickness parameter is the second most effective parameter for the dispersion curve after the S wave velocity as a result of the model trails. The increase in the thickness decreases the frequency of the phase velocity and increases the slope of the curve.

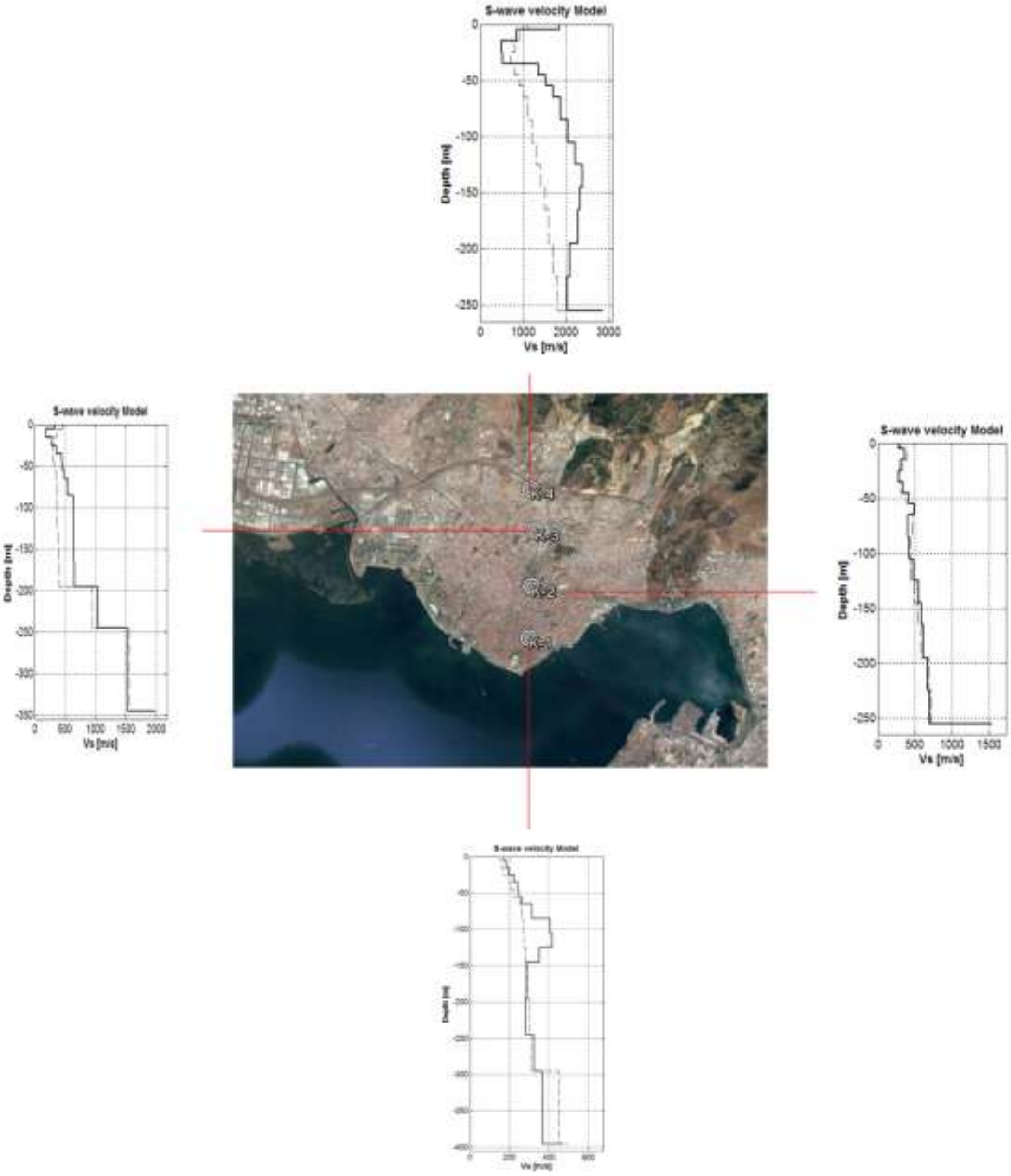

Fig. 8: Summarizing of S-wave vertical velocity models for all measurement points

IV. Conclusion

As a result of the study, it has been observed that the evaluation results of SPAC and microtremor methods are coherent. The SPAC evaluation results display that most of the study area yielded shear wave velocity (Vs) values implying the Z4 soil class except Ornekkoy (Z1) area according to Turkish Earthquake Code. K-1, K-2 and K-3, K–4 sites can be represented by E, C, and A soil classes respectively regarding the National Earthquake Hazards Reduction Program (NEHRP) and the Uniform Building Code Vs 30. Low frequency (or high period) values were observed by using microtremor method at the places where the shear wave velocities calculated by SPAC method were low. High frequency (or low period) values were also observed where high shear wave velocities were calculated. Obtained results from two different methods are coherent with geology.

The additional added value of this study is that SPAC method is one of the preferable methods in determining the velocity of shear waves for deeper layers. It is low cost and environment-friend method. Data processing stages and obtained results indicate that microtremor and SPAC techniques are sufficient to determine the soil characteristics in the study area.

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