

## Investigation of Shear Wave Velocity and Predominant Period Properties of Bornova Plain (İZMİR) and Its Surroundings

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**Abstract:** We used surface wave methods which includes single-station microtremor methods, Multichannel Analysis of Surface Waves (MASW), Refraction Microtremor (ReMi) for determining the shear wave velocity structure, which is important input parameter of ground and soil type definition in geotechnical earthquake analysis, and predominant period features of Bornova Plain (İzmir) and its surroundings in İzmir, Turkey. Engineering bedrock ( $V_s > 760$  m/s) depths are obtained in north and south parts of the study area. When compared,  $V_s$  values, predominant periods and geology are generally compatible.

**Keywords:** Shear Wave Velocity; Predominant Period; Bornova Plain, İzmir

### I. Introduction

In defining earthquake-soil common behaviour, soil-bedrock models are used as a base. In these descriptions, S-wave velocity ( $V_s$ ) is used as a base. The layers are called soil where the  $V_s$  is  $< 760$  m/s, the bigger ones are called bedrock as well [1]. Surface waves methods can be used for  $V_s$ -depth profiles. Surface waves can be classified into two groups; active source (e.g., MASW) and passive source (e.g., ReMi and spatial autocorrelation method (SPAC)).  $V_s$  and thickness values are the basic parameters to create the soil-bedrock models. Various geophysical methods (MASW, ReMi, SPAC etc.) are used for obtaining these parameters. The methods have been used by numerous researchers [2, 3, 4, 5, 11, 13, 14, 15].

The aim of this study was to determine soil characterizations that indicate shallow shear wave velocity structure and predominant period features in Bornova Plain and its surroundings, an area of İzmir (Figure 1). We utilized both active and passive surface wave methods for this purpose. The level cross sections were created up to 50 using  $V_s$  values. The soil thickness and predominant period are more than 30m and 1 sec, respectively especially close by the bay. Soil thickness and predominant period decrease towards north and south part of the study area. The pre-Neogene Bornova Complex, the Neogene andesite and limestone show engineering bedrock properties in the north and south part of the study area.

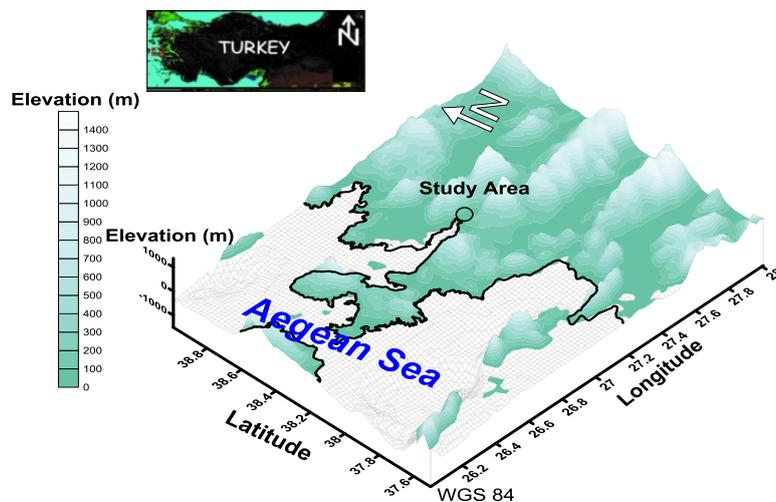


Figure 1. Location map of study area.

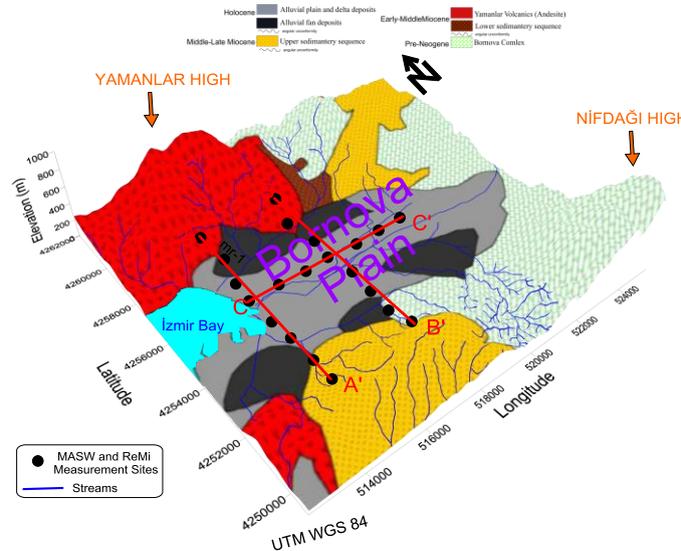
### II. Geology Of Study Area And Its Surrounding

Bornova melange is in the oldest geological unit position in the study area. Neogene aged sedimentary rocks come on to Bornova melange as unconformity. These sedimentary rocks are; pebbles, argillaceous limestones and silicified limestone. Volcanite cover the Neogene sedimentary rocks as unconformity [6,1]. According to geological studies, Miocene andesite and its derivatives are located to the north of study area and Neogene age limestones to the south of study area. The middle parts of the study area are the Quaternary

alluvial delta deposits (Figure 2).

### III. Geophysical Methods

The geophysical site characterization was utilized in the Bornova Plain and its surroundings. MASW, ReMi and single station microtremor (21 sites) measurements were carried out in the study area (Figure 2).



**Figure 2.** Location of MASW and ReMi measurement sites with geology map of the study area (geology map [modified from 7, 8]).

#### 3.1. MASW and ReMi methods

MASW, which is active surface wave method, and ReMi, which is passive surface wave method, are methods of estimating the shear-wave velocity profile from surface waves. They use the dispersive properties of Rayleigh waves for imaging the subsurface layers [9, 10]. In MASW method, surface waves can be easily generated by an impact source (sledgehammer etc.) [9]. ReMi has widely been used to determine shear wave velocity profiles using ambient noise recordings. This array analysis technique finds average surface-wave velocity over the length of a refraction array [10]. Table 1 shows that used surface wave methods parameters for this study.

The MASW data processing contains three steps basically. The first step is the preparation of a multichannel record, the second step is dispersion-curve analysis and the last step is to obtain the  $V_s$ -depth cross section using the inversion (the least-squares approach etc.). In addition, ReMi measurements were carried out at the same locations where the MASW measurements were conducted. The ReMi data processing consisted of three steps like MASW data analysis; 1) Velocity spectral (p-f) analysis. 2) Rayleigh phase-velocity dispersion picking, 3) Shear wave velocity modeling [10]. In this study,  $V_s$ -depth cross sections were obtained from combined dispersion of ReMi and MASW.

**Table 1.** Used Surface Wave Methods Parameters for This Study.

	MASW	ReMi
Recording channels	24	24
Geophone type	Vertical 4.5-Hz	Vertical 4.5-Hz
Source type	45 kg sledgehammer	-
Geophone interval	5 m	5 m
Offset	5, 10 and 15 m	-
Number of stacks	3	10
Sampling rate	0.5 ms	2 ms
Record length	1 s	30 s
Recording system	Geode	Geode

Combined dispersion curves were used in the study in order to increase the depth of the research and to identify the velocity differences that occur within the soil in detail (Figure 3). According to  $V_s$ -depth sections obtained from each measurement site, sudden velocity differences were observed in a lateral and vertical direction within the soil (Figure 4). These changes need to be considered for soil dynamic analysis studies.

Based on the Vs distributions at different depths are made for soil type identification. It has been observed that Vs values change from 100 to 1500 m/s in A-A', B-B' and C-C' cross sections.

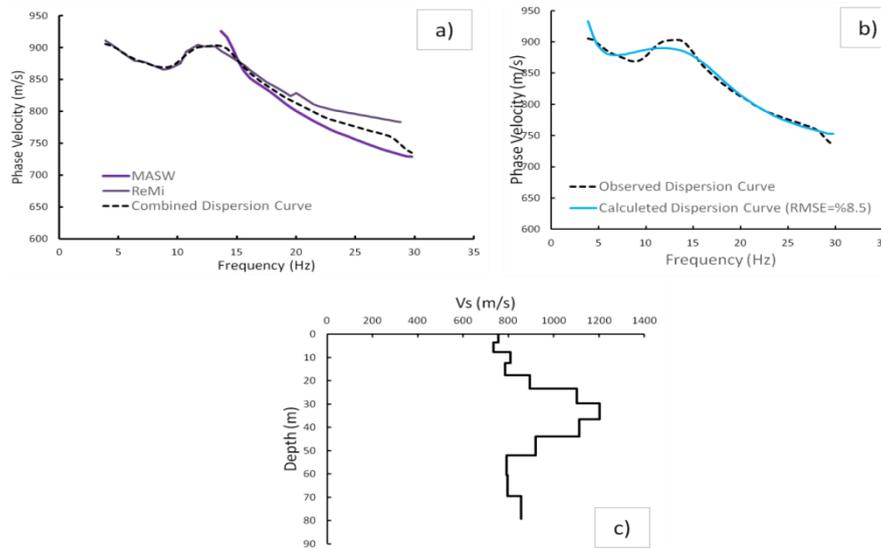


Figure 3. Vs-depth cross section were obtained by inverting the combined dispersion curve at MR1 site.

### 3.2 Single station microtremor method

Nakamura's method is based on a theory developed by Nakamura (1989), who demonstrated that the ratio between the horizontal and vertical ambient noise records related to the fundamental frequency of the soil beneath a site. Microtremor observations were carried out at 21 sites in the study area. We used Guralp Systems CMG-6TD seismometer in microtremor measurements. The recording duration was 30 minutes with a sampling rate of 100 Hz at each location. To remove intensive artificial disturbance in data processing, all signals were filtered in a band-pass of 0.05-20 Hz. Then they were divided into 80-second windows and tapered individually using the Konno-Ohmachi smoothing method. For each window, the amplitude spectra of the three components were computed using a Fast Fourier Transform (FFT) algorithm. As a result, the average spectral ratio of horizontal-to-vertical noise components was thus calculated.

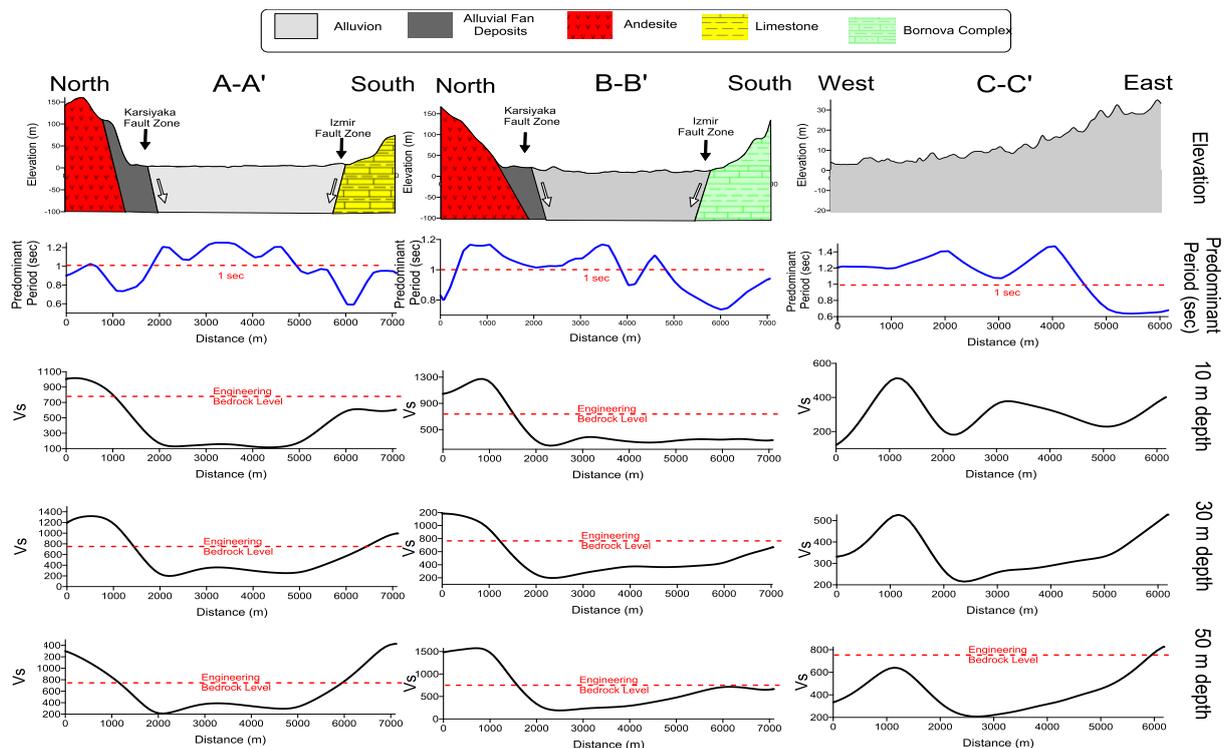


Figure 4. Average Vs distribution for different depths and predominant periods of Bornova plain and its

surroundings

#### IV. Conclusion

When these velocity changes and the geological structure of the area are considered together, andesite's and Miocene pyroclastic in the north of the study area and Miocene aged limestone and pre-Neogene aged Bornova Complex in the south of study area were observed to have higher Vs values compared to the rest of the study area. The threshold value of bedrock's Vs values is also observed higher than 760 m/s. In spite of this, Vs values change between 100 and 300 m/s especially in the areas nearby the sea and Vs values along the Bornova plain are lower than 500 m/s. The predominant period in the range of 0.6–1.4 sec, which indicates that the area exhibits lower predominant periods and less soil thickness (Figure 4).

In north and south part of the study area, decreasing in predominant period values remarked by the reason of increasing topography and finding a different geological units. The period values are observed to be higher than 1 sec and Vs values are observed to be much lower than 500 m/s, especially in Quaternary aged and mostly consist of soil layers that are thicker than 30m.

The Vs distribution profiles were obtained at five different depths, 10 m, 20 m, 30 m, 40 m and 50 m, respectively for determining the average shear wave velocity distribution with depth. When examining the Vs distribution which is created up to 50 m velocity values from 10m to 50 m at the Bornova plain in general are observed to be below 500 m/s. Due to the relative increase in velocity when going to the east away from the sea, a decrease in the soil thickness is observed. Vs values at the north and south of the bay are observed to be higher than 760 m/s. In addition, Vs values suddenly change in lateral and vertical directions between the depths of 10 m and 50 m. Therefore, it is necessary to make in-situ geophysical measurements along the study area to obtain the dynamic parameters. In addition, we suggest creating the 2D and 3D soil-bedrock models to produce more valuable results.

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