©2018 Published in 2ND International Symposium on
Natural Hazards and Disaster Management 04-06 MAY 2018 (ISHAD2018 Sakarya Turkey)

ANALYSIS OF STRONG GROUND MOTION RECORDS OF KOCAELI REGION FOR THE ASSESSMENT OF SITE FUNDAMENTAL FREQUENCY

[1]Ali Yesilyurt, [1]M.Rizwan Akram and [2]A. Can Zulfikar

[1]PhD. Students., Earthquake and Structural Eng. Department, Gebze Technical University,Turkey
[2]Asst. Prof. Dr., Civil Eng. Department, Gebze Technical University,Turkey

Abstract

Turkey ranks third on the planet as far as earthquake related losses are concerned and eighth with respect to total number of individuals affected with such natural seismic events. Disaster and Emergency Management Authority (AFAD) in Turkey manages the strong ground motion data records for the whole country. For the current research, Kocaeli province has been selected. 32 stations data is available for Kocaeli region on AFAD website. For the current research 16 stations have been taken into consideration. The objective is to identify the predominant frequencies of the station sites through the acceleration data and to investigate the site response consistency. The system consists of more than 300 strong motion records with earthquakes of magnitudes between 4.5 to 6.5 Richter scale. These recordings are thus utilized to investigate whether classical site response tool such as Horizontal to Vertical spectral ratio (HVSR) yield consistent results throughout the region of Kocaeli. In calculating HVSR, 16 stations with the number of recordings three and above have been chosen. Further, the predominant frequency values for current results have been compared with NEHRP, Eurocode 8 and Turkish Earthquake Code (TEC 2007) to assign site classes. It has been seen that results achieved from the current study shows compatibility with the site classes in the region.

Key words: Local site effects, HVSR, Strong ground motion records

1. Introduction

In structural designing, mostly horizontal component (i.e. east-west or north-south) of input ground motion has been considered for analysis. But for the design of critical structures, vertical component (i.e. up-down) also play an important role and need to be considered. Both horizontal and vertical records provide same information regarding source and path etc. which shows that there is some common relationship between both components [1].
The characteristics of earthquake shaking are affected by the local site conditions. Therefore, for evaluation of site fundamental frequency of a site, Horizontal to Vertical Spectral Ratio (HVSR) method has been used by many researchers in the past. This technique consists of using the spectral ratio of the horizontal to the vertical component of ground motion and estimates the Fourier amplitudes in different frequency ranges. Figure-1 shows the general layout of the method which was first applied to the S wave portion of the earthquake recordings obtained at three sites in Mexico City [2].

*Corresponding author: Address: Earthquake and Structural Eng. Department, Gebze Technical University, TURKEY. E-mail address: aliyesilyurt@gtu.edu.tr, Phone: +90 (262) 605 16 38

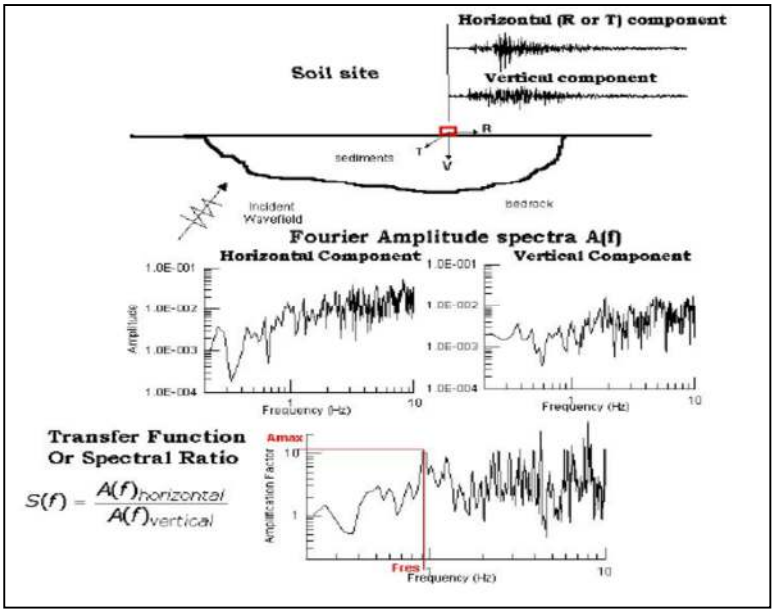

Figure 1. Description of the Horizontal to Vertical Spectral Ratio Technique (HVSR)

Local site conditions have been observed in several catastrophic seismic events in different seismic areas, for example 1985 Michoacan-Mexico [3], 1989 Loma Prieta[4], 1994 Northridge [5], 1995 Kobe [6], 1999 Kocaeli[7-11], 1999 Chi–Chi earthquake event [12] and 2000 Western Tottori [13].

Observations in recent earthquakes reveal that surface geology is one of the important parameters affecting seismic ground motion and damage. In the current study, Kocaeli province has been selected. 32 stations data is available for Kocaeli region on AFAD website [14]. For the current research 16 stations have been taken into consideration. The objective is to identify the predominant frequencies of the station sites through the acceleration data and to investigate the site response consistency. The study consists of more than 300 strong motion records with varying amplitudes. These recordings are thus utilized to investigate whether a classical site response tool such as Horizontal to Vertical spectral ratio (HVSR) yield consistent results throughout the region of Kocaeli. In calculating HVSR, 16 stations with the number of recordings three and above have been chosen. Further, the predominant frequency values for current results have been compared with NEHRP and Eurocode 8 to assign site classes. The results have been also compared with the report of the Microzonation work conducted by Kocaeli Metropolitan Municipality and TUBITAK in 2008 [15].

2. Strong Ground Motion Records for Kocaeli Province

In the current research, Kocaeli region has been selected. Total 32 station records have been available on AFAD website. Out of 32 stations as shown in figure-2 below, 16 stations has been considered for the current study. All 16 stations have number of data records given in Table-1 and all of these records have been used for evaluation of site classifications.

Figure 2. Strong ground motion stations of Kocaeli region [14]

Table-1 provides the brief introduction about the station codes, their latitude and longitude, installation date and total number of records available in each station.

Table-1 Detail of selected stations

No	Station Code	Station Latitude	Station Longitude	Province	Installation Date	Number Of Record
1	4102	40.78463	30.02649	Alikahya_Izaydas	2010-09-28	11
2	4103	40.78577	30.02504	Alikahya_Izaydas	2008-03-11	8
3	4104	40.68038	29.96998	Basiskele_Yuvacik	2010-09-28	36
4	4105	40.67441	29.96935	Basiskele_Yuvacik	2008-03-11	44
5	4107	40.76021	29.93244	Karabas	1999-09-12	33
6	4110	41.06910	30.15250	Kandira	2010-05-14	19
7	4111	40.68440	29.58880	Karamursel	2010-05-14	43
8	4112	40.72450	29.84000	Golcuk	2010-05-14	19
9	4113	40.77680	29.73350	Korfez	2010-06-10	24
10	4120	40.76761	30.02737	Alikahya	2012-04-25	15
11	4121	40.72277	29.96985	Kullar	2012-04-25	23
12	4123	40.71515	29.84794	Ihsaniye	2012-04-25	14
13	4124	40.78308	29.60625	Hereke	2012-06-06	8
14	4125	40.76650	29.91721	Kozluk_Meteor	2012-07-06	7
15	4126	40.76252	29.91485	Kozluk_Muze	2013-08-16	15
16	4128	40.72490	30.02435	Kartepe	2014-10-21	10

2.1. Local site classifications

The Metropolitan Municipality of Kocaeli and Marmara Research Center of TUBITAK have produced a microzonation report in 2008 including soil classification map for implementation of Hazard Mitigation. Figure-3 shows site classification map for Kocaeli region produced by above two agencies.
In that report, a large number of geological, geophysical surveys and investigations have been

done. These surveys contain macro level site investigations and measurements of S wave profiles for 60 types of sites that have been selected at various locations. Thus, site classification map has been developed based on the average S wave velocity passing through 30 m depth of soil. For investigation of deep underground structure of Izmit Basin, S wave profiles and gravity data from 327 points have been collected for 3D bedrock depth map development. It has been noticed that bedrock is available at the middle of the basin at a depth of 750-800 m.
HVSR method has been adopted to obtain the site resonance frequency and horizontal to vertical amplification parameters. For this, a total of 422 three component micrometer measurements have been made [15].

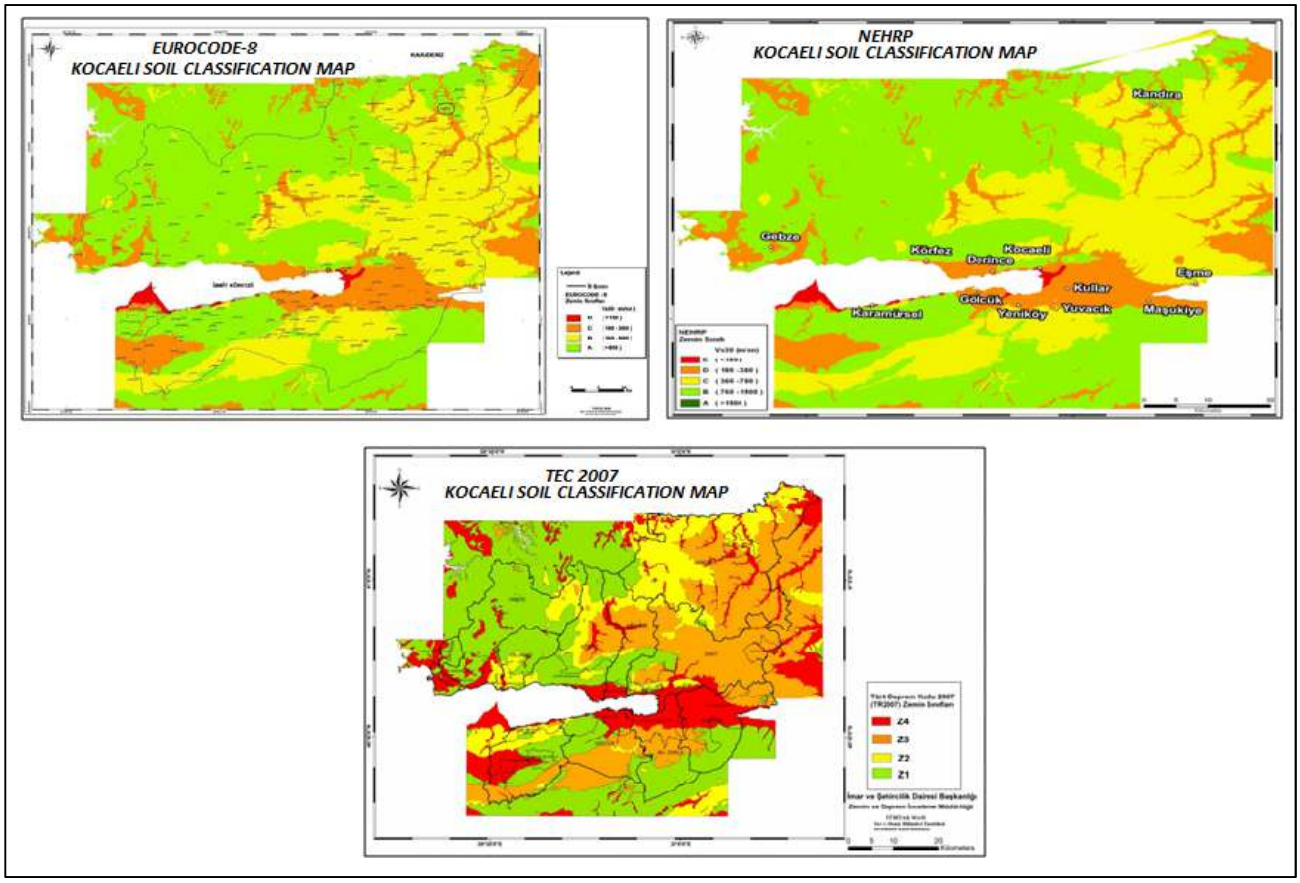

Figure 3. Kocaeli soil classification map according to Eurocode 8, NEHRP and TEC 2007[16-18]

According to the Eurocode 8 procedure adopted by the Municipality of Kocaeli and TUBITAK Marmara Research Center soil classification has been divided into four categories (A-D site classes). Similarly, According to NEHRP, soil classification has been divided into five categories (A-E site classes). Whereas, Turkish Earthquake Code 2007 classifices the soil (Z1-Z4 site classes). Figure-3 shows the soil classification map presented for Kocaeli region according to Eurocode 8, NEHRP and TEC 2007.

For the current research, Figure 3 have been used as reference maps for comparison of the results. Total 16 stations have been considered for the current research to check their soil classifications.

Strong ground motion records have been obtained from AFAD website. All three components of records have been considered. Firstly, raw data is analyzed by using MATLAB code [19] and then most suitable records are selected for further processing.

In the analysis, it has been noticed that there are noisy waves for frequencies smaller than 1 Hz and higher than 50 Hz approximately. Similar cases have been observed in the recordings for the 3 components in surface and bedrock, therefore, a baseline linear correction and a bandpass butter worth filtering, with a range of 1 Hz and 50 Hz is applied.

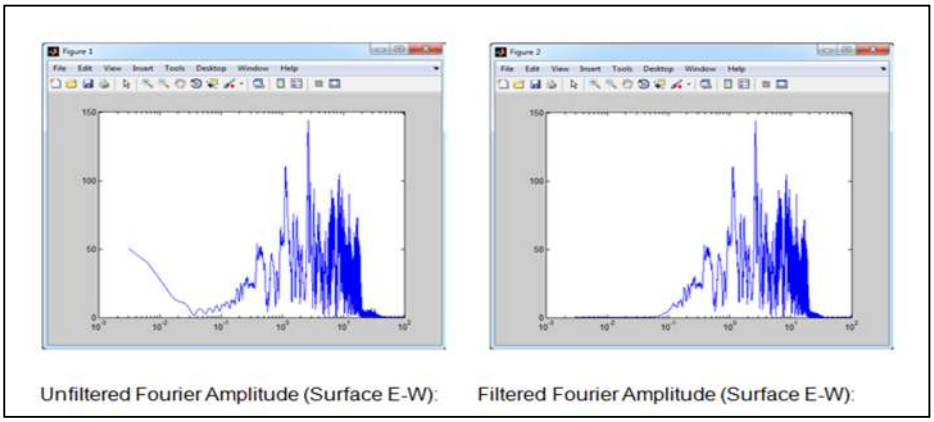

Figure4. Unfiltered (a) and Filtered (b) earthquake time history fourier spectra

After that, HVSR method has been used for current research.

$$HVSR = \frac{A(f)_{Horizontal}}{A(f)_{Vertical}}$$

Standard deviation of the HVSR ratios is shown in the Figure 5-6. The analysis shows that HVSR are consistent with each other. The obtained ratios can be grouped in the following frequency ranges: f_0<1.0 Hz, 1.0<f_0<2.0 Hz, 2.0<f_0<3.0 Hz and3.0<f_0<5.0 Hz [20].

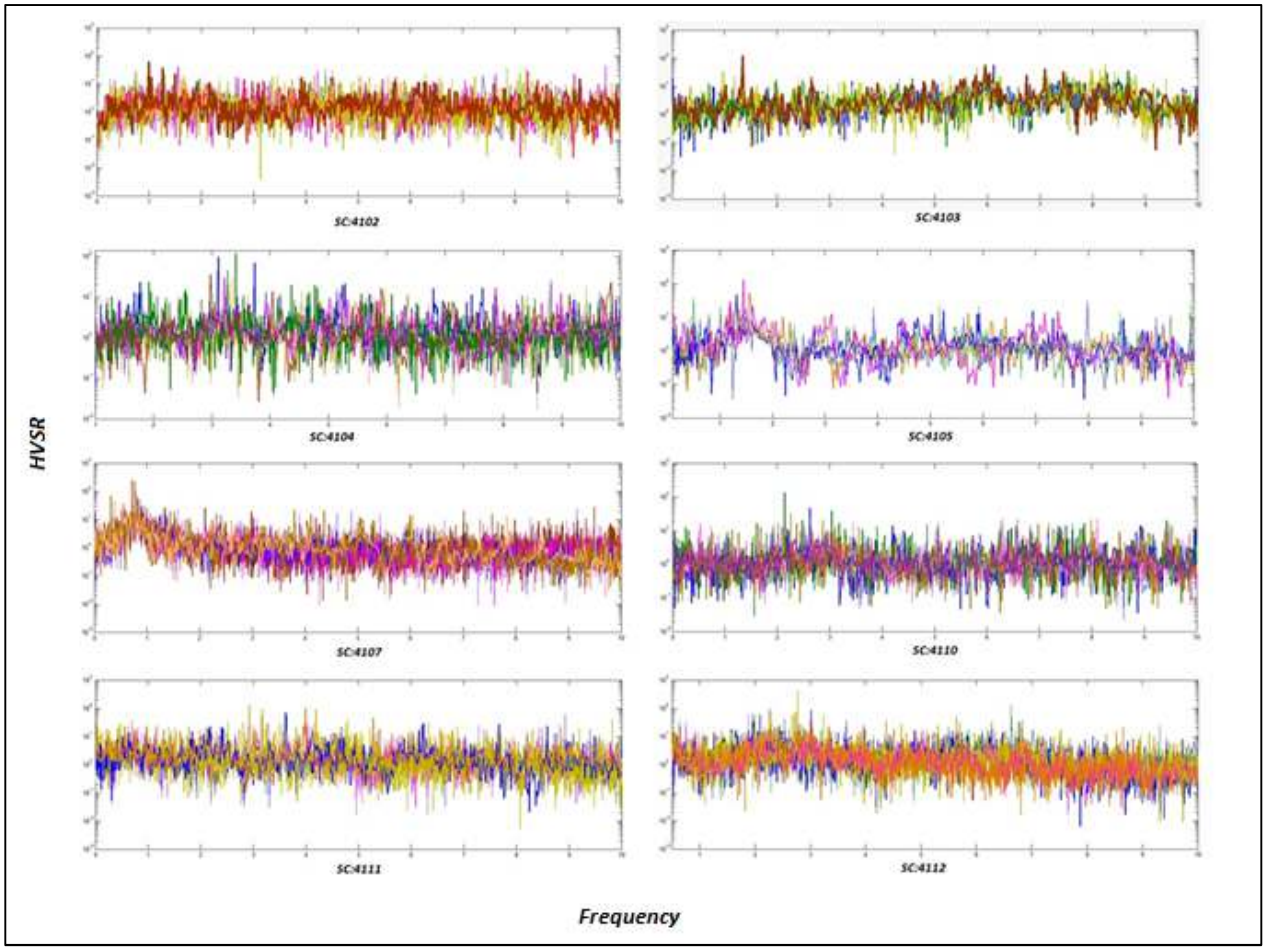

Figure5. Fundamental frequencies of the first 8 stations in Kocaeli region

From Figure-5, SC denotes station codes for selected stations. It has been observed that for SC4102, SC4103, SC4105 and SC4107, the fundamental frequency ranges $1.0<f_0<2.0$, Hence according to the current research selected station site is classified as B site.
Similarly, fundamental frequencies for SC4104, SC4111 and SC4112 are within the range of $3.0<f_0<5.0$, so such sites are classified as D class.
For SC4110, the dominant frequency range of $2.0<f_0<3.0$ has been observed, thus it is classified as C class site.

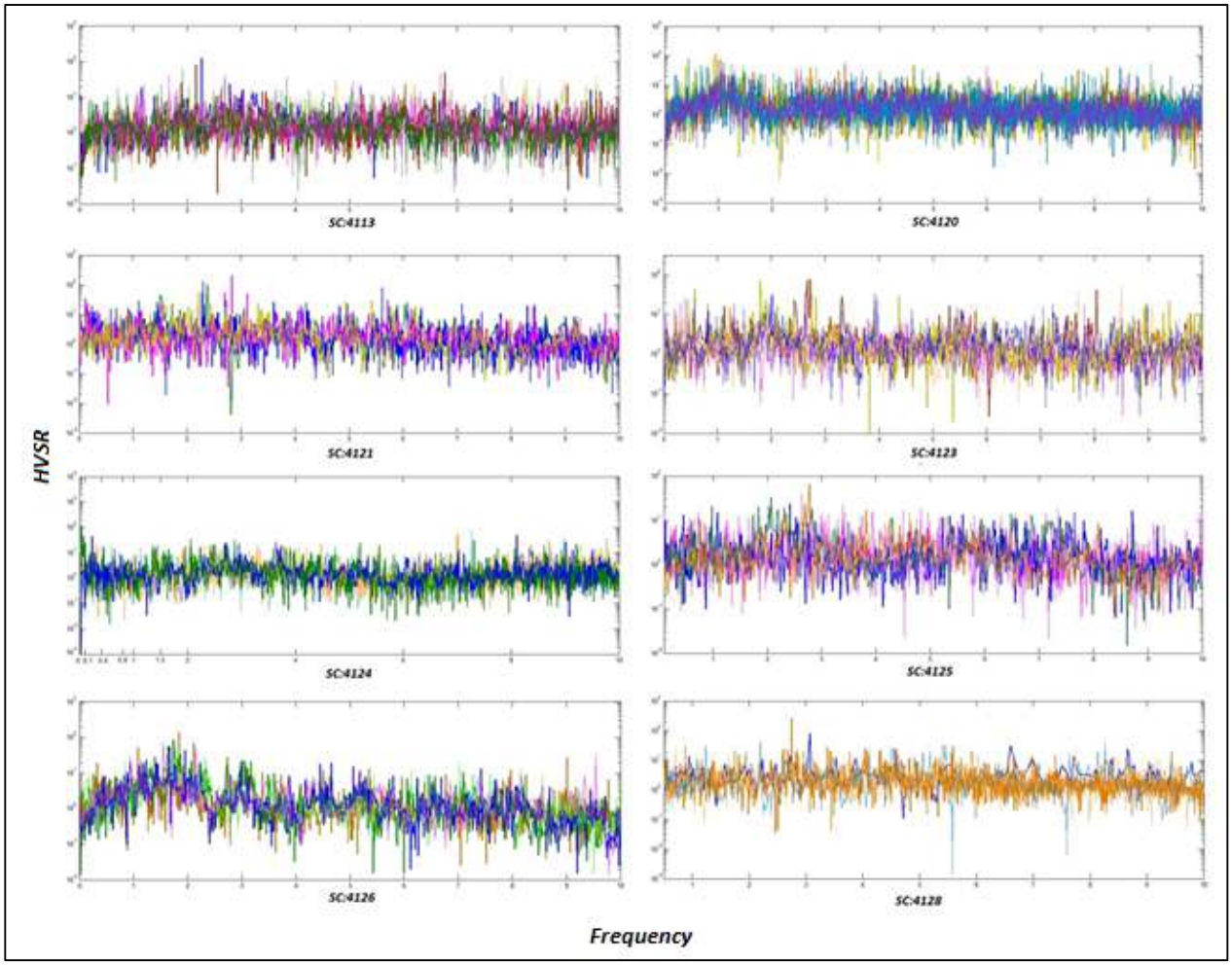

Figure 6. Fundamental frequencies of last 8 stations in Kocaeli region

From Figure 6, using HVSR method the dominant frequency has been observed for selected station sites. It has been seen that SC4113, SC 4121, SC4123, SC4125 and SC4128 are within the range of $2.0<f_0<3.0$, thus a site class C is assigned. Similarly, fundamental frequencies of SC4120 and SC4124 lies in the range of $f_0<1.0$, so, a site class A is named for that site. But the station SC4126 shows the dominant frequency range of $1.0<f_0<2.0$, it is classified as B class.

2.2. Comparison of site fundamental frequencies with the site classes

The distribution of the fundamental site frequencies for the selected Kocaeli stations is then compared with the local site classes in different codes. Site classification maps given in Figure 3 have been used for comparison. Table-2 yields the comparison results and it can be seen that HVSR provides similar results like other techniques used before for site classification. Thus, HVSR method can also be recommended for the site classification because it is simple and quick method to evaluate fundamental frequency of a site.
In the Table-2, the site classification has been done for the current study in terms of A (frequency ranges: $f_0<1.0$ Hz), B (frequency ranges: $1.0<f_0<2.0$ Hz), C (frequency ranges: $2.0<f_0<3.0$ Hz)

and D (frequency ranges: $3.0<f_0<5.0$ Hz) respectively.

Table-2. Comparison of the site classifications with the current research

					Current Research		
Station Code	**$V_{S(30)}$**	**NEHRP**	**Euro Code 8**	**TEC 2007**	**Dominant Frequency**	**Frequency Range**	**Site Classification**
4102	1000	A	A	Z1	1.0	$1.0<f_0<2.0$	B
4103	1013	A	A	Z1	1.0-2.0	$1.0< f_0<2.0$	B
4104	770	C	B	Z3	3.0-4.0	$3.0< f_0<5.0$	D
4105	-	C	B	Z3	1.0-2.0	$1.0< f_0<2.0$	B
4107	305	D	C	Z3	1.0	$1.0< f_0<2.0$	B
4110	380	D	C	Z3	2.0-3.0	$2.0< f_0<3.0$	C
4111	300	E	D	Z4	3.0-4.0	$3.0< f_0<5.0$	D
4112	352	D	C	Z3	2.0-3.0	$3.0< f_0<5.0$	D
4113	300	D	C	Z1	2.0-3.0	$2.0< f_0<3.0$	C
4120	-	A	A	Z1	1.0	$f_0<1.0$	A
4121	-	D	C	Z4	2.0-4.0	$2.0< f_0<3.0$	C
4123	-	D	C	Z3	2.0-3.0	$2.0< f_0<3.0$	C
4124	-	A	A	Z1	0.2	$f_0<1.0$	A
4125	826	D	C	Z4	3.0	$2.0< f_0<3.0$	C
4126	-	D	C	Z4	2.0	$1.0< f_0<2.0$	B
4128	-	D	C	Z4	3.0	$2.0< f_0<3.0$	C

Conclusions

Analysis of earthquake ground motion records show that all the selected stations are located at sites that can be characterized by four fundamental frequency ranges. The obtained ratios can be grouped in the following frequency ranges: $f_0<1.0$ Hz, $1.0<f_0<2.0$ Hz, $2.0<f_0<3.0$ Hz and $3.0<f_0<5.0$ Hz. Results shows that HVSR method gives reasonable similar results like other site classification techniques and can be used for the quick site response classification and analysis.

References

[1] VanKatsuhiro Shirao et al; 3World Conference on Earthquake EngineeringVancouver, B.C., CanadaAugust 1-6, 2004Paper No. 623.
[2] Lermo and Chávez-García.(1993). Site effects evaluation using spectral ratios with only one station, Bull.Seism. Soc. Am., 83, 1574 – 1594.
[3] Seed HB, Sun JH.(1989).Implication of site effects in the Mexico City earthquake of September 19, 1985 for Earthquake-Resistant Design Criteria in the San Francisco Bay Area of California, Report No. UCB/ EERC-89/03, Earthquake Engineering Research Center, University of California, Berkeley
[4] Seed RB, Dickenson SE, Riemer MF, Bray JD, Sitar N, Mitchell JK, Idriss IM, Kayen RE, Kropp AK, Harder LF, Power MS. (1990).Preliminary report on the principle geotechnical aspects of the October 17, 1989 Loma Prieta earthquake, Report No. UCB/EERC-90/05,

Earthquake Engineering Research Center, University of California, Berkeley
[5] Moehle J. (1994).Preliminary report on the seismological and engineering aspects of January 17, 1994 Northridge Erathquake. University of Calif, at Berkeley, Earthquake Engineering Research Center, Report No. UCB/EERC-94/01
[6] Takemiya H, Adam M. (1997).Seismic wave amplification due to topography and geology in Kobe during Hyogo-Ken Nanbu Earthquake. J StructMechEarthqEng 14(2):129–138
[7] Erdik M, Doyuran V, Gulkan P, Akkas N. (1985).A probabilistic assessment of the seismic hazard in Turkey. Tectonophysics 117:295–344
[8] Tezcan SS, Kaya E, BalIE, Ozdemir Z. (2002).Seismic amplification at Avcılar, Istanbul. EngStruct 22:661–667
[9] Ergin M, Ozalaybey S, Aktar M, Yakin MN.(2004).Site amplification at Avcilar, Istanbul. Tectonophysics 391:335–346
[10] Ozel O, Sasatani T. (2004).A site effect study of the Adapazari basin, Turkey, from strong and weak-motion data. J Seismol 8(4):559–572
[11] Cabalar AF, Cevik A. (2009).Genetic programming-based attenuation relationship: an application of recent earthquakes in Turkey. ComputGeosci 9:1884–1896
[12] Pavlenko OV. (2008).Characteristics of soil response in near-fault zones during the 1999 Chi–Chi, Taiwan Earthquake. Pure ApplGeophys 165(9–10):1789–1812
[13] M. Rizwan Akram et al. 4th International Conference on Earthquake Engineering and Seismology, 11-13 October 2017, Anadolu University Eskisehir, Turkey
[14] Disaster and Emergency Management Authority (AFAD). (2009). Retrieved from https://www.afad.gov.tr/
[15] The Metropolitan Municipality of Kocaeli and Marmara Research Center of TÜBİTAK report towards Site Classification and Seismic Hazard Assesment of Kocaeli Province of Turkey (October, 2008) Retrieved from https://www. kocaeli.bel.tr/
[16] CODE, Price. Eurocode 8: Design of structures for earthquake resistance-Part 1: General rules, seismic actions and rules for buildings. Brussels: European Committee for Standardization, 2005.
[17] National Earthquake Hazards Reduction Program (US), Building Seismic Safety Council (US), & United States. Federal Emergency Management Agency. (2001). NEHRP recommended provisions for seismic regulations for new buildings and other structures. Building Seismic Safety Council.
[18] Code, T. E. (2007). Specification for buildings to be built in seismic zones. Ministry of Public Works and Settlement, Government of Republic of Turkey.
[19] Guide, Matlab User's. The mathworks. Inc., Natick, MA, 1998, 5: 333.
[20] A.C Zulfikar, H Alcik and E Cakti. Analysis Of Earthquake Records of Istanbul Earthquake Rapid Response System Stations Related to the Determination of Site Fundamental Frequency.15 WCEE Lisbon 2012.