Determination of fundamental vibration period from microtremor and down-hole methods (case study: Qazvin)

Asghar Azadi[1], Mozhdeh Azadi[2],Alireza Siahvoshi[3]

[1]*Assistant Professor, Payame Noor University,Parand, Tehran, ,asghar_azadi_2007@yahoo.com*
[2]*M.Sc. Student,Islamic Azad University, Science and Research Branch, Tehran, ,mozhdeazadi1990@gmail.com*
[3]*M.Sc. Student,Islamic Azad University, Science and Research Branch, Tehran, ,ar.siahvoshi@gmail.com*

ABSTRACT

In order to completing geotechnical information and determining of resonance frequency in the Qazvin site, Single station microtremor measurements and downhole methods were carried out. Single station microtremor measurements were done at 5 stations in the Qazvin site. Data were recorded by 2 Hz seismometers and were processed based on the Nakamura (1989) method. The resonance frequency of the ground were determined from the horizontal to vertical (H/V) spectral ratios of microtremors and was developed for the site on the basis of the variation of the resonance frequency. Also, seismic profile testes with depth of 30 m and spacing 1.5 m included shear wave velocity with 3 channel have been done. Ultimately the results of microtremor measurements and down-hole methods were compared. The results indicated that both methods are in agreement with each other with the average value of 3.46 and 4.5 (s) for vibration period.

Keywords: Nakamuramethod, resonance frequency, horizental to vertical (H/V), microtermore, down-hole methods

INTRODUCTION

Among the empirical methods the H/V spectral ratios on ambient vibrations is probably one of the most common approaches. The method, also called the “Nakamura technique” (Nakamura, 1989), was first introduced by Nogoshi and Igarashi (1971) based on the initial studies of Kanai and Tanaka (1961). Since then, many investigators in different parts of the world have conducted a large number of applications

For estimation the resonance fundamental frequency of the ground in the site, single station microtremor were measured at about 5 stations. Data measurements were taken according to sesame (2004) guidelines. Recording duration at each measurement was 60 minutes (two 30 minute). The processing was done based on the Nakamura (1989) method and sesame (2004) recommendations.

On the other hand, a code for inversion of layered ground structures from horizontal-tovertical spectral ratios of microtremor was published by Herak (2008). Sánchez-Sesma et al. (2011) introduced an innovative method inspired in the possibility of retrieving the 3D elastodynamic Green’s tensor between two stations embedded in an elastic medium from the average time-domain cross-correlation of their ambient noise records (ambient noise interferometry). Some applications of this method have been developed by Salinas et al. (2014), the theoretical foundations of this general theory were developed in several research works (and confirmed in experiments with microtremors by Shapiro and Campillo (2004). The equations used here for modelling the HVSRN appear naturally in the particular case of the interstation distance tending to zero. Method described by Knopoff (1964). Equivalent results can be obtained using a generalized view of the modal equipartition proposed by Margerin (2009). A more complete review of these theories appeared recently in Lunedei and Malischewsky (2015). The authors made a thorough description of the various theoretical models explaining the HVSRN that developed in the last three decades, including the diffuse field assumption, and compared the corresponding theoretical curves for a set of test models.

METHODOLOGY

Stability of the H/V ratio shows that it can be applied to determine the site characteristics. The resulting spectrum is independent of source and path and is used to determine fundamental periods or predominant frequencies, which appear as peaks in the spectra. The HVSR method eliminates the requirement of a reference or basement site to derive the transfer function for sedimentary basins.Schematic Diagram of the H/V Microtremor Method is Shown(Figure 1).It has well been accepted that the H/V peak period represents the natural site period of the ground. However, the interpretation of the H/V ratio is different among different researchers.

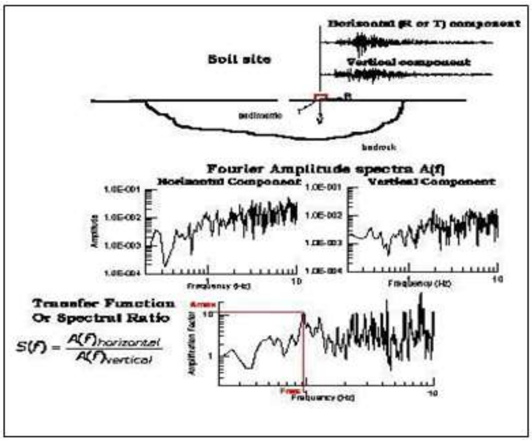

Figure1.Schematic Diagram of the H/V Microtremor Method

Microtremorstudies

For estimation the resonance fundamental frequency of the ground in the site, single station microtremor were measured at about 5 stations. Microtremor data were collected on Sara SL07, The SL07 consists of a 24 bit 3 channel digitizer a GPS receiver and a CPU with recording capability. Data measurements were taken according to sesame (2004) guidelines. Recording duration at each measurement was 30 minutes. The processing was done based on the Nakamura (1989)   method and sesame (2004) recommendations.

The resonance frequency of the ground vibration at each station was then estimated from the H/V Spectral ratio plots. The H/V spectrum ratio were plotted for each Stations. For example the H/V curve at Station 5 is displayed in Figure 2. The obtained resonance frequency of each station(table1).

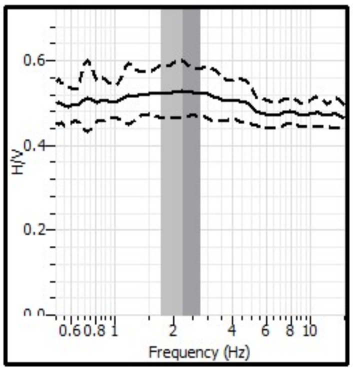

Figure (2).H/V curve at S5

Table 1. Obtained resonance frequency

Station	Fo
S1	3.2
S2	3.2
S3	4.5
S4	4.2
S5	2.2
average	3.46

Down hole test

Identifying subsurface layers condition and its dynamic properties are main factors in dynamic analysis of construction. In order to completing geotechnical information, seismic testes down-hole has been done. In this study 3 down-holes seismic profiles of p-wave has been taken.Three down hole seismic profile with depth 30 m and spacing 1.5 m,the changing of compressional and shear velocity verse depth is plotted in Figure 3. A summary result of site soil classification is presented in table (1). The result of geotechnical information from three bore holes drilled in the investigated site are summarized in figure. As it can be seen from logs (figure4), the constituent materials are the mainsilty clayey and SPT N-value greater than 50 in the studied area which are in the agreement with downhole results.

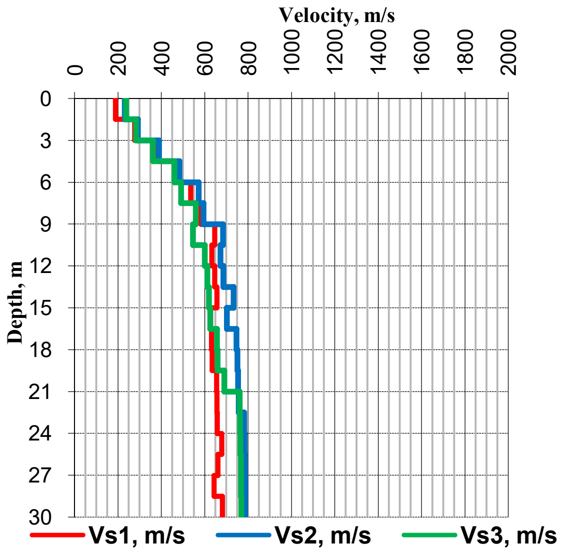

Figure 3.the changing of compressional and shear Velocity verse depth in three boreholes

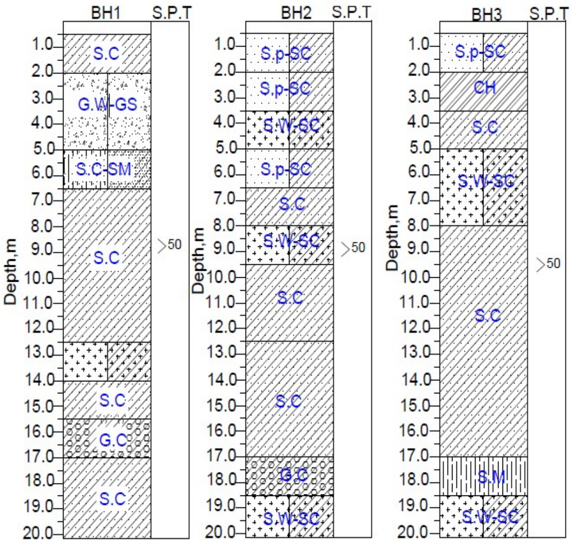

Figure 4.the result of geotechnical surveys

Various techniques have been used in applications of determination of earthquake risks and micro-zoning based on GIS in accordance with the variation of the shear wave velocity (Huntera, J. A. et all., 2002). Map of fundamental vibration period of the ground (T_f) is one of the maps used for determining regional earthquake risk that makes use of the shear wave velocity. Figure 5. Locations of geophysical resistivity measurements Fundamental vibration period of the ground (Tf) is determined using the following equation. According to (Huntera, J. A. et all., 2002):

$$T_f = \frac{4\times V_S}{H} \qquad (1)$$

Where: H = the thickness of the alluvial ground focal length and Vs = the average shear wave velocity the vibration period of the ground is presented in table 2.which is higher than the values from the microtremor measurements**.**

Table 2. Summary result of site soil classification

Borehole no.	Mean Vs of 30 mm/sec	2800 code type	IBCtype	T_f(S)
BH-1	516	II	C	4.3
BH-3	577	II	C	5
BH-5	538	II	C	4.5

CONCLUSION(S)

The variation of the resonance frequency map in the study area was extracted. The zonation was according to IBC site classification system. The other extracted map is Amplification factor map. This map shows that the most of the site has amplification factor of 2-3 and less than 2.The results from this study are expected to serve as a basis for a detailed seismic hazard assessment of the site. Such study provides a basis for site-specific risk analysis, which can assist in mitigating earthquake damages.

From this study, it is clearly shown that the fundamental frequency of ground vibration is high. Close earthquakes can cause ground vibration with a short period in the region.There is a relation between the period at a corresponding PGA (T) level and he period from microtremor observations (T0) as below (Tuladhar, 2002):

$$T=T0\ (1.74\times PGA+1) \qquad (2)$$

Fundamental frequency of site is between 2 to 4 Hz. By assuming 3 Hz as the fundamental frequency of site (0.33 s as fundamental period) and also maximum 0.2 g of PGA (based on the past Bushehr earthquake events), it is expected that the Bushehr earthquakes have period as 0.44 s or frequency of 2.3 Hz. Which means that the earthquakes of this area are high frequency (short periods) events. Hence, special attention should be given towards earthquake resistant structures, especially the structures with short natural periods.

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