Preliminary results on the implementation of the H/V spectral ratio technique on ambient vibrations in the town of Yambol

Предварителни резултати от прилагането на метода на H/V спектрално съотношение за анализ на случаен шум за град Ямбол

Dragomir Gospodinov[1], Boyko Ranguelov[1], Vassilios Karakostas[2], Eleftheria Papadimitriou[2], Atanas Tanev[1], Aleksandre Kandilarov[3]
Драгомир Господинов[1], Бойко Рангелов[1], Василис Каракостас[2], Елефтерия Пападимитриу[2], Атанас Танев[1], Александър Кандиларов[3]

[1] Geophysical Institute, Bulgarian Academy of Science, Sofia; E-mail: drago_pld@yahoo.com; branguelov@gmail.com
[2] Geophysics Department, Aristotle University of Thessaloniki, GR54124 Thessaloniki, Greece;
E-mail: vkarak@geo.auth.gr; ritsa@geo.auth.gr
[3] Bergen University, Norway; E-mail: kandilarovi@gmail.com

Key words: ambient vibrations, H/V Technique, site effects, fundamental frequency, bedrock

Introduction

A significant part of damage observed in destructive earthquakes around the world is associated with seismic wave amplification due to local site effects. Site response analysis is therefore a fundamental part of assessing seismic hazard in earthquake prone areas. Usually the procedures for evaluation of the site effects contribution to seismic hazard assessment are quite expensive. Ambient vibration recordings combined with the H/V spectral ratio technique present a cheaper alternative both for the survey and analysis. A number of experiments are required to evaluate local site effects. 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. An important requirement for the implementation of the H/V method is a good knowledge of the local geological conditions supported by geophysical and geotechnical data. However, it should be pointed out that the H/V technique alone is not sufficient to characterize the complexity of site effects and in particular the absolute values of seismic amplification. The method has proven to be useful to estimate the fundamental period of soil deposits. However, measurements and the analysis should be performed with caution. The main recommended application of the H/V technique in microzonation studies is to map the fundamental period of the site and help constrain the geological and geotechnical models used for numerical computations. In addition, this technique is also useful in calibrating site response studies at specific locations. In spite of its limitations, the H/V technique is a very useful tool for microzonation and site response studies. This technique is most effective in estimating the natural frequency of soft soil sites when there is a large impedance contrast with the underlying bedrock. The method is especially recommended in areas of low and moderate seismicity, due to the lack of significant earthquake recordings, as compared to high seismicity areas. This is exactly the case with the seismic zone around Yambol and this motivated us to perform ambient noise measurements in the town and evaluate the fundamental frequencies at the considered points.

Data, method and results

We executed ambient noise measurements at 38 points around the whole town of Yambol, which were scattered on a nearly uniform grid. The average distance between two points is 800–1000 m and this makes the grid quite sparse but our aim was to check whether there is any variability in the fundamental frequency values. A positive answer to this question should stimulate us to continue the analysis on a

denser grid. The measurements in the Municipality of Yambol were performed using a GeoSIG GBV-316 portable seismic station. The GBV-316 is a three component data acquisition system equipped with a sixteen bit digitizer. The H/V Spectral Ratio Technique on ambient vibrations is a cheap and easy-to-use method. It was proposed in 1989 by Nakamura (Nakamura, 1989) for estimating the site response spectra. It makes use of ambient seismic noise that is always present in the Earth. It is based on the spectral ratio of the horizontal and the vertical components of a short seismic record and it provides a reliable estimate of the fundamental site frequency. That is the frequency on which the strongest amplification occurs due to local site effects and therefore it is the most important from seismic hazard perspective. The method has been refined and dedicated software has been developed during the extensive 3-years project ***S***ite ***E***ffect***S*** assessment using ***AM***bient ***E***xcitations (SESAME), funded by the European commission (Atakan, 2003). The methodology requires some minimal length of the measuring time periods according to which we determined a 20 minutes period of ambient noise recording for each point (two records of 10 minutes). The recordings were analyzed through the J-SESAME software. It is a multi platform H/V processing software (Atakan, 2003). J-SESAME is a JAVA program for providing graphical interface for calculating H/V spectral ratios from records of ambient seismic noise. The program consists of four basic modules — browsing module, window selection module, processing module and display module. In the browsing module we organize the data in individual projects. We create a project for each area and the different points in that area, for which we have measurements, are displayed as subfolders of the project folder. For the most adequate interpretation of the obtained results about the fundamental frequencies we needed to have geological and geotechnical information about Yambol. We managed to supply data about the bedrock depth for about 40 points in the town. A specific feature of this data for the town is that the bedrock depth varies considerably through the town territory from nearly zero to about 100 m. According to the applied methodology this should reflect in the lateral variation of the fundamental frequency, too. Really our results revealed that the fundamental frequency deviations follow the changes in the bedrock depth and bigger frequencies related to smaller depth. The applied technique provides a possibility that if the local thickness is known, the average S-wave velocity of the surface layer may be estimated with the formula $V_{S,\,av} \approx f_0.4h$; if a reliable estimate of the S-wave velocity $V_{S,\,surf}$ is available close to the surface, then a lower bound estimate of the thickness may be obtained with the formula $h_{min} \approx V_{S,\,surf}/4.f_0$. Knowing the bedrock depth and the fundamental frequency at a number of points allowed us to assess the S-wave velocity at these sites and the results are in agreement with the velocities known for the type of soils at the points.

Conclusions

The applied H/V Spectral Ratio Technique on ambient vibrations turned to be an inexpensive and easy-to-use method which gave us the possibility to determine the fundamental frequency values at a number of sites around the whole town of Yambol. The observed lateral variation of the determined frequencies are in a certain correlation with the changes of the bedrock depth in the town territory and using both sets of data gave us the possibility to assess the S-wave velocity at some of the examined sites. On our knowledge this is one of the first applications of this technique in Bulgaria after the study made by Kandilarov in 2006 for the central part of Plovdiv and the results exhibit the method as a suitable tool in site effects assessment as part of the general microzonation procedure.

References

Atakan, K., P.-Y. Bard, B. Moreno, P. Roquette, A. Tento. 2003. *J-SESAME User Manual. Multiplatform H/V Processing Software. SESAME Project WP03 H/V Technique: Data Processing*. Department of Earth Science, University of Berge, 12 p.

Nakamura, Y. 1989. A method for dynamic characteristics estimation of subsurface using microtremor on the ground surface. — *Quarterly Report Railway Tech. Res. Inst.*, *30-1*, 25—30.

Kanai, K., T. Tanaka. 1961. On Microtremors. VIII. — *Bull. of the Earthquake Research Institute*, *39*, 97—114.

Nogoshi, M., T. Igarashi. 1971. On the amplitude characteristics of microtremor (part 2). — *Jour. Seism. Soc. Japan, 24*, 26—40.