Comparison of Geopsy and J-Sesame software results from the ambient noise analysis at some new sites in Plovdiv, Bulgaria

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Abstract
New recordings of seismic noise in an unexplored area on the territory of Plovdiv have been analyzed in this paper for defining the so-called fundamental frequency for each point of registration relevant to the assessment of seismic hazard. Seismic hazard research is critical to safety when a future earthquake occurs. Its estimation at a site is based on three elements, among them general seismicity, affecting the site, the seismic waves attenuation laws and last but not least, site conditions are an important factor, influencing seismic hazard. The estimated fundamental frequencies are for a region, where two basic types of buildings are observed – low height houses (one-two stories) and higher buildings (7-8 stories). The estimated frequency values vary in the range 0.9 – 2.5 Hz, which puts smaller buildings at bigger danger from seismic impact. The studied region borders one of Plovdiv hills and there the highest fundamental frequency was determined (~ 2.5 Hz) which is in line with theory, because near the hill the bedrock at lower depth. We applied two different software packages – Geopsy and J-Sesame and the obtained results are quite similar, which reveals that we can use any of them, depending on the initial data formatting.

Сравняване на резултатите от анализа на случаен сеизмичен шум в някои точки в Пловдив с помощта на софтуерните програми Geopsy и J-Sesame

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Резюме
В настоящата статия са анализирани нови записи на сеизмичен шум в неизследвана зона на в Пловдив за определяне на т.нар. фундаментална честота за всяка точка на регистрация, свързана с оценката на сеизмичната опасност. Изследванията на сеизмичната опасност са критични за безопасността при възникване на бъдещо земетресение. Сеизмичният хазарт в определена точка се основава на три елемента: обща сеизмичност, засягаща точката, законите за затихване на сеизмичните вълни и локалните условия. Оценените фундаментални честоти са за регион, където се наблюдават два основни типа сгради - с малка височина (1-2 етажа) и по-високи сгради (7-8 етажа). Изчислените стойности на честотата варират в диапазона от 0,9 - 2,5 Hz, което поставя по-малките сгради в по-голяма опасност от сеизмични въздействия. Районът граничи с един от хълмовете на Пловдив и там е определена най-високата фундаментална честота (~ 2.5 Hz), която е в съответствие с теорията, защото близо до хълма скалната основа е на по-малка дълбочина. Приложихме два различни софтуерни пакета - Geopsy и J-Sesame, а получените резултати са доста сходни, което показва, че можем да използваме който и да е от тях.

Introduction

The shallow structure of the Earth's crust is of great importance in analyzing the engineering characteristics of the site of exploration as well as in seismic hazard research at the site. investigating seismic hazard is of particular importance for safety in the event of a future earthquake and it is based on three main elements.
The first element is related to the whole seismicity that would affect the point in the future. The second element explores the attenuation laws of seismic waves with distance. The third element examines the impact of local conditions on the site on the seismic signal. Over the last fifteen to twenty years, particular attention has been paid to the third element, which until then has been less studied, is examining the local conditions in a particular location. These site conditions can be investigated as some physical characteristics of the rocks, such as mechanical wave velocity, depth to bedrock, etc. There are different ways of analyzing these features, one of the ways being by drilling.. Drilling provides the most complete and accurate information about the shallow Earth's crust structure, however, is very expensive and can only be applied to selected points. Other auxiliary methods of investigation are by using some geophysical methods of measurement and analysis of the magnetic gravitational field as well as some electrical properties of the rocks.
A relatively new approach of examining local conditions is by analyzing random seismic noise recorded below the point of investigation, with the term random being understood as noise without sufficiently accurately determined

origin (Bard et al, 2003). One such method was first developed by the Japanese scientist Nakamura (Nakamura, 1989), later defined as the horizontal to vertical spectral ratio (HVSR) method. This method allows determining the depth to the bedrock below a given point and in the presence of some additional data, to determine the velocity of the transverse waves in the layer below the measuring point. It is based on the analysis of the ambient noise recordings and their spectral characteristics for particular sites. Similar studies have been done before for Plovdiv (central part; Kandilarov et al., 2009), using the J-Sesame software for the spectral processing. The purpose of the current study is to consider some new points outside the city center and to verify whether there would be a difference in the obtained results if another software (Geopsy) is also applied.

Methods

To determine the response spectrum for a site Nakamura (1989) offers an inexpensive and easy-to-use method. It analyzes ambient seismic noise (microseismic noise), which is always present in the shallow layers of the earth. It is based on the spectral ratio of the horizontal and vertical components of a short seismic record, and by analyzing it, a reliable estimate of the fundamental frequency f_0 of the recording location can be presented. This is the frequency at which the greatest increase of this ratio occurs due to conditions below the recording point. This amplification is of great importance and is a particularly important factor in the study and evaluation of seismic hazard.
According to Nakamura, the spectrum of horizontal surface movements is influenced by the seismic noise in this layer, which is present as Relay waves (Nakamura, 1989; 2000). The effect of Relay waves must be reflected in the vertical component spectrum, but it should not be included in the spectrum of vertical movements of the bedrock.
The technique is known as the Nakamura technique or Horizontal to vertical (H/V) spectral ratio (HVSR) technique. Using this technique gives many advantages, one of which is that we do not need a reference point to compare, so we do not have to wait for a seismic event. But its biggest advantage is that it is cheap and easy to apply. A big advantage over other methods is that when calculating the H / V spectral ratio, the method gives very good experimental results consistent with underground geology at the site, but estimating the amplification factor is not that successful.

Results

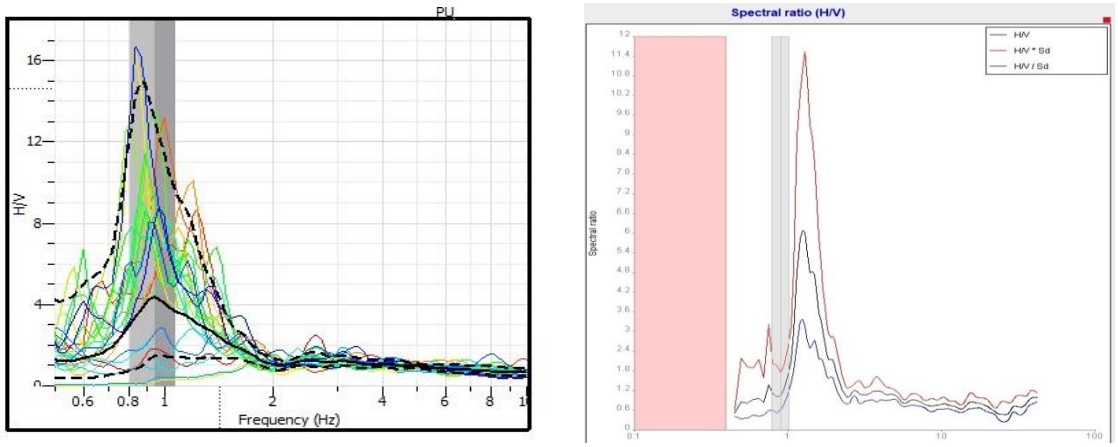
In our studies we used the HVSR technique to examine an unexplored area from the city of Plovdiv in its western part. The measurements were made by a network of points distant at 150 m from each other, with three records being recorded at each point for ten minutes. The network of points at which the records are made is shown in Fig.1. The results for the fundamental frequency f_0 were obtained by both, Geopsy and J-Sesame software, and after that they were compared. We show on Fig.1 the results only for several points of the ones, we analyzed, which we think, are enough to reveal whether both software are similar.

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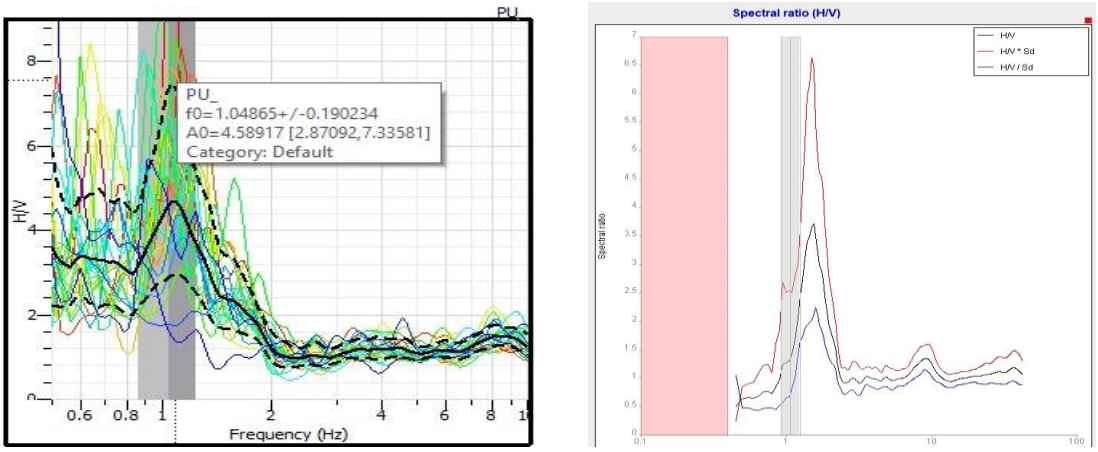
Fig.1 A network of points (green circles), at which the recordings were made, located in the western part of Plovdiv.

As can be seen on Fig.1, the estimated fundamental frequencies are for a region, where two basic types of buildings are observed – low-height houses (one-two stories in the eastern part of the area) and higher buildings (7-8 story block of apartments in the western sector of the region). The fundamental frequency values vary in the range 0.9 – 2.5 Hz, which puts smaller buildings at bigger danger from seismic impact. That is because their own resonance frequencies are in this range, too (Dikmen & Mirzaoglu, 2005). The studied region is next to one of Plovdiv hills and there the highest fundamental frequency was determined (~ 2.5 Hz) which is in accordance with theory, because near the hill the bedrock at lower depth and shallow bedrock leads to higher fundamental frequencies. We applied two different software packages – Geopsy and J-Sesame and the obtained results are quite similar, which reveals that we can use any of them, depending on the initial data formatting.



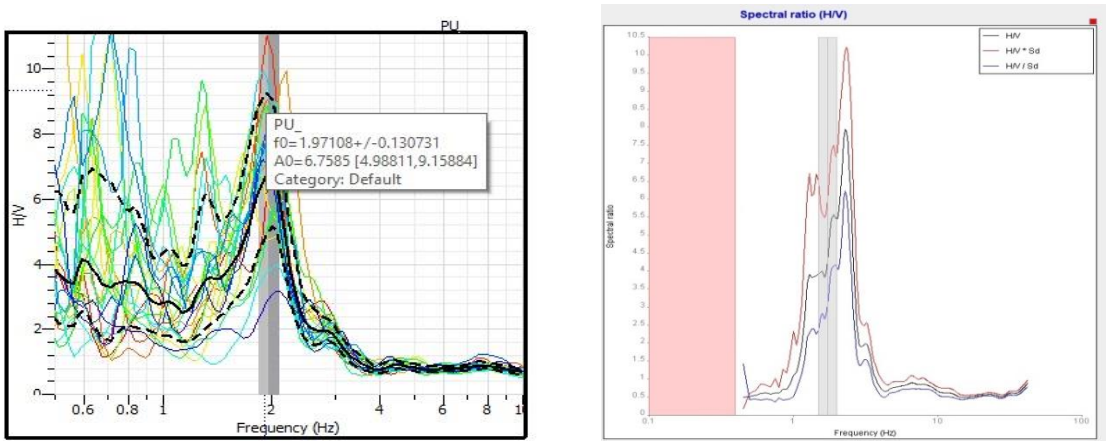
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Fig.2 The results of the estimated fundamental frequency f_0 at point P0201 for the two processing software: a) Geopsy – 0.94Hz; b) J-Sesame – 0.95 Hz



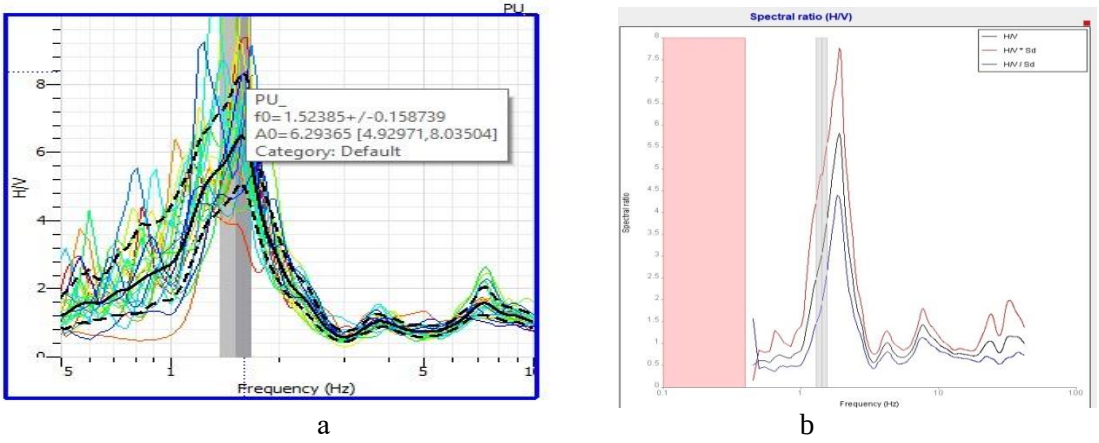
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Fig.3 The results of the estimated fundamental frequency f_0 at point P0209 for the two processing software: a) Geopsy – 1.04 Hz; b) J-Sesame – 1.08 Hz



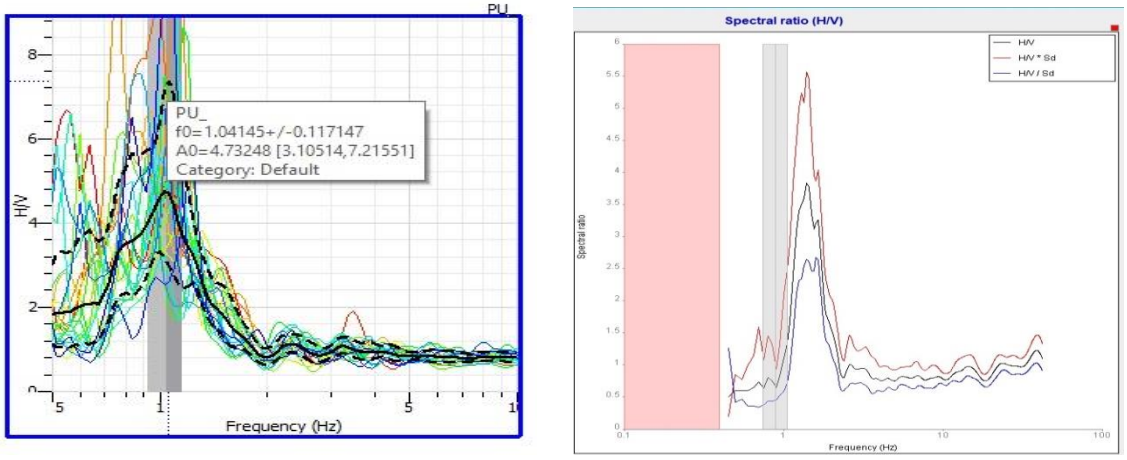
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Fig.4 The results of the estimated fundamental frequency f_0 at point P0215 for the two processing software: a) Geopsy - 1.97Hz; b) J-Sesame - 2.1Hz



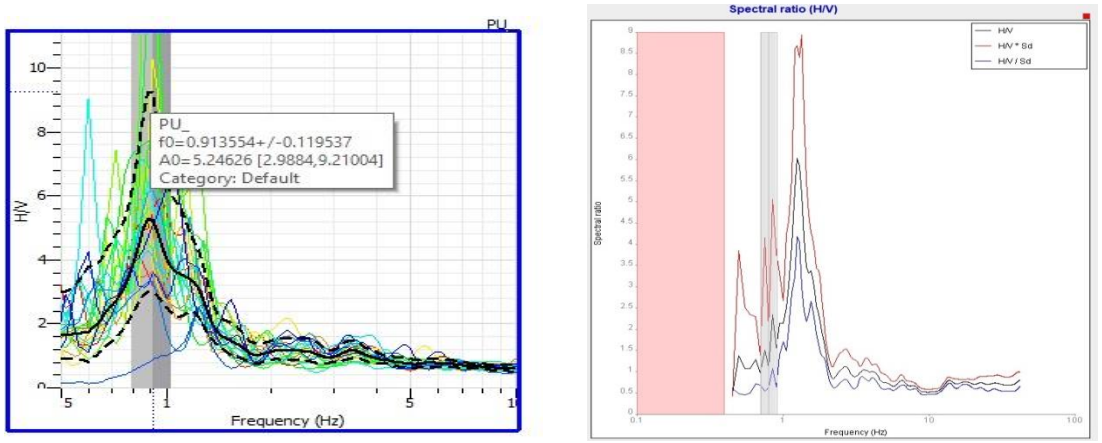
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Fig.5 The results of the estimated fundamental frequency f_0 at point P0217 for the two processing software: a) Geopsy - 1.52Hz; b) J-Sesame – 1.54Hz



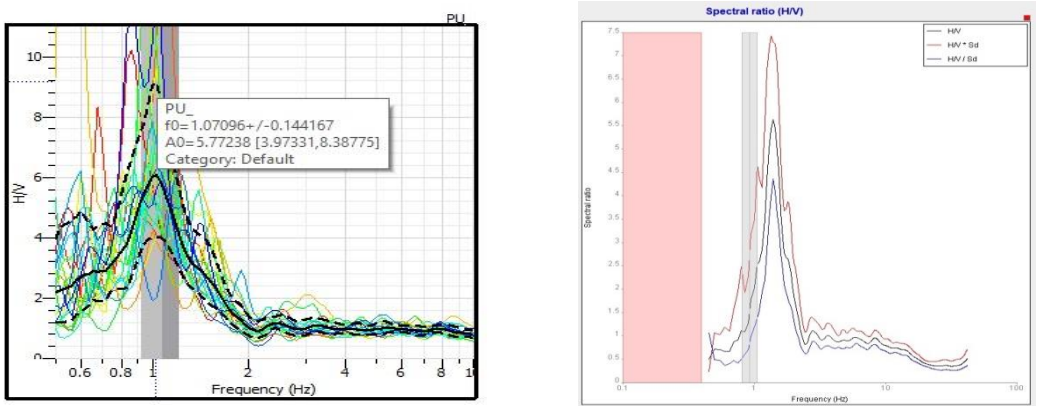
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Fig.6 The results of the estimated fundamental frequency f_0 at point P0224 for the two processing software: a) Geopsy - 1.04Hz; b) J-Sesame – 0.94Hz



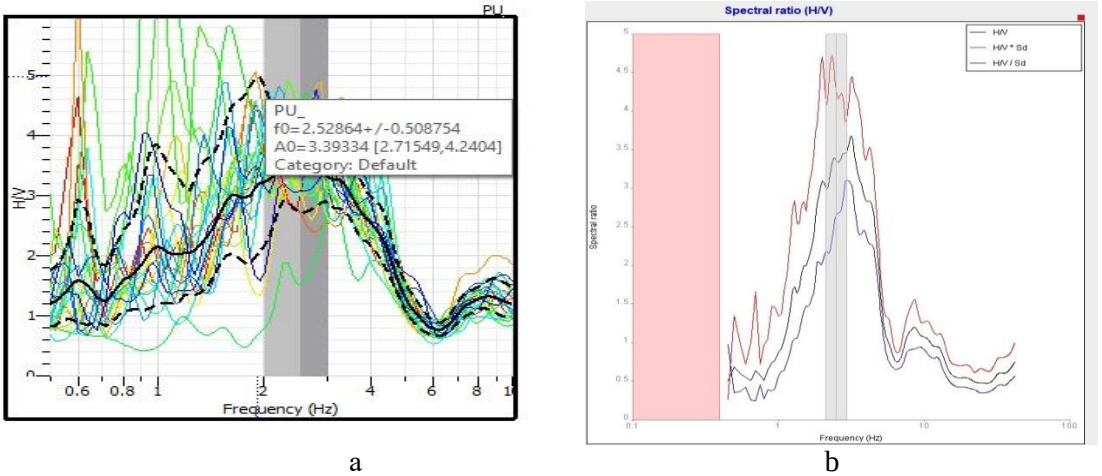
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Fig.7 The results of the estimated fundamental frequency f_0 at point P0230 for the two processing software: a) Geopsy – 0.91Hz; b) J-Sesame – 0.9Hz



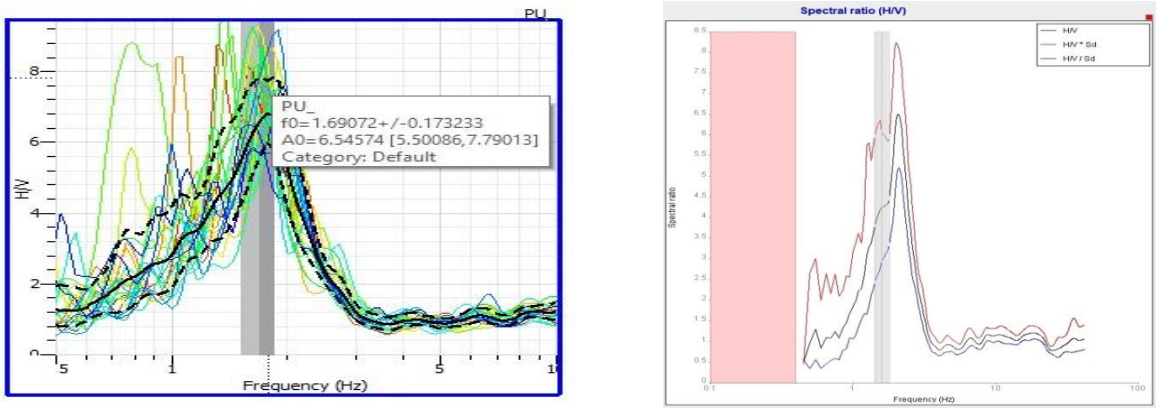
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Fig.8 The results of the estimated fundamental frequency f_0 at point P0235 for the two processing software: a) Geopsy - 1.07Hz; b) J-Sesame – 0.98Hz



a b

Fig.9 The results of the estimated fundamental frequency f_0 at point P0243 for the two processing software: a) Geopsy – 2.5Hz; b) J-Sesame - 2.7Hz



a b

Fig.10 The results of the estimated fundamental frequency f_0 at point P0247 for the two processing software: a) Geopsy - 1.69Hz; b) J-Sesame – 1.7Hz

Conclusions

In this paper we analyzed the distribution of the fundamental frequency f_0 at some new points in the western part of Plovdiv. We applied two types of software – Geopsy and J-Sesame to verify whether they provide similar results. The examined points can be seen on Fig.1 (green circles) and the estimated fundamental frequencies are for a region, where two basic types of buildings are observed – low-height houses (one-two stories in the eastern part of the area) and higher buildings (7-8 story block of apartments in the western sector of the region). All fundamental frequency values are in the range 0.9 – 2.5 Hz (See Fig. 2 - Fig.10). This fact indicates that smaller buildings are at bigger danger from seismic impact. Such buildings have their own resonance frequencies in this range, too. The results turn to be different for the eastern most part of the studied region, which is next to one of Plovdiv hills. There the highest fundamental frequency was determined (~ 2.5 Hz). This result is similar to the ones, obtained by Kandilarov et al. (2009) for points at other hills in the central part of Plovdiv. It is also in accordance with the theory of the HVSR technique, by which lower depth of bedrock is related to higher fundamental frequencies. The results from the application of the two different software packages – Geopsy and J-Sesame, are similar and reveal that both can be used, depending on the initial format of the data.

References

Atakan K., Bard P-Y., Moreno B., Roquette P., Tento A., 2003, J-SESAME User manual. SESAME Project WP03 H/V Technique: data processing, Department of Earth Science, University of Bergen, 12 pp.

Dikmen Ü., Mirzaoglu M., 2005, The seismic microzonation map of Yenisehir-Bursa, NW of Turkey by means of ambient noise measurements, Journal of the Balkan Geophysical Society, 8 (2), 53-62

Kandilarov A., Atakan K., Havskov J., Gospodinov D., 2009, An investigation of the significance of local site effects in Plovdiv, Bulgaria, Bull Earthquake Eng (2009) 7:181–198, DOI 10.1007/s10518-008-9091-4

Nakamura Y., 1989, A method for dynamic characteristics estimation of subsurface using microtremor on the ground surface, Q Rep RTRI, 30:25–33

Nakamura Y., 2000, Clear identification of the fundamental idea of Nakamura's technique and its applications, Paper presented at the 12th world conference on earthquake engineering, Aukland, New Zealand, 8 pp