# Analysis of Horizontal to Vertical Spectra of Microseisms for Baku City

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***Abstract***— **The 25th November 2000 earthquake raised public awareness about earthquake catastrophe. Although the city did not witness the heavy damages and life losses, however the event traced slight to moderate damage in Baku city. The distribution of damage is caused by local site effect. In this study, aiming to estimate local site effect, analysis of the ratio of horizontal to vertical spectra of microseisms on the basis of microtremor measurements was performed. The measurements are conducted with the Guralp CMG-5TD accelerometer with the Nakamura's approach. Dynamic characteristics of surface ground (predominant frequency *F*, amplification factor *A*) are estimated. The maps showing the distribution of the amplification and resonance frequency for the grounds of Baku city were developed which demonstrate variability and heterogeneity of ground characteristics in the city. The results can be applied for urban seismic hazard assessment researches in the future.**

***Keywords— Baku city; seismic hazard; microtremor measurements; Nakamura technique***

## I. INTRODUCTION

Microtremor measurements have been used for a long time to investigate site effects in a large variety of seismic environments (Kanai et. al., 1954; Aki, 1957; Kobayashi et. al., 1986; Lermo et. al., 1988; Field et. al., 1990; Yamanaka et. al., 1994; Panou et. al., 2004, Arai et. al., 2008). Microtremor measurement is one of the practical methods to estimate the effect of ground motion characteristics due to an earthquake. It is very useful tool in identifying seismic ground motion amplification for earthquake hazard assessment, because it is very simple and economical in operation. The objective of the present study is to analyze the experimental study of microtremors for investigation of ground characteristics in Baku city by estimating local site effects through the ratio of horizontal to vertical spectra of microseisms applying Nakamura's technique. The parameters that were analyzed are amplitude spectra, classification of soil conditions, *H*/*V* spectral ratio, resonance frequency and amplification ratio in site location. In this study, microtremor measurements were done in 200 points in Baku city.

## II. WHY DO WE NEED TO APPLY MICROTREMOR TECHNIQUES FOR BAKU CITY?

Baku is a fast growing megacity (availability of multi-stored buildings, residential places, industrial constructions, new roads, bridges, tunnels, fashionable hotels) that influences the economic and industrial developments much of the country. This region has experienced many earthquakes since ancient times and faces severe seismic threats from the Caspian and Absheron seismic events. Within the historical time period, peninsula, as well as, Baku city have shaken as a result of occurrences of a number of seismic events, such as 1842 Mashtagi earthquake with magnitude *M*=5 (25 km northward from Baku), 1983 Nardaran-Bilgyah earthquake with *M*=5, 1986, 1989 Caspian earthquakes with *M*=6.0-6.5, the last strong 2000 earthquake with *M*=6.3, which occurred southward from Baku city. Intensive city planning, erroneous land using, construction of many industrial and residential buildings, roads, tunnels, bridges, change of soil conditions due to the various geodynamic and seismic processes, lack of knowledge about modern ground characteristics of Baku city accentuate the necessity to apply microtremor measurements technique which is one of the useful method in investigating ground characteristics and estimating local sites effects, especially in the urbanized areas.

## III. SEISMICITY OF REGION

The regional seismicity can be considered in the framework of the seismicity of the Absheron peninsula. Absheron peninsula with the part of the Absheron water area (Azerbaijan sector of Caspian Sea) lies in the south-eastern downwarp of the Greater Caucasus. Most epicenters of earthquakes in this zone can be placed in a group with magnitude range of 5.5-6.5. Two main seismically active zones exist over Absheron peninsula (Agamirzoyev, 1987).

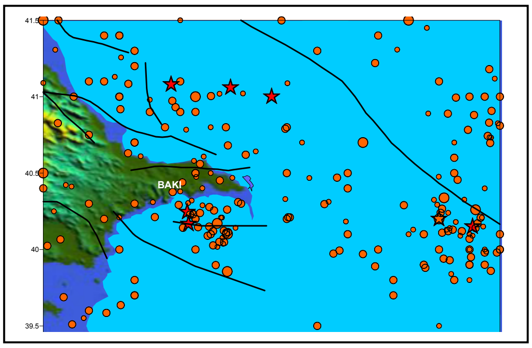


Figure 1. Event distribution map for Absheron peninsula for the period 1902-2010 with magnitude $M \geq 3$.

One zone is located in the northern part of peninsula with 100-year return period and with magnitude 8, and another zone surrounds Absheron from south with return period of 1000 years with the same magnitude. The zone from north is a continuation of Main Caucasus Fault System running through northern coastal side of Absheron peninsula and Caspian Sea territory to the west of Turkmenistan. The destructive Mashtaga earthquake of 1842 (25 km to the north-east from Baku) occurred in this zone. Besides, some moderate earthquakes with magnitude $M$=6.0-6.5 (1983, 1989) occurred within this zone. Second one is a southern zone bounding Absheron peninsula from south. The recent Caspian earthquake of November 25th, 2000 ($M$=6.3) occurred in this zone (35 km to the south from Baku), which caused 35 victims, 1,292 buildings were damaged, and 3 buildings out of them were collapsed as a result of numerous consequent aftershocks (Babayev, 2006). The first information on the regional earthquakes can be found in old Arabic chronicles, hand-writings, notes of pilgrims etc. Modern (instrumental) period in regional seismology started after the 1902 $M$=7 Shamakhy earthquake, which epicenter was located at the distance of 100 km westward from Baku. Geologically, Baku is located in the trough outlined by the outcrops of Quaternary limestones representing a high risk to buildings and other constructions due to soil properties (Babayev et. al., 2010). Owing to the presence of north-western dislocations from the west and east, the trough represents a fan-shaped depression (Shikhalibeyli, 1996). The fault in the central part of the Baku city causes landslides along its extension toward the sand bars located in the south-eastern part of the trough.

## IV. METHODOLOGY

There are different methods to perform and interpret microtremor measurements, which require several instrumentation set-ups and assumptions. This study focuses on applications and interpretation of microtremors, with the emphasis on the method proposed by Nakamura (1989). Nakamura's technique, which is simply based on calculation of spectral ratios of Fourier spectra of horizontal and vertical microtremor velocity components, is the most feasible option among the other methods in assessing the predominant soil periods, amplitude, resonance frequency and soil amplifications.

## V. EXPERIMENTAL MEASUREMENTS

In order to obtain the fundamental frequency of resonance and its variation within the area of interest, a campaign of systematic ambient noise measurements has been carried out, involving over 200 measurements for Baku city. The measurement points have been selected to give a good coverage of the study area, a large selection of different quaternary sediments and sediment thicknesses. Observed microtremors and the Fourier spectra as an example are given in Figure 2.

From this ambient noise data set, it was able to map the amplification and resonance frequency of grounds in the Baku city, which are shown in Figure 3 and 4, respectively.

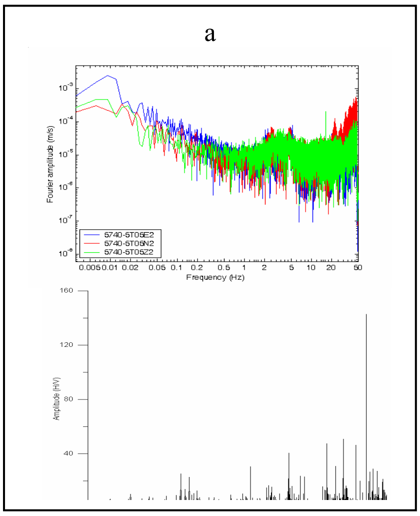


Figure 2. Example of Fourier spectrum for three components ($H$, $Y$, $Z$) (a); Fourier spectra $H/V$ (horizontal over vertical) component in logarithmic scale (b).

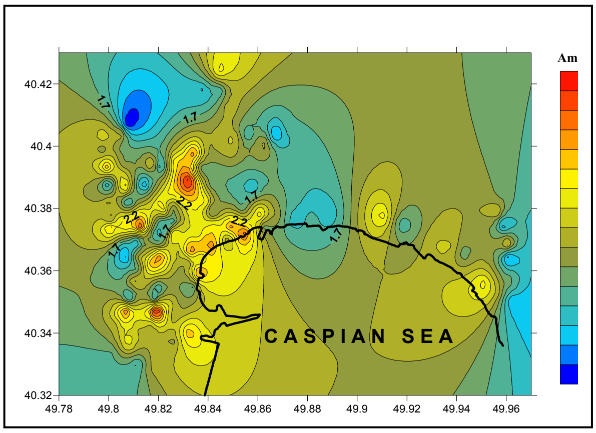


Figure 3. Map of the ground amplification distribution for Baku city.

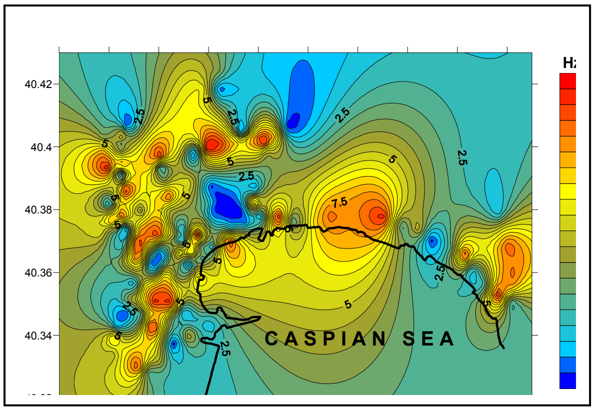


Figure 4. Map of resonance frequency distribution for Baku city.

## VI. DISCUSSIONS

The analysis of the preliminary maps shows the existence of seismic hazard in terms of site effect at some areas. Spectral amplitude of microtremors has good relation with soil structure and seismic behaviour of the surface. As a result of thorough investigation and observation of two above-mentioned maps, it was found out three zones with various ground conditions appeared over the area of study: hard soil, soft soil and intermediate type of soil. Preliminary analysis of amplitude-resonance properties of soil demonstrates that the larger part of the study area is covered by hard soil types. Intermediate type of soil (moderate ground conditions) can be observed in the north-western and north-eastern parts of the city. The soft soil (least stable soil) types are mainly spread in the shoreline area and cross the central part of the city. It is worth mentioning that with this approach, it is possible to reveal the influence of uncertainties on the resonance properties of the grounds. As the further step, it would be recommendable to compare the obtained values with the spectrum of earthquake properties and theoretical transfer function. That comparison and finding a fitting will be important for the next estimation of ground motion at each point of the earthquake area to reveal if microtremors are the same as earthquake motions at the same area in period characteristics.

## VII. CONCLUSION

According to the result of the observations and analysis discussed before, the characteristics of microtremors are dependent on the type of soils. At the same time, the amplitude is not stable due to the fact of influence on type of source. Site effect plays an important role in microtremors measurements. Presumably, in the next stage of this research, the comparison of microtremors with the earthquake peculiarities can be very beneficial and applied for engineering purpose, such for estimating site effects of strong ground motion.

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