PRELIMINARY SEISMIC MICROZONATION Of BOJNORD USING MICROTREMORS

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ABSTRACT

Seismic hazard assessment of big cities is imperative to mitigate the potential damage and loss of life due to earthquakes. Local ground conditions substantially affect the characteristics of incoming seismic waves during earthquakes. Soft soil deposits amplify certain frequencies of ground motion and extend the duration of the motion, thereby increasing earthquake damage. Seismic waves are trapped in the soft soil layer and multi-reflection phenomenon occurs. As a result, the ground vibrates severely with a specific dominant period. This period is called the predominant period of the ground, and the vibration of structures on the surface is highly influenced by it.

Microtremor observations can be used to determine the dynamic properties of a site and, hence, can be used for microzonation. In order to clarify the surface ground motion characteristics at Bojnord City, a microtremor measurement grid has been designed. Different 1-hour microtremor measurings during day and night have been carried out. The horizontal to vertical spectral ratio technique, also called Nakamura's method (Nakamura, 1989) or HVNR was used as a principal data processing procedure in order to extract the experimental transfer function of the site. Fundamental frequencies of the sites using HVNR have been extracted. Following this extraction, the city zonation considering the low-rise, mid-rise and high rise building has been carried out and finally distribution maps of site periods and peak ground acceleration throughout the city were developed.

INTRODUCTION

Seismic microzonation and seismic vulnerability assessment of building stock at a certain location is of importance in order to reduce the potential damage from future earthquakes. Seismic microzonation is considered as an important tool for earthquake mitigation which provides a basis for site-specific hazard analysis. It provides information regarding the use of different areas of a city in an order such that structural, geological, seismologic and geotechnical factors can be considered. In the recent years microzonation is becoming more popular and has been started to be applied in different areas of the world (Haghshenas et al., 2008).

Different seismic events have been occured in Iran which have left large casualties in the recent decades. Lack of suitable development and difficulties in earthquake risk management have led to lots of human and physical damages in these events. These tragedies made the government believe that seismic hazard zonation and microzonation of vulnerable inhabited cities for appropriate urban planning are necessary actions for earthquake risk mitigation in the country (Khandan Bakavoli et al., 2011).

This study is focused on the microzonation of Bojnord area using microtremor observations at different sites. The microtremor method measures ambient vibrations in the order of microns present on the ground surface. The main sources of these vibrations are traffic, and industrial and human activities. Observation and analysis of microtremors can be used to determine the predominant period of vibration of a site (Bard, 1998).

GEOLOGICAL AND GEOTECHNICAL CONDITIONS

This mountainous area has been developed due to the latest Alpine orogenic which was followed by an erosion, has provided a relatively thick middle Jurassic sedimentaries of 8000 m which extends to the present age. The tectonically movements in Kopeh-Dogh region have caused facies changes in interval stages. These movements have been both orogenic and epirogenic movements. The Koph Dagh is made up of a sequence of mostly conformable and complete Mesozoic-Tertiary sedimentary rocks. These consist of limestone, marl and sandstone sequences, which have been shortened into open symmetric folds.

Bojnord City consists of variant formations such as Formation of Quaternary age and the second geology age. Orbitolina gray limes of Tirgan Formation related to the Cretaceous period have formed northern and eastern sectors of central part. Old terraces of alluvial plains cover the north-west-south part of Bojnord Town. Red Marl and neogene covers the south part and areas near the alluvial valleys. Turquoise is extended to the north. It brought sandstone and Shurijeh red marl of Cretaceous period on limes of Jurassic period. Most urban population lives in formation of old alluvial terraces.

SEISMICITY OF BOJNORD

The Kopeh Dagh is a linear mountain range separating the shortening in Iran from the stable, flat Turkmenistan platform. In its central part is an array of active right-lateral strike-slip faults that obliquely cut the range and produce offsets of several kilometres in the geomorphology and geological structure. They are responsible for major destructive earthquakes in the 19th and 20th centuries and represent an important seismic hazard for this now-populous region of NE Iran. These strike-slip faults all end in thrusts, revealed by the uplift and incision of Late Quaternary river terraces, and do not continue beyond the Atrak river valley, which forms the southern margin of the Kopeh Dagh.

The epicentral distribution of earthquakes in the studied region has been demonstrated in Fig. 1.

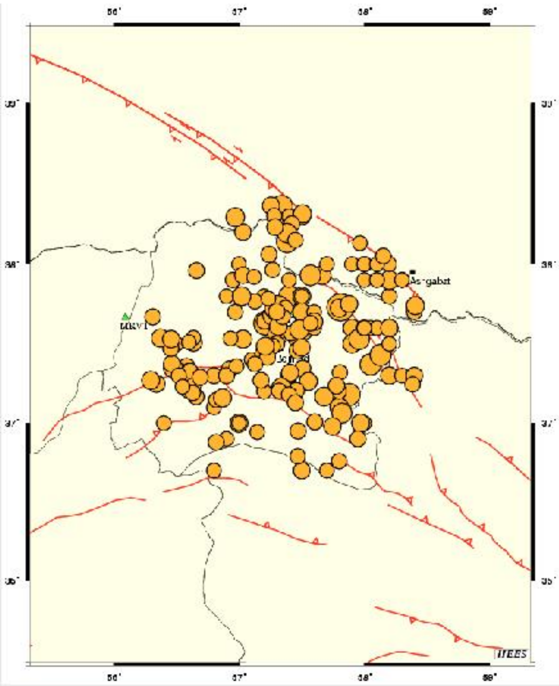

Figure 1. Epicentral distribution of seismic events in the last 100 years in Bojnord and its surroundings

EQUIPMENT USED

The short period CME-3311 seismometer is used for field experiments which characterized by wide dynamic range, low self-noise, high gain, low power consumption. It's very reliable and has no moving parts to be broken or wear out. Like other molecular-electronic seismometers, this model has no demands on mass centering at installation and mass locking for transportation.

The 3-components seismometer is well suited for portable and permanent installations in locations with the background noise close to the Low Noise Model. It can be used in exploration seismology, engineering geophysics, industrial vibration monitoring and many other applications. The sensors were coupled with 24-bit PDER datalogger (http://www.geoparsian.com). The set of each station has been shown in Fig.2.

Figure 2. The 3-components seismometers and PDER data logger

FIELD EXPERIMENTS

The field experiment was carried out during January 26th to February 4th 2015 in 27 different single stations each one at least 1hour microtremor recordings. The layout of the instrumentation was shown in Fig. 3. The sampling frequency was set as 200 Hz. The sta1 and sta2 installed stations have been shown in Fig. 4.

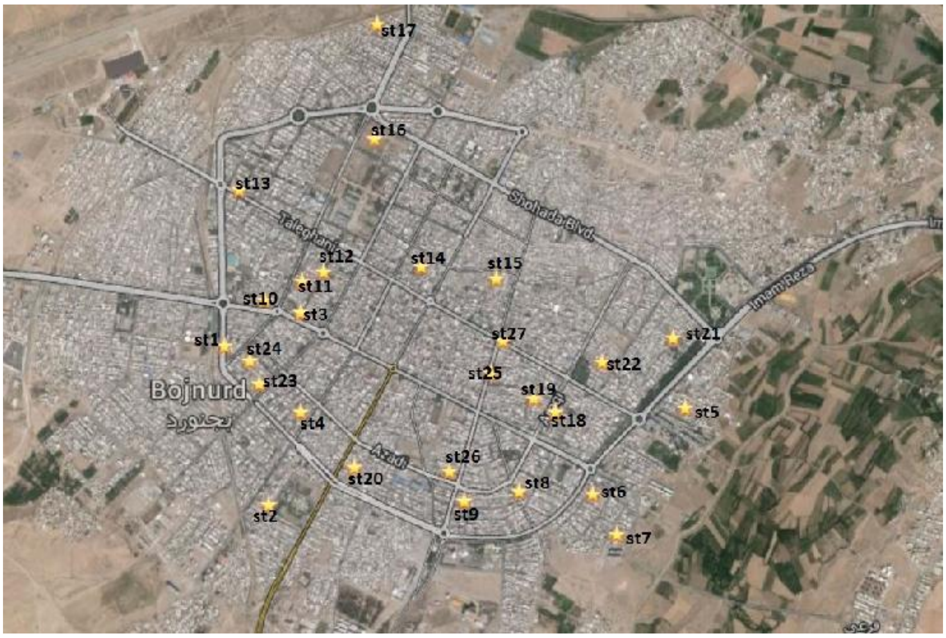

Figure 3. The location of seismological stations in the city

DATA PROCESSING

The horizontal to vertical spectral ratio on noise (HVNR), also called Nakamura's method (Nakamura, 1989) was used as a principal technique in order to extract the experimental amplification function of the sites. The method relies on interpretation of Rayleigh waves in a single layer over half space. A further assumption is that vertical component of motion is not amplified by soft soil layer. Thus an estimate of site effect is given by spectral ratio between the horizontal to vertical component of motion at the surface (Lermo and Chaves-Garcia, 1993). The last supposition may be in direct relationship with the transfer function definition for S-waves that supports the use of microtremor for assessing topographic site effect. Moreover, some experimental studies have confirmed the capability of microtremor for identifying site effect.

HVNRs were calculated using the Geopsy software (http://www.geopsy.org/) provided by the European SESAME consortium applying the following procedure. The continuously recorded data were split into 15-minutes microtremor records for different experiments. Mean and linear trend were removed from the records. Finally the signals were band-passed filtered between 0.2-25 Hz. The stationary noise windows of 20 to 30 seconds were selected by the anti-triggering algorithm incorporated in the software with a 5% window overlapping. Then the squared average was used to combine different horizontal spectra components. The Konno-Ohmachi smoothing function was used to avoid spurious peaks or sharp troughs in the spectra (Konno and Ohmachi, 1998). To minimize the border effects due to the windowing of the Fourier spectra, 5% cosine taper was used. The results are presented in the following paragraphs for each experience separately.

Figure 4. The stations installed in the city.

RESULTS OF MICROTREMORS MEASUREMENTS

Many spectral ratios were computed, they cannot all be displayed here. The average curves for each station have been plotted in Fig. 5.

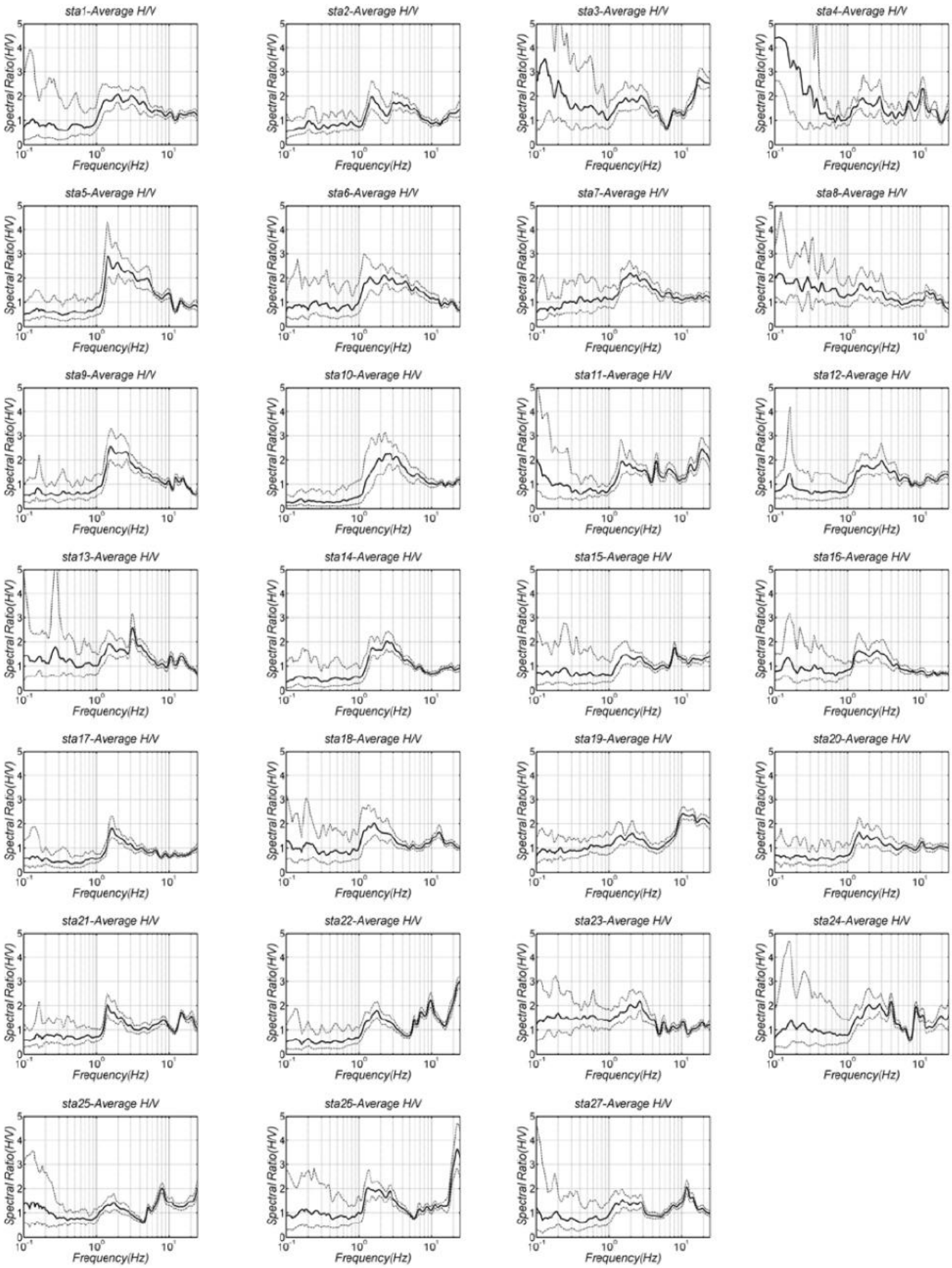

Figure 5. HVNRs plotted for each single station

As the results show we can see, H/V curves in frequency range 0.1 to 25 Hz in city of Bojnord. The microtremor measurements show that most of the sites have a mid-range predominant frequency around 1Hz to 2Hz. According to variation of the predominant period of the ground the city is divided into four zones

Zone I - period less than 0.4 sec.
Zone II - period ranging from 0.4 to 0.6 sec.
Zone III - period ranging from 0.6 to 0.8 sec.
Zone IV - period longer than 0.8 sec.

According to this preliminary zonation, the city can be classified into different region with special permission of building low-rise, mid rise and high rise building. Besides special landuse could be specified to these regions.

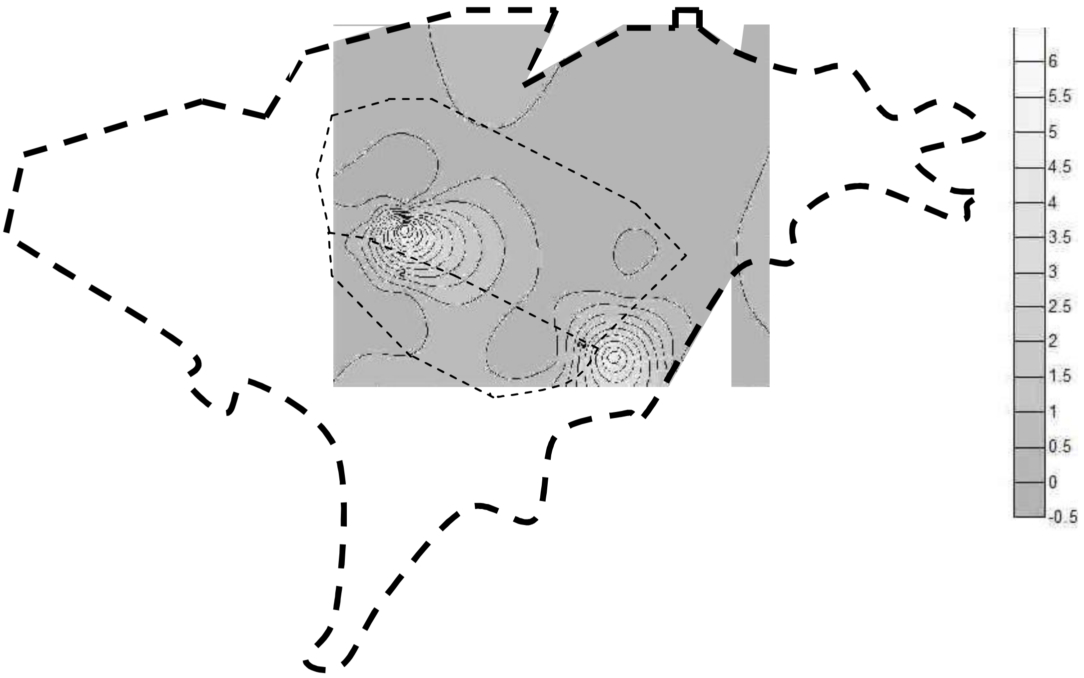

Figure 6. Predominant frequency of different sites inside the city

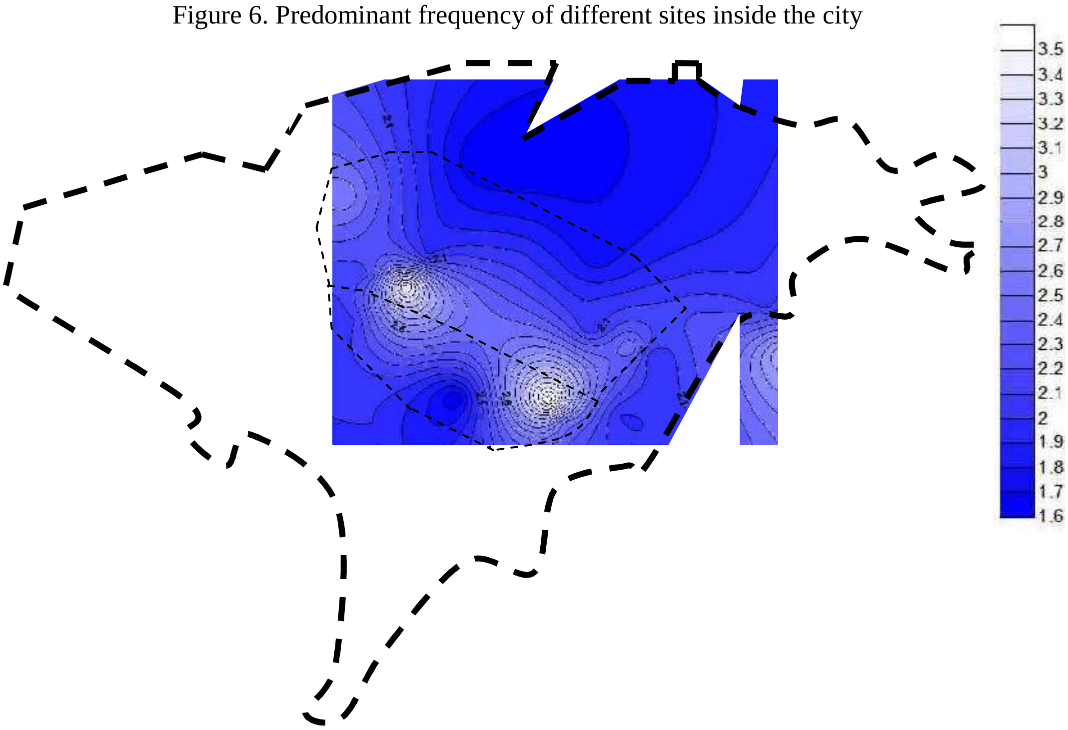

Figure 7. Amplification of each single station

CONCLUSIONS

In this study, microtremor measurements were carried out at more than 27 sites in the city. The predominant periods of the sites were obtained using the H/V method. The study showed that the predominant period varied from considerably high values even 6 sec. to low values, less than 0.1 sec. On the basis of variation of the predominant period, Bojnord area was classified into four different zones that with respect to the fundamental period the low-rise, mid-rise and high-rise building would be the most appropriate land use plan.

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