MICROTREMOR STUDIES IN SOUTH OF TEHRAN

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SUMMARY

More than three decades microtremor measurements method is being used for dynamic site characterisation of sedimentary basins. Although this method seems to function correctly for site natural period evaluation of the site, it is still controversial concerning site amplification factor. In Tehran microzonation project, considered as one of the most important national projects for earthquake mitigation program in Iran, microtremor measurements have been used to evaluate site natural period of south of Tehran plain.

Before starting the measurements, two conventional methods (Reference station & Single station Methods) have been compared with each other in a limited area in Azadeghan Park located in Southeast of Tehran. Due to the presence of Tehran bedrock outcrop near this Park, it was possible to apply these methods and compare the results.

A good agreement was observed between the results of these two methods and therefore the single station or Nakamura method, the most used method for microtremor measurement analysis, was adopted for conducting the study in south of Tehran. The measurements have been performed in more than 70 points in the south of Tehran (30 points in Southeast and 40 points in Southwest of Tehran). In this paper the results of pilot project in Azadeghan Park will be discussed. Also the results of site natural periods, evaluated from microtremor measurements in Southeast of Tehran, will be compared with the fundamental periods obtained from site response analysis using SHAKE program.

The following main conclusions could be derived from this comparison:

(1) In many of the measured points there were a good correlation between the value of the natural periods obtained from microtremor measurements and site response analysis.

(2) The most part of the non-conformity of results corresponds to the region where the subsurface layering is rather complex and not correctly evaluated.

(3) Besides of natural period evaluation of the sedimentary basins, the microtremor technique could be used, in case that the geotechnical data are not available, for the reference bedrock definition used for site response analysis.

INTRODUCTION

One of the important steps in earthquake engineering studies is the evaluation of the surface ground motion taking into consideration the local site effect. Amplification potential and natural (or fundamental) period of the sedimentary basins are the main parameters in this regard. The microtremor measurements could present an easy and fast technique to evaluate, at least, the natural period of the site. This technique has been used, in Tehran south microzonation projects (Jafari et al 1998, Jafari et al l999), in parallel with site response analysis based on

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geotechnical profiles of the measured points. As it was the first time to use the microtremor measurements in Tehran, the two following conventional methods have been compared together in Azadeghan Park in Southeast of Tehran:

In the first method, called reference station method, microtremors are considered as the white noises applied to the bedrock and could be amplified in some periods by the alluvium layers. Therefore microtremors should be measured simultaneously on the seismic reference bedrock and at the surface of the alluvium layer. In this method the site natural period is obtained from the predominant period of the spectral ratio of the two measurements.

In the second method, named single station method, it is supposed that the top alluvium layer amplifies the horizontal component of microtremors while it does not affect the vertical component. In this method the measurement is limited only on the surface of the alluvium layer and no reference bedrock is needed. The predominant period of the site is obtained, in this case, from the spectral ratio of horizontal to vertical components of the measured microtremors. The known Nakamura method could be classified in this category.

PILOT STUDY IN AZADEGHAN PARK

Microtremor measurements in Azadeghan Park area have been performed in one day and in three stations. In this study with the objective of comparison and evaluation of the reference and single stations method, the three stations are selected as follows (Fig. 1):
1) One fixed station on rock site on Bibishahrebano Mountain (Station B1);
2) The second fixed station on soil (station B2) inside Azadeghan Park and in the north of station B1;
3) The third station, which is a mobile station, inside Azadeghan Park (R1, R2, R3, and R4).

The mobile stations R1, R3 and R4 are selected in the direction B1- B2 but the R2 station is located outside of the South-North direction B1-R4 to define a triangular array for evaluation of microtremor technique effectiveness. The distance of B2 from R1 and R2 are approximately 250 meters and from R3 and R4 are 500 meters and 750 meters respectively.

The measurements were performed using the SSR-1 seismometers equipped with three SS-1 short period sensors, in 60 seconds with 10-millisecond intervals. To reduce the noise effect in some recordings, due to the neighbouring traffic, the 20 seconds windows, which are less affected by local noises, have been selected.

MICROTREMOR STUDIES IN SOUTHEAST OF TEHRAN

Reference Station Method

In reference station method, the dominant frequency is evaluated from the spectral ratio of soil to rock station recordings. In figure 2 the Fourier spectrum of horizontal component of the reference rock station B1, the soil fixed station B2 and the soil mobile station R are illustrated respectively. Comparing the results in this figure, the soil amplification effect could be observed by the increased amplitude of motion from 2.5 to 7 Hertz. Based on this method, the spectral ratio of B2 and R stations to B1 rock station is calculated to obtain the predominant period of the microtremors (Fig. 3). From 1 to 2.5 Hz. a "weak" predominant frequency and from 2.5 to 7 Hz. an "good" predominant frequency could be observed.

Single Station Method

In single station method it is considered that the vertical component of the motion at the surface is not influenced by the site soil condition and it has the same frequency characteristics of the base rock. Therefore the predominant period of the motion at the surface could be evaluated from the spectral ratio of the horizontal to vertical components of motion in a single station (Fig. 3). As it could be seen in this figure, the same observation for the reference station method stands here also, i.e. from 1 to 2.5 Hz. a "weak" predominant frequency and from 2.5 to 7 Hz. an "good" predominant frequency could be defined.

Analysis of Results in Azadeghan Park Area

The microtremor measurements performed in Azadeghan Park presents an important amplification potential in the range of 2.5 to 7 Hertz. If we consider that the frequency of the first mode of vibration of the site is in the frequency range of 1 to 2.5 Hz., we should have seen amplification potential more important than the second mode supposed in the range of 2.5 to 7 Hertz. This is not the case indicating that a non-site source is responsible for this "weak" amplification potential in this range of frequency. The high potential of amplification in the frequency range of 2.5 to 7 Hz is therefore the frequency range in which the first mode of vibration is situated and could be used for site natural period evaluation.

We have also repeated the measurements, five months later to verify the stationary characteristics of the microtremors. The spectral ratio calculation in the new measurements has approved the previous results supporting the main conclusions derived in the pilot project performed in Azadeghan Park.

CONCLUSIONS

Based on detailed analysis of the results, the following conclusions could be derived:

1) The conformity of the results between the microtremor studies and site response analysis, concerning natural site period evaluation, could be observed mainly in two regions. First, in the coarse grain material zone where the thickness of the alluvium layer reaches up to 12 meters (verifying also the appropriate selection of the seismic bedrock in this area with 900 m/s). Second, in the fine grain material zone in which the thickness of the alluvium layer increases up to 60 meters.

2) More than 90% of non-conformity of the results corresponds to the region where the subsurface layering is rather complex and not correctly evaluated. This region covers mainly the near mountain region, the transition zone between coarse and fine grain materials and the zone with coarse material interbeddings. The other reasons for this non-conformity could also be given in the recording and in the spectral analysis procedure. In the case of very noisy recordings, the spectral ratio of the horizontal to vertical components presents many peaks in H/V spectrum. In this case, the definition of the predominant periods becomes relatively a difficult task. At the other hand when the contrast of the shear wave velocity between different layers are not important, the site natural period evaluation using H/V spectral method is not feasible (Tokeshi et al, 1996).

3) The microtremor measurement technique could serve, therefore, as a complementary method to the analytical approach (site response analysis) for site natural period evaluation. It also could help to define the seismic bedrock where the geotechnical data are not available up to rocktype layer with high shear wave velocities.

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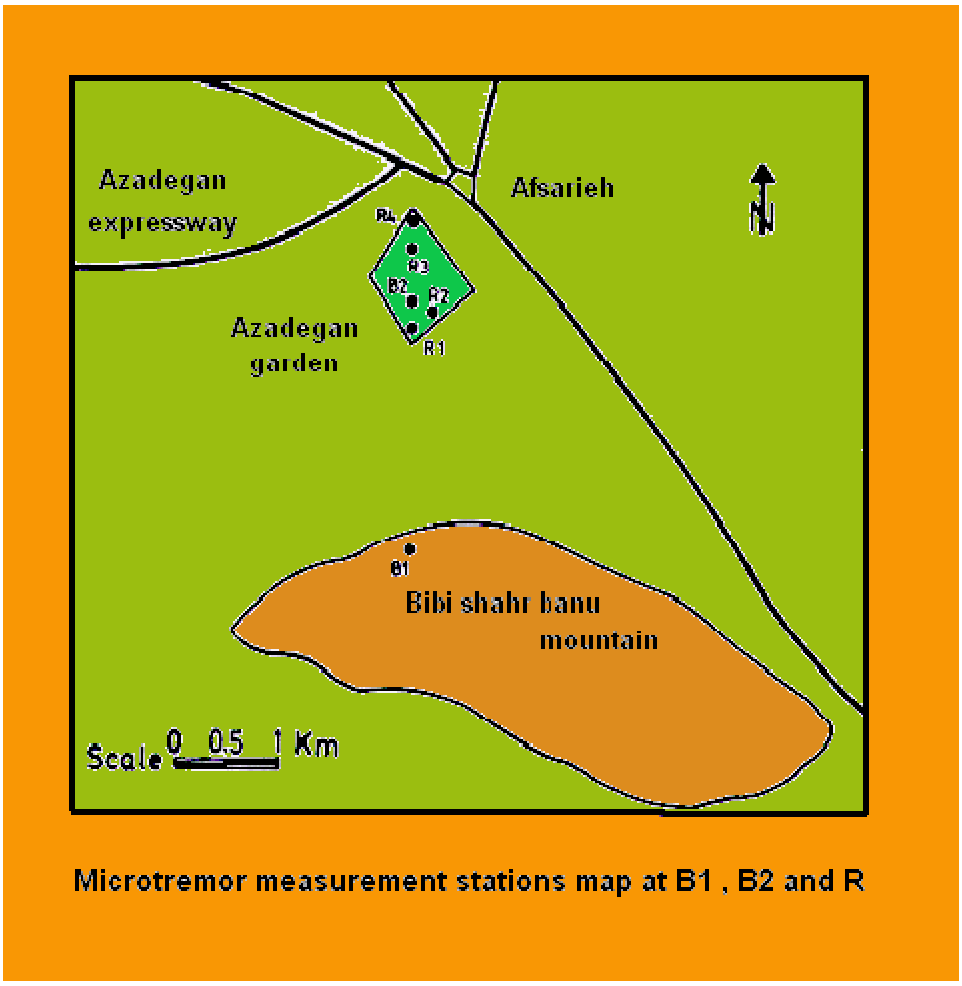

Figure 1: Microtremor measurement stations in pilot project area,

reference rock station B1, fixed and mobile stations B2, R1, R2, R3, and R4

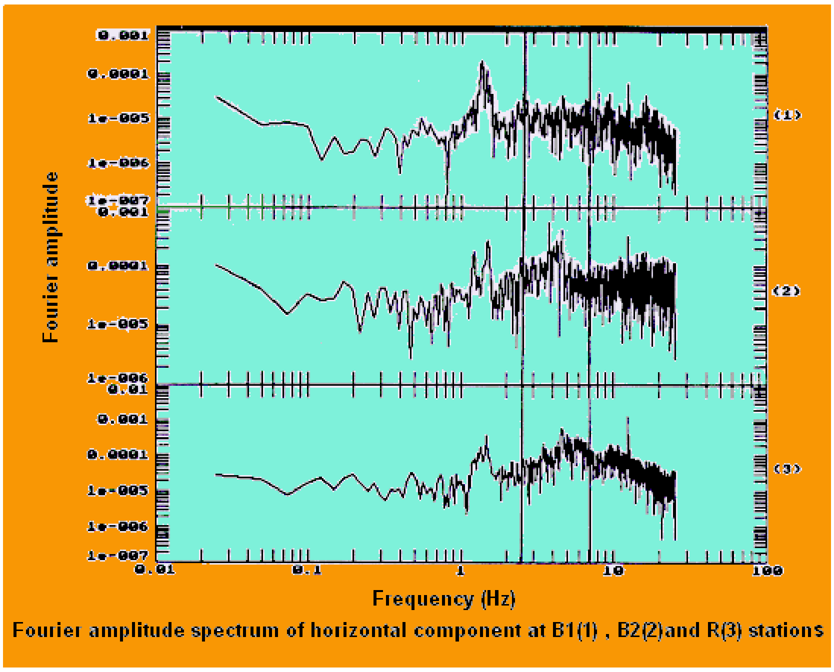

Figure2: Fourier spectrum of horizontal component of the reference rock station B1(1),

the soil fixed station B2 (2)and the soil mobile station R (3)

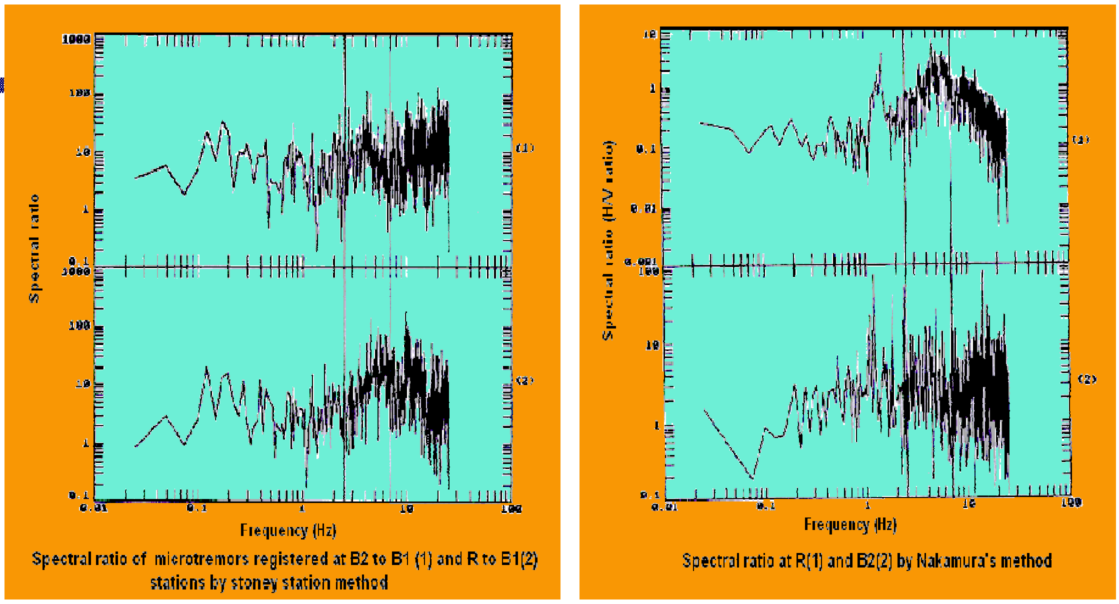

Figure 3: The spectral ratio of B2 and R stations to B1 rock station (left) and

the spectral ratio of the horizontal to vertical components of motion in stations R1 and B2 (right)