Evaluation of seismic site response over and nearby Karaj (Iran) subway tunnels (the preliminary result of experimental measurements)

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SUMMARY:
The effect of underground cavities in assessing local seismic response was studied over the subways tunnels that are under the construction in the city of Karaj. The city covering an area near to 300 km² and a population near to 3 million, situated 25 km west of Tehran, Capital of Iran. Like Tehran, Karaj suffered from the high seismic hazard and risk due to its vicinity to active faults, the probability of ground motion amplification and also a very fast development. The present study have been carried out in the framework of the site effect evaluation for this city, with the aims of assessing the influences of the under construction subway tunnels on seismic motions at the ground surface. In this purpose some seismological and ambient noise measurements is designed over the tunnels and the neighboring area. The present paper shows the result of some ambient noise measurement in some section of the Line 2 of Karaj subway.

Keywords: Seismic Site Response, Subway Tunnels, Karaj, Iran

1. INTRODUCTION

The evaluation of effect of local geological and geothechnical condition on ground surface seismic motion is an essential step in seismic hazard mitigation studied, especially in a heavily urbanized area located in seismic prone area like Karaj that is affected by several destructive historical earthquakes.

The presence of the underground cavities (natural or artificial) is one of the local site features that may affect the ground surface motion due to the diffraction of incident seismic waves. However, there are not so many researches in this regard especially using experimental measurements. Almost all of the researches that have been previously carried out in this topic are of type analytical calculation or numerical modelling (ex: Crichlow, 1982; Lee et al. 1992; Smerzini et al. 2009). There have been only a few experimental efforts in characterizing the effect of the subsurface cavities on seismic ground motion by Lombardo and Rigano (2004, 2010) and Sgarlato et al (2011).

This research deals with the problem of evaluating local seismic response related to the presence of subway tunnels in the city of Karaj (Iran) in the framework of a bigger research project of the local seismic hazard studies of this town. This city with a population near to 3 million situated 25 km west of Tehran and encircled by many active faults, capable to create an earthquake with magnitude greater than 7 (Fig. 1). On the other hand the city is installed on a series of thick alluvial deposits prone to significant amplification. These alluviums are the product of Alborz mountain erosion by the Karaj River and some other minor rivers originated from the mountainous area at the north of city.

Rapid growth of the city during the recent decade and the problem posed by very fast augmentation of population conducted the municipality of the city to decide to construct a subway network, consisting of 5 lines with a total length of 72 Km (Fig2). The project now is under construction and the excavation of line 2 (27 Km) was nearly completed. As the figure shows a considerable area of the city will be covered by this subway network that can be affect the seismic site response, at least for the

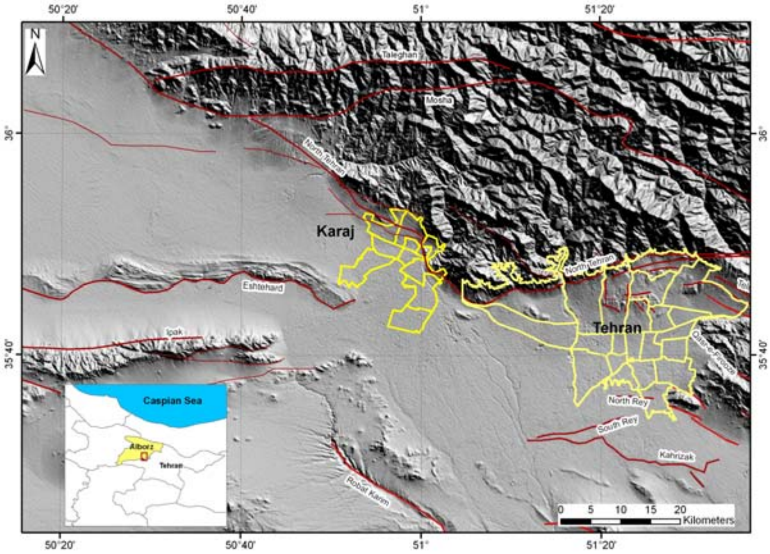

Figure 1. Situation of the city of Karaj in southern Alborz foothills and the active faults that can threat the city.

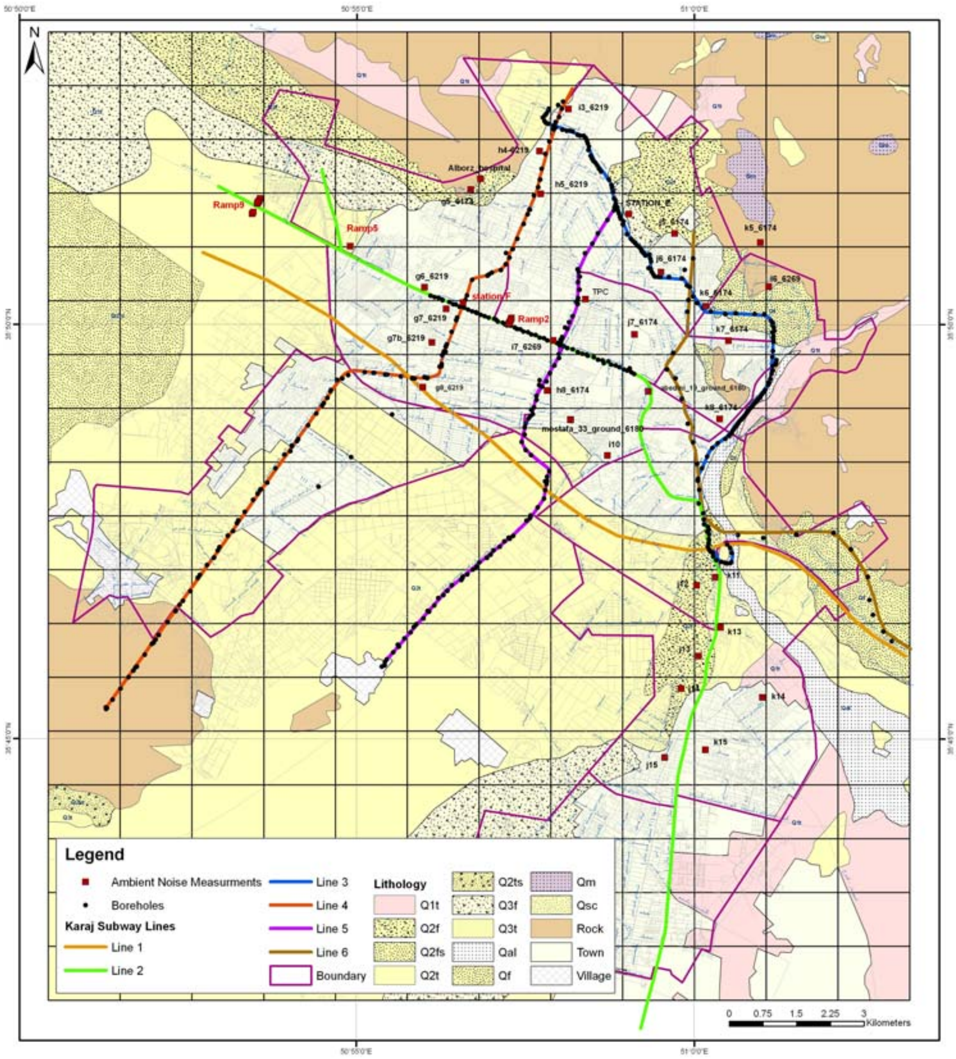

Figure 2. Location of single and multi station ambient noise measurements that have been performed up to now over the generalized geological map of studied area.

localities up or near the tunnels. In the present research we are going to study: firstly; if the effect of these tunnels will be important and secondly; how far from the tunnels can be affected and its dependence to tunnels characteristics such as depth, height and diameter. A series of experimental ambient noise measurements and numerical modeling is considered. This paper shows the result of some ambient noise measurements, have been carried out up to now.

2. DATA ACQISATION

As mentioned before the data used in this study come from data acquisition that is going on in the framework of earthquake geotechnical microzonation of Karaj. The locations of the measurements are shown on Figure 2, including some of performed single station ambient noise measurement and some multi station measurement on subway tunnel (line 2). Figure 3 shows the schematic configuration of multi stations data acquisition for 4 places (Ramp2, Station F, Ramp 5 and Ramp 9 on Figure 1).

The seismological materials include Guralp broad band velocimeters (CMG-6TD) with 30 minutes records for single station and 2-3 hours of records for multi station measurements. The sampling frequency is 100 samples per second.

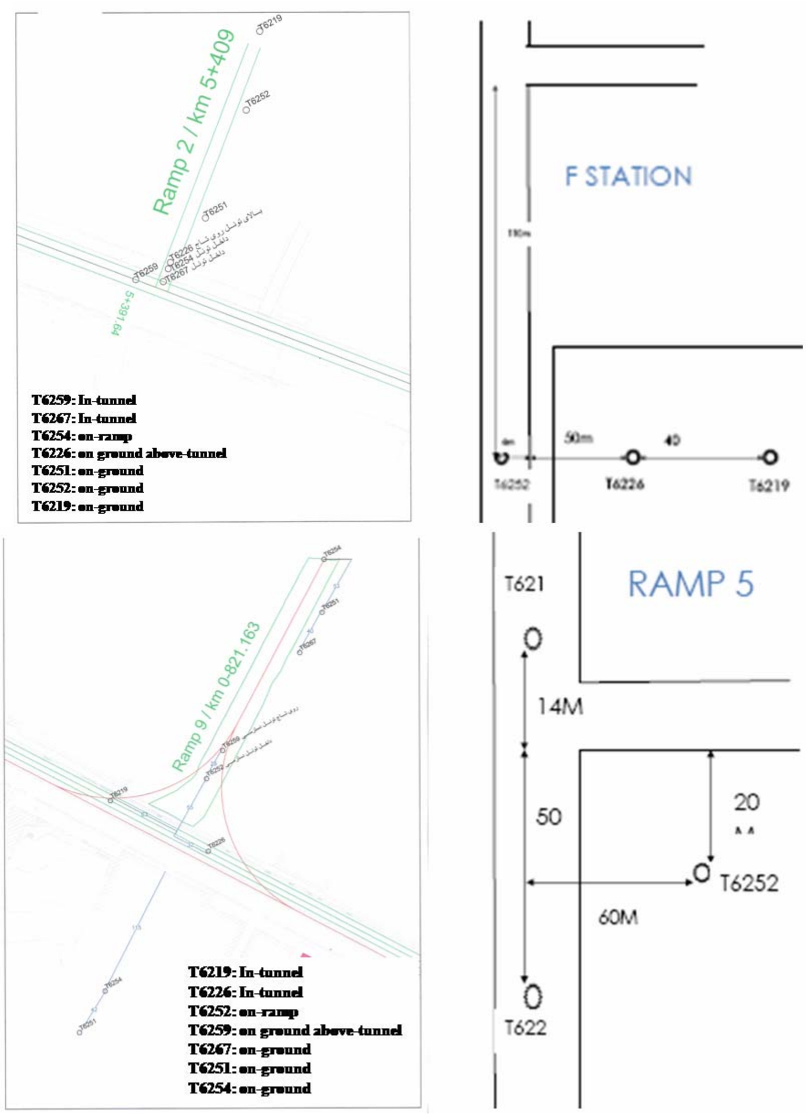

Figure 3. Schematic of multi station ambient noise measurement, performed in 4 sections along the Karaj subway tunnel (line 2).

3. DATA PROCESSING AND RESULTS

All the single station and multi station ambient noise data were processed using H/V technique (Nakamura, 1989) and site/reference spectral ratio (SSR) method (Borchert, 1979) considering the in-tunnel stations as references. Some steps of calculation were performed using the Geopsy software package (http://www.geopsy.org; Wathelet et al., 2008). The stationary time windows of 40-60 sec length were selected using anti-triggering algorithm.

Figure 4 present the obtained results for single station H/V spectral ratio for all stations. As can be seen almost for all the measured station there is relative clear peak in low frequency part (0.8 Hz). This low frequency peak is not consistent with near surface geological and geotechnical condition of the studied area, especially when we consider the distribution of these 30 station extended from extreme northern part of the city up to extreme southern parts (see figure 2). This may be due to the existence of a deep impedance contrast (geological bedrock) at the base of very thick alluvial deposits of the Karaj with a gradient shear wave velocity increment. The same condition has been previously reported for Tehran at 25 Km east of Karaj (Haghshenas 2005).

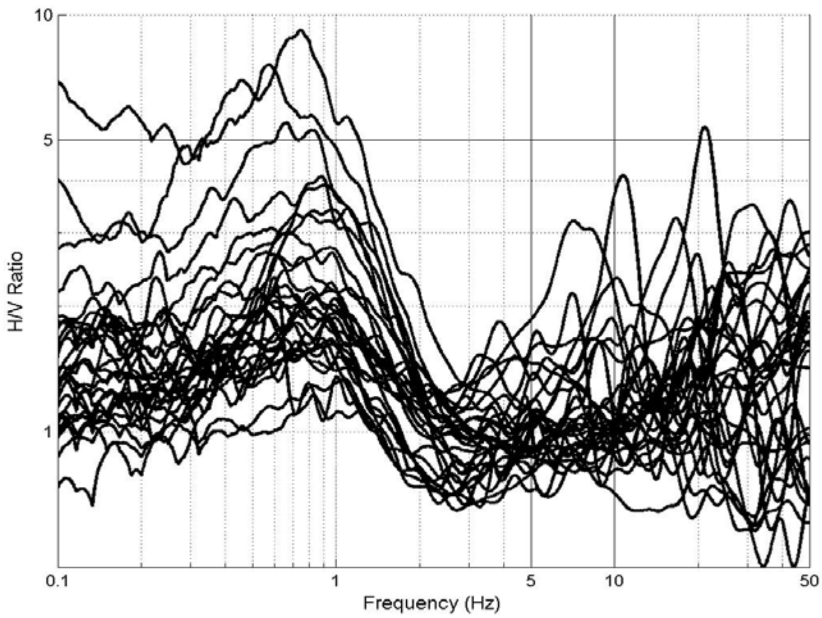

Figure 3. Average of H/V spectral ratio for 30 single station ambient noise measurements showing a more or less clear peak in low frequency (0.8 Hz) for all the station, despite of their vast distribution over the studied area and some high frequency peaks.

As it concerned with multi station measurement and the effect of subway tunnel on site seismic response (the main objective of this paper) the results are shown in figures 5 to 9 respectively for Ramp2, F station, Ramp5 and Ramp9 locations.

A general result for all of these measurements that can be deduced is a clear amplification of seismic motion for the stations installed just above the tunnel location and the stations installed at distances less than 40 meters from the tunnels axis. For further distances, although the peak become larger and less clear but can be seen yet even to distances about 100 meters of the tunnels. For the further distances we did not measured yet and will be performed in future.

Another interesting observation is that there is not complete agreement between SSR and H/V spectral ratios both in resonant frequency and amplification factor.

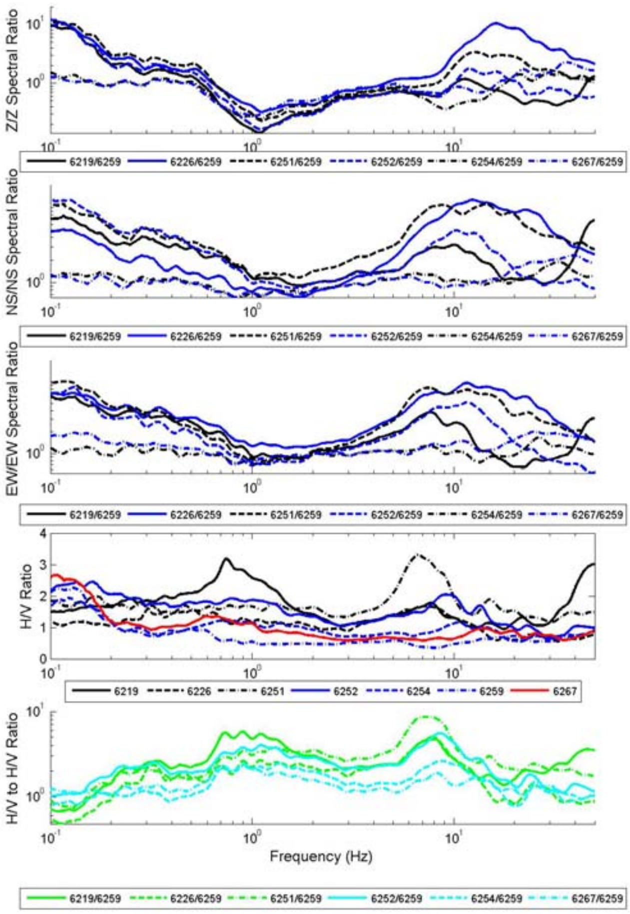

Figure 4. SSR and H/V spectral ratios for multi station measurement preformed near to ramp 2 of subway line 2. The SSR spectral ratios were calculated considering both in-tunnel station 6259 and 6267 as reference stations. Due to the similarity of the results only the result of reference 6259 are shown here.

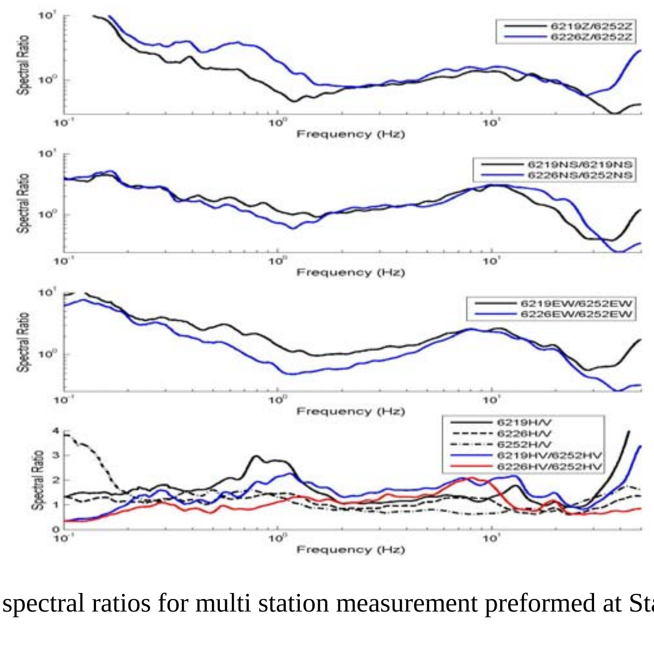

Figure 5. SSR and H/V spectral ratios for multi station measurement preformed at Station F of subway line 2.

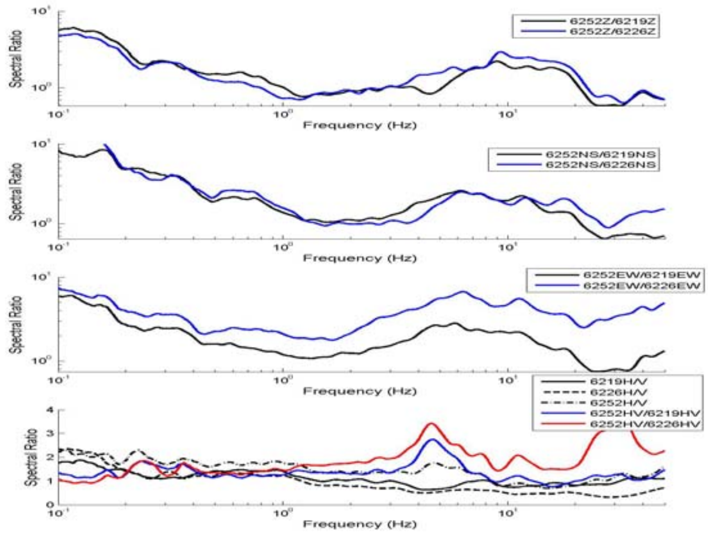

Figure 6. SSR and H/V spectral ratios for multi station measurement preformed at ramp 5 of subway line 2.

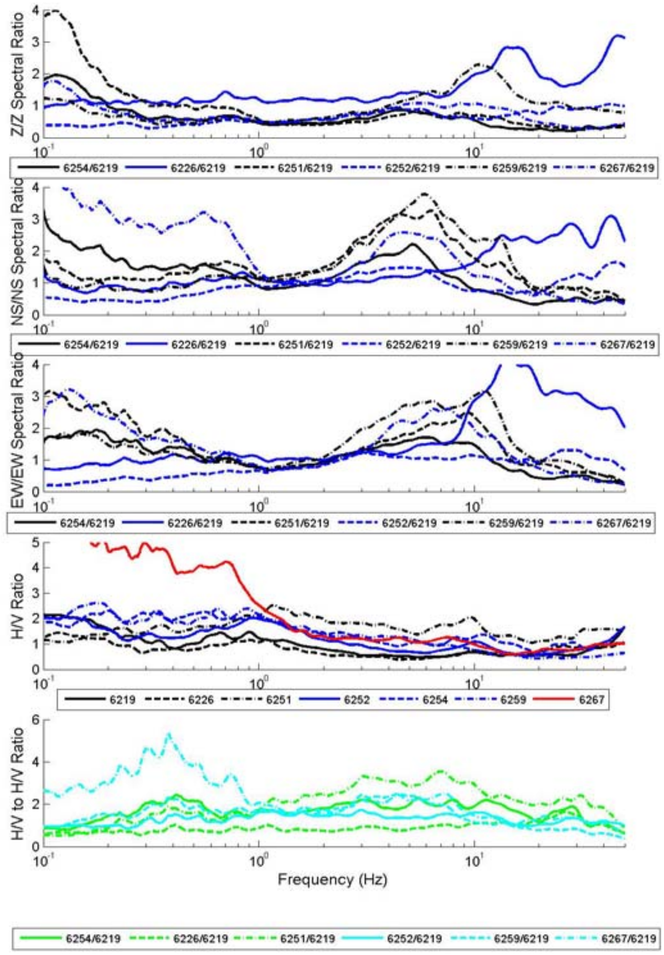

Figure 7. SSR and H/V spectral ratios for multi station measurement preformed near to ramp 9 of subway line 2. The SSR spectral ratios were calculated considering both in-tunnel station 6219 and 6226 as reference stations. Due to the similarity of the results only the result of reference 6219 are shown here.

3. CONCLUSION

A series of single and multi station ambient noise measurement have been preformed in the framework of Earthquake geotechnical microzonation of the city of Karaj. The objective was to asses the general site effect in the city in one hand and on the other hand to estimate the effect of the subway tunnel on the site seismic response. The results show that despite of a general trend of low frequency (0.8 Hz) amplification detected by single station H/V ratio in different part of the city this trend is modified significantly for the area located around the subway tunnel. For these areas the multi station SSR method revealed that the resonance frequencies shifted to high frequency part with higher amplification ratios. This amplification is higher for the station installed just above the tunnel or in a distance lower than 40 meters from the tunnel axis. This observation is in contradiction with some numerical studies, have been performed previously, showing the decreasing of amplification for the top of the underground cavities. For the moment data measurement as well as numerical modelling of the Karaj subway tunnel is going on and these result will be completed in a near future.

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