

Seismic Site Effect Estimation Using Microtremor Studies in Zarqa City in Jordan

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Abstract In this study we determined the local site effect by means of the horizontal-to-vertical (H/V) spectral ratios. The Nakamura's concept (Nakamura Y. 1989) is applied in Zarqa city in order to determine the resonance frequencies and amplification factors for, finding the dynamic characteristics for structural engineering purposes. Results obtained in this study shows that; dominant frequencies F varies between 0.37 Hz and 2.98 Hz in the city area, while, the amplification factor A varies "between" 0.8 to 8.55. This means that structural culture in most localities of the study area might be seriously affected by any of eventually major short periodic earthquakes released by the nearby seismologic active sources westward, except of localities characterized by long periodic dominant frequencies of the study areas, considering that most structures of the study area are characterized by one to three story profiles.

Keywords Microtremor, Ambient Noise, Dominant Frequency, Site Effect, Microzonation

disciplines that range from seismology (engineering and/or engineering seismology) to geotechnical engineering. Our discussion herein is focused on the effects of shallow soil layers on ground motion, which is basically a wave propagation phenomenon.

Tectonic Setting of the Region

The Dead Sea transform fault system is the major active tectonic and morphotectonic feature of the region. It strikes in an N-NE direction and extends over some 1000-1100km from the Gulf of Aqaba northwards along Wadi Araba, Dead Sea, Tiberias, Yammouneh fault and Ghab depression to the continental collision in the Taurus-Zagros Mountain belt (Figure 1). The nature of this DSTF was strongly related to the opening of the Red Sea (Girdler, 1985; Quennell, 1984[8]), and responsible for most geological structures of the region (Freund, 1965; Freund et al, 1970; Joffe et al, 1987; Al-Zoubi, 2003 and Al-Zoubi, 2005). Seismicity information including historic and pre-historic data indicates that major destructive earthquakes occurred in the transform region.

1. Introduction

Zarqa governorate considered as one of the important governorates in Jordan. It is the second populated city in the country with a strategic location that gives the city a great importance. The city lies on the main international junction that leads to Syria, Iraq and the Saudi Arabia. Numeric national industrial complexes are in the city.

Site effects associated with local geological conditions constitute an important part of any seismic hazard assessment. Many examples of disastrous consequences of earthquakes have demonstrated the importance of reliable analyses procedures and techniques in earthquake hazard assessment, as well as in earthquake risk mitigation strategies. Ambient vibration recordings combined with the H/V spectral ratio technique have been proposed to help in characterizing local site effects (SESAME, 2004).

In designing critical and/or strategic facilities, taking site effects into consideration, associated with ground motions is an important step that requires significant input from several



Figure 1. Tectonics of the Arabian Plate and the surrounding regions (Johnson, 2005).

Instrumental seismicity of the region indicates a concentration of earthquake activity along the major trend of the Dead Sea Transform Fault (hereafter nominated as DSTF) and its associated zones (Ambraseys et al., 1994[3]) (Figure 2).

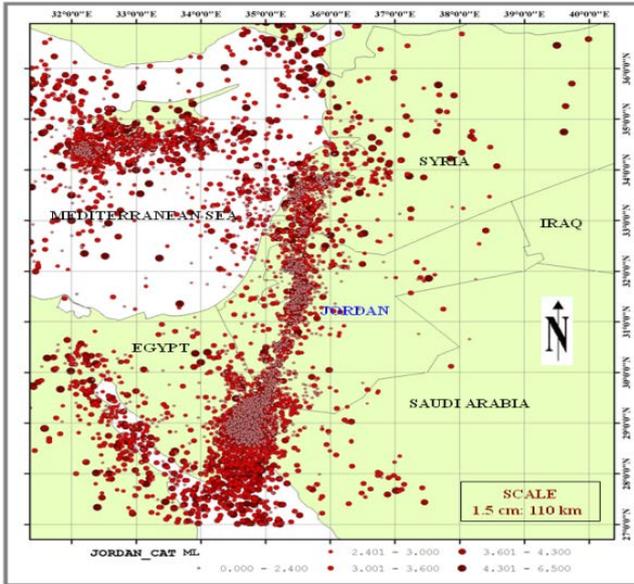


Figure 2. Seismicity map of the Dead Sea transform Fault region for the period 1900-2006, Data from JSO (1984-2006) and Al-Tarazi (1992)[2].

Location and Topography of the Study Area

Zarqa city is located in the northern part of Jordan, about 30 km north east of the capital Amman. The area of Zarqa city is (60) km² in which population is over 351 thousand (ZM, 2007). This implies that the population density is 5850 (person/ km²), which is the highest population density in Jordan. Zarqa is also the industrial capital of Jordan and the 2nd main city after the political capital Amman (Figure 3).

The study area, which is part of the northern highlands, varies in elevation from less than 440 m above sea level in River Zarqa in the western part to 883 m in Umm Hajar region in the central western part.



Figure 3. Location map of the study area marked by red box.

The geology of Zarqa was a target of several studies (i.e.: Quennell 1951[8]; Masri 1963[5]; Bender 1974[4]; Powell, 1989[7]). The most detailed study is carried out by Abu-Qudaira, 2004[1]. In this study, the geological description of Zarqa city is as follows:

The overlying Amman Silicified Limestone Formation and Al-Hisa Phosphorite Formation (Campanian-Maastrichtian) consist of grey and brown, thin to medium bedded chert, exhibiting a variety of textures ranging from homogeneous to brecciated, interbedded with limestone, dolomitic limestone, marl, silicified chert and phosphate. The thickness of Amman Formation is up to 40m, whereas the exposed part of Al-Hisa Formation is up to 20m. The Amman Formation is characterized by syndimentary undulations, which were caused by tectonic processes contemporaneous with sedimentation. The decreasing of chert content and increasing of the trace fossils characterize the Al-Hisa phosphorite Formation include fossils of bivalves, gastropods and ammonites. The two formations were deposited in subtidal to shallow environment (Figure 4).

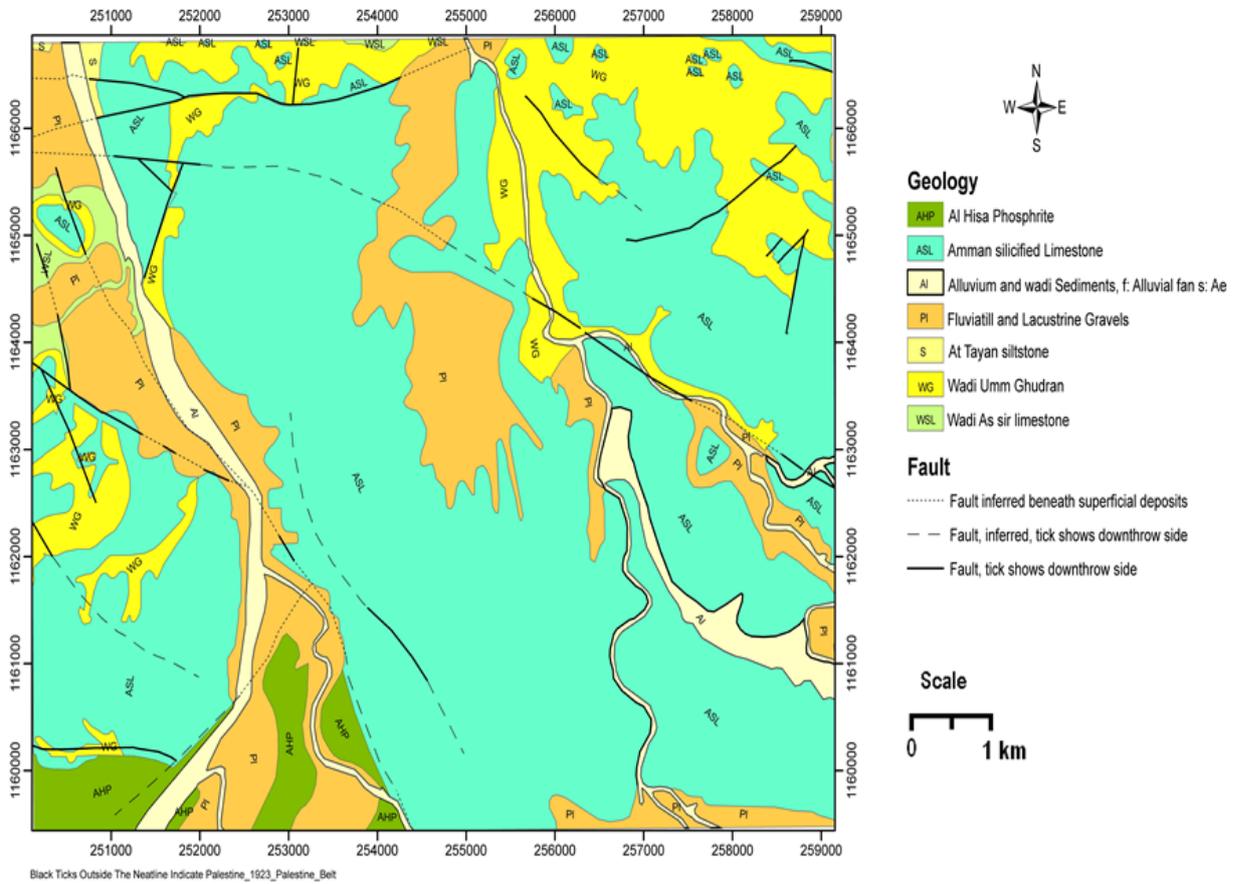


Figure 4. Geological Map of the Zarqa Area (slightly modified after Abu Qudaira, 2004 [1]).

2. Data Acquisition and Processing

Field ambient vibration records were carried out in Zarqa city [Latitude (36° 03' 40" - 36° 09' 26") and Longitude (32° 01' 37" - 32° 05' 57")] that covers an area of 74.115 km² in addition to Hashemite University campus. The field work was in the period between August 2006 and February 2007. Recording were made for duration of (10 – 15) minutes per site and for a total of 151 sites in different lithological units.

In this work, updated digital technology of records, storage, and analysis were used. Three-component short periodic seismometer of 2Hz free oscillation and a set of three L-4C one free oscillation seismometers were used as necessary at each recording site.

Obtained data were recorded, digitally converted, and stored using SSR-1. Spectral analysis we performed using SEISPECT which is compatible with XMGR software.

3. Results and Discussion

Results obtained of ground records spectral analysis in this study show an increase of H/V resonant frequencies toward south and south east-ward of the city itself. The maximum resonant frequency obtained in this area of the city was 2.98 Hz, while the minimum obtained frequency of

0.37 Hz found at the periphery of the city (Figure 5).

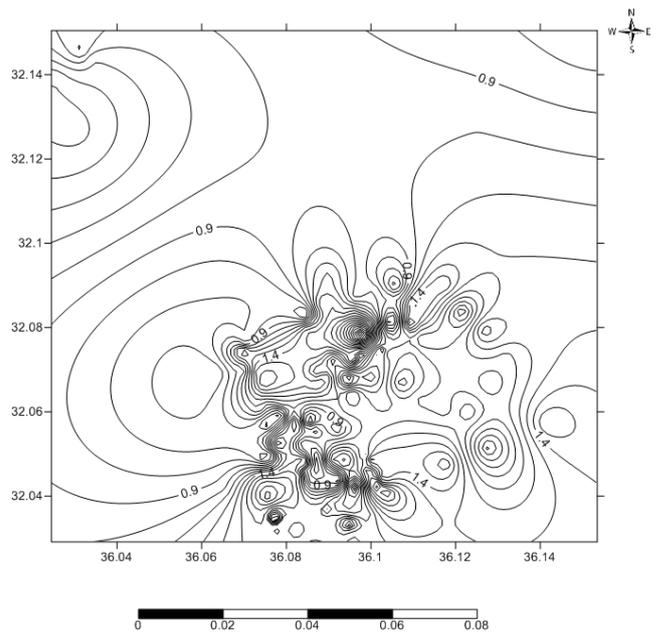


Figure 5. Study area resonance frequency contour map.

Results of the H/V amplification as shown in (Figure 6) are nearly harmonized with the previously referred results

of the dominant frequencies. The maximum obtained amplification is 8.55Hz, while the lowest amplification is 0.8Hz. The amplification map also refers well to the topographic effect that dominates the area. An increase of the amplification here and there reflects the effect of hill tops of the area as well as to the soft deposits here and there and also due to the weathered prevailed conditions.

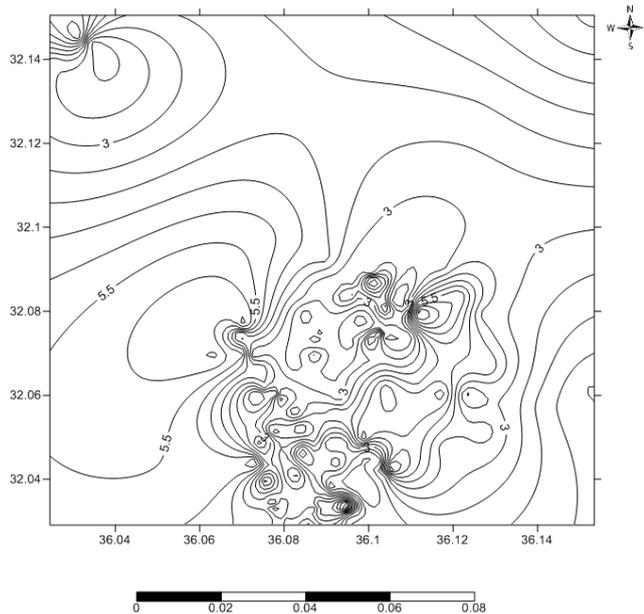


Figure 6. Study area H/V spectral ratio contour map.

Generally speaking, although the study area is mountainous but so weathered due to arid conditions that prevailed the area. In addition and due to the climate conditions that prevail the city of Zarqa and due to real situation of weathered surface geology, the surface geology characterized by relatively lower dominant frequencies as obtained. Thus future constructing measures should be taken for decreasing loses during any of future eventually earthquake.

4. Conclusions

- The dominant frequency increases south and south east-ward of the city.
- The amplification factor generally increases southward and south-westwards of the city considering the effect of topography and the increase thicknesses of soft deposits originated by historical flooding of Zarqa River in its course.
- The study area is mountainous and so weathered due to arid conditions that dominate the area.
- The surface geology characterized by relatively lower dominant frequencies.

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