SITE EFFECT EVALUATION IN QESHM ISLAND (IRAN) USING EARTHQUAKE RECORDING AND MICROTREMOR MEASURMENTS

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ABSTRACT :

Un earthquake of Mw =6.0 struck the central part of Qeshm Island, the greatest Iranian island in the Persian Gulf in November 27, 2005 (13:52 local time) after a relatively long period of seismic silence during 20th century in the region. This earthquake caused some of causalities and important damages to rural areas. This leads the Qeshm free zone organization and International Institute of Earthquake Engineering and Seismology (IIEES) to conduct a comprehensive study on the surface ground motion characteristics and earthquake geotechnical engineering in this Island. This paper shows some of the results obtained using earthquake data and Microtremors measurements.
In this regards, the data of a seismological network consisting of 17 stations, installed after the earthquake (from 2005 December 2 to 2006 February 26) and 49 single station Microtremors measurements were used. More than 100 seismic events have been extracted for each station to estimate site effect by conventional methods such as Standard Spectral Ratio (SSR), General Inversion (GI) and horizontal/vertical spectral ratio (HVSR) Methods. Microtremor measurements were mostly focused on the 2 important city of the region, Qeshm and Dargahan.

The comparison of the results with the destruction map of 2005 Qeshm Island earthquake show a moderate level of amplification for some of the localities severely damaged during Earthquake, specially in the Tomban and Gavarzin villages due to the existence of loose sandy-silty soils. However for most part of the seismological stations we do not observed a significant amplification, despite of the existence of weak geological formations.

KEYWORDS: Site effect, Qeshm Island, spectral ratio, general inversion, H/V

1. INTRODUCTION

Qeshm island, with a population near to 100000 situated on the north-western flank of the strait of Hormuz and is a free trade zone. The population distributed in 2 cities of Qeshm and Dargahan and 64 villages. Due to its commercially importance, the island has been developed rapidly during the recent years. Unfortunately the most part of the structure in region have been constructed without considering the seismic design regulations. The occurrence of recent earthquake in November 2005, which destroyed 3 villages, showed the vulnerability of the region from this point of view and the need for comprehensive studies in this regards.
The widespread outcrops of weak marly geological formations and also silty-clayey unconsolidated quaternary deposits proposed an important effect of surface geology on seismic motion in the region. To check this preliminary idea we conducted a series of studies on the seismic microzonation. In this paper we intended to present some of the results obtained using the earthquake and Microtremors records.
A seismological network of 17 stations was installed by IIEES seismological department (Gholamzadeh, 2006) in the epicentral region of November 2005 earthquake with the main objective of the aftershocks and crustal structure study. This provides us the opportunity to use the earthquake data to investigate the site effect in the region. We also used 49 Microtremors 30 minutes duration measurement, recorded mainly in 2 cities of the area.

2. GEOLOGICAL AND GEOTECHNICAL CONDITIONS

Qeshm, the greatest island of the Persian Gulf, with a length of about 110 km and a surface of about 1536 to 1602 km2, form the northern flank of the Strait of Hormuz. Within this area of the southeastern marginal foreland of Zagros geostructural and geomorphological Province, the main structures are anticlines that have different axial trends with related posterior axial changes, as well as salt diapers (Haghipour, 2005).
The main prominent geological formations additional to Late Proterozoic/Early Paleozoic salt complex of the Namakdan Group (southwest of Island) are the extended outcrops of the Mio-pliocene to Early Pleistocene marly and sandy to silty deposits of Mishan-Agha Jari and younger equivalent formations, with Quaternary coverage especially of calcareous Marine terraces (Figure 1). In addition to calcareous Marine terraces the other important quaternary deposits, consist of unconsolidated sandy (a minor part gravelly) alluvial fans, sandy to silty alluvial plains and sand dunes.

3. SEISMICITY OF QESHM ISLAND

Figure 2a show the epicenter location of historical earthquake reported in the region around the Qeshm island. The region has experienced 17 events since 1336 A.D, 4 of them had a reported epicenter within the Qeshm Island. On the other hand one of the most seismically active region of the Iran with many recorded instrumental earthquake during 20th century placed in north of Qeshm island in the mainland part (Haji_Abad region, north of Bandar-Abbas). Despite to these 2 fact there is not any instrumentally important recorded earthquake with the epicenter within the Qeshm island until the recent earthquake in November 2005.
Geologically some reverse and strike-slip faults parallel to the main structure of the Island can be observed. The most prominent of them, located inside the island is Qeshm thrust fault (Figure 2b) with a length of 60 km, which passes from south of the city of Qeshm to south of Qeshm Airport. The aftershocks distribution (Figure 2b) suggests this fault as its causative fault of the recent earthquake. The surface rupture correspond to main-shock can be observed south of Jijan over this trend and in accordance to the focal solution. However the interesting feature of this earthquake is that the calculated mechanism for its strongest aftershock, Mw 5.5 that occurred ~ 6 hours after the main-shock, is a strike-slip mechanism (Figure, 2b) that is completely different from the pure reverse for main-shock (Gholamzadeh et al 2007). Further field investigation by Hessami and Tabasi (in Haghshenas et al 2007) confirm the existence of a left-lateral strike slip component for this fault.

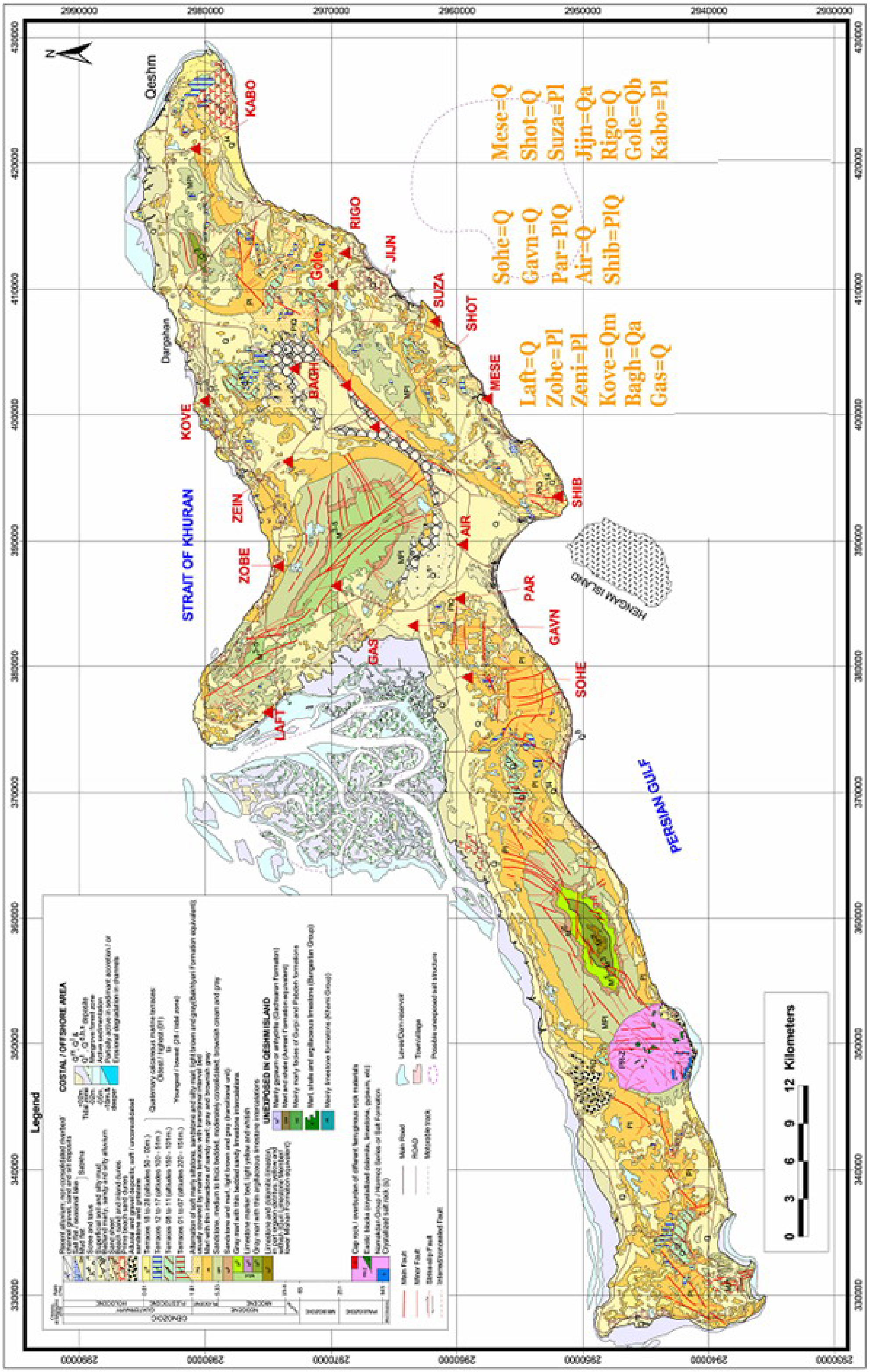
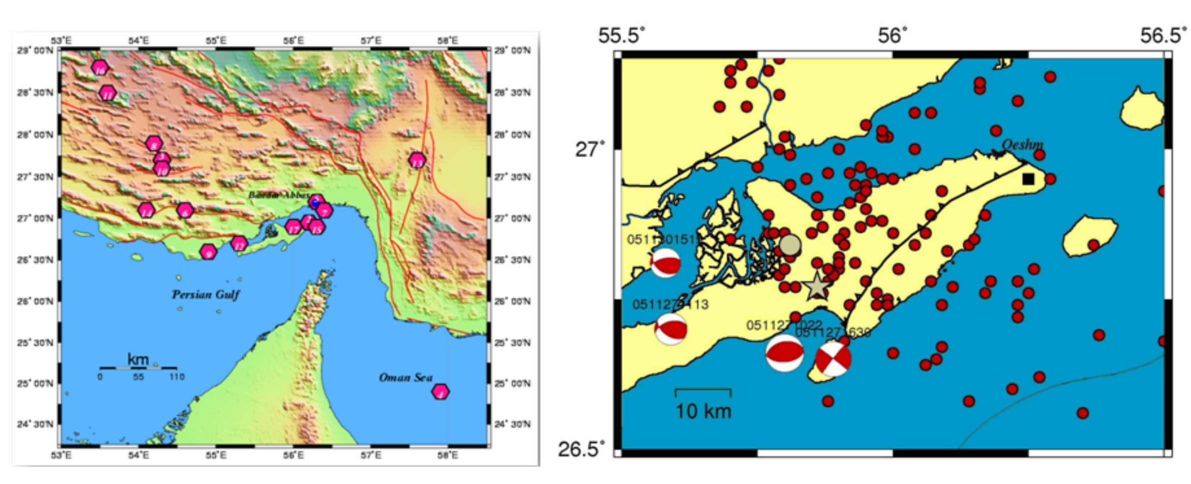


Figure 1 Geological map of Qeshm Island (digitized after Haghipour et al. 2005). Seismological network stations were plotted by triangles.



(a) (b)

Figure 2 a) Historical seismicity of the region (haghshenas et al 2007) and b) Epicentral distribution of the November 27, 2005 Qeshm earthquake aftershocks (IIEES catalogue); star is epicenter of the main-shock and the gray circle is the epicenter of the largest aftershock (USGS catalogue); CMT solution of the main-shock and its 3 aftershocks from Harvard. (Gholamzadeh et al 2007)

4. SEISMOLOGICAL MEASUREMENTS AND DATA PROCESSING

The data used in this study come from 2 seismologic surveys. First, a temporary seismological network consisting from 17 stations installed in the studied region from 2005 December 2 to 2006 February 26 by IIEES (Figure 1). The seismological materials include 17 Guralp broad band velocimeters (CMG-6TD). More than 2000 events, mostly the Qeshm earthquake aftershocks and a few regional and teleseismic events have been recorded. We selected 150 events with a good signal to noise ratio for this study. The second group of data was, the Microtremor measurements in 49 stations including 24 stations in Qeshm and 12 stations in Dargahan and 13 stations in different places of the Island. These measurements were carried out during 2006 winter using Guralp velocimeters (CMG-6TD) in a 30 minute window with sampling frequency of 100 samples per second.

5. EARTHQUAKE DATA PROCESSING

Figure 3 shows an example of the recorded earthquake in our temporary seismological network. We chose an earthquake with magnitude Ml = 4.6 occurred in west of Haji-Abad (the epicenter is show by star on the index map, plotted in the right-down corner of the Figure) sufficiently far from the Qeshm Island and so the source and path effect can be supposed identical for all stations. The recorded velocity ranges from 0.08 mm/s for GAS station to 0.20 mm/s for AIR station. We ignored the velocity of 0.28 mm/s in ZOBE station because our detail investigation shows that this high amplitude is due to the existence of an industrial noise with a frequency around 6 Hz near this station. Regardless this exception, the comparison of the recorded velocity for other stations shows clearly the variation of recorded surface seismic motion due to surface geological condition. This can be deduced specially by higher amplitude observed in AIR station compared with lower amplitude in GAS station, despite of longer epicentral distance for AIR station. In addition to the time domain observation we studied systematically the effect of surface geology in the frequency domain using the general inversion (Boatwright et al 1991) standard spectral ratio (Borchert, 1970) and horizontal/vertical spectral ratio (Lermo and Chavez-Garcia 1993) methods. The results are shown in figures 4 to 6.
The SUZA was chosen as a reference site in application of the SSR and GI methods. For SSR method we use only the earthquakes with sufficiently large epicentral distances to respect the identity of path effect for both site and reference stations. This limitation obliged us to use a few number of events using SSR technique. For all the methods we calculate the spectral ratios only for the frequencies with signal to noise ratio greater than 3.
The figures show that for most parts of the stations the amplification ratio is not very important, however for some

sites such as GAV, AIR and GOLE we can observe the clear amplification in frequencies between 5 to 8 Hz.

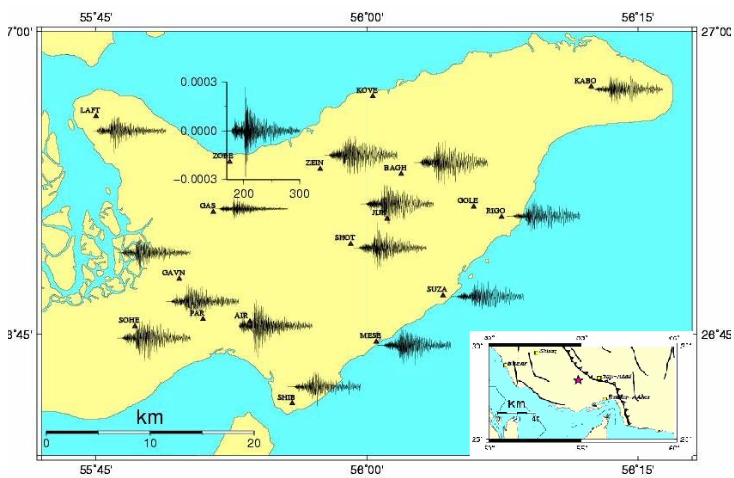


Figure 3. Velocity traces (m/s) for NS component of an earthquake with Ml = 4.6 in west of Haji-Abad

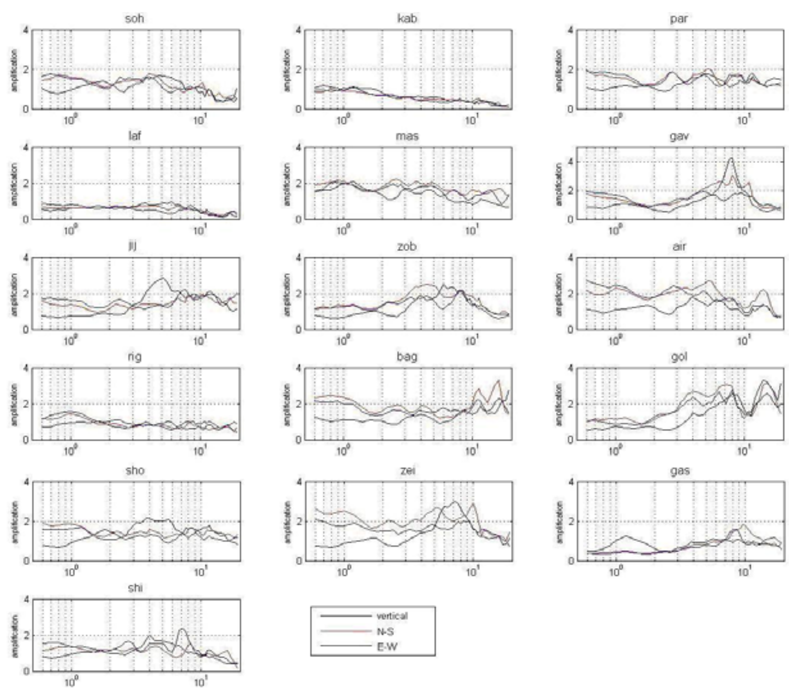


Figure 4. Amplification ratios obtained by the GI method for all stations

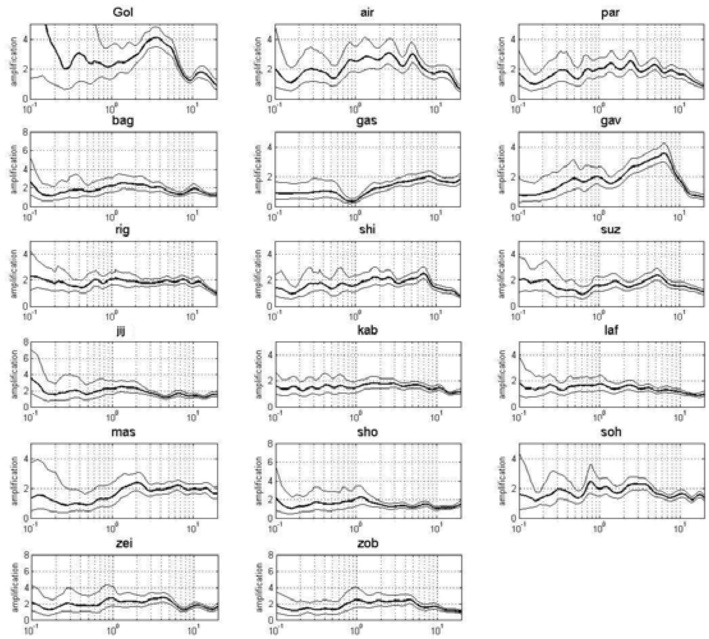


Figure 5. Amplification ratios obtained using HVSR method for all stations

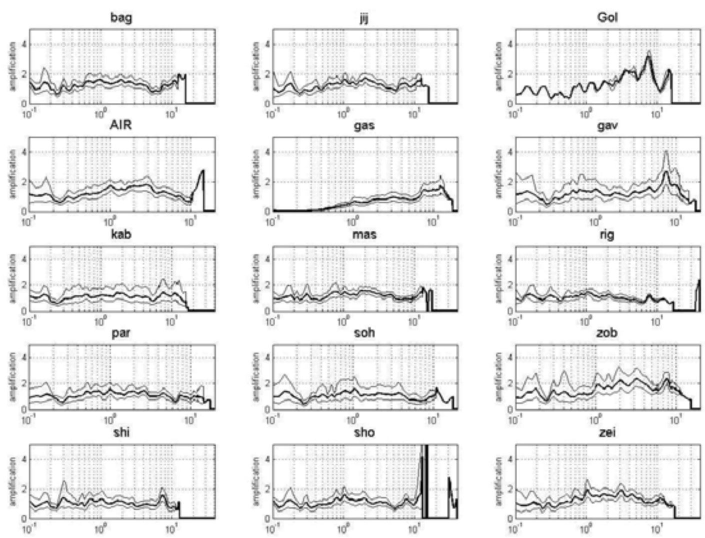


Figure 6. Amplification ratios obtained using SSR method for different stations

6. SITE EFFECT EVALUATION USING MICROTREMORS

Figure 7 shows the location of single station Microtremor measurements in the cities of Qeshm, Dargahan and some point in other part of the study area. The well known H/V spectral ratio was calculated for these sites using the Jsesame software. The results are presented if figures 8 and 9. As the results show we can see the clear peaks on H/V curves in frequency range 3 to 4 Hz in city of Dargahan. This city is mainly constructed on Quaternary unconsolidated silty-clayey deposits. For city of Qeshm there are not any clear peaks on the H/V curves. The geological surface layer in this city is mainly a relatively thick layer of limestone (thickness of about 20 meters), belong to the Quaternary marine terraces. The general shape of the H/V curve is the same for all the sites measured in this city even in southern part of the city with a sandy surface layer.

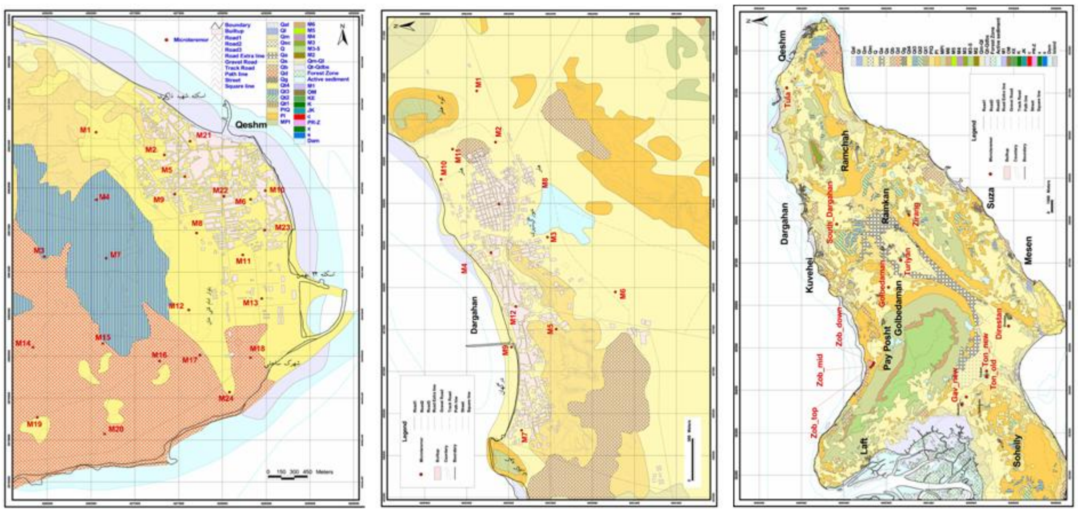


Figure 7. Location of Microtremor measuring stations (from left) Qeshm city, Dargahan city, other stations across the Island.

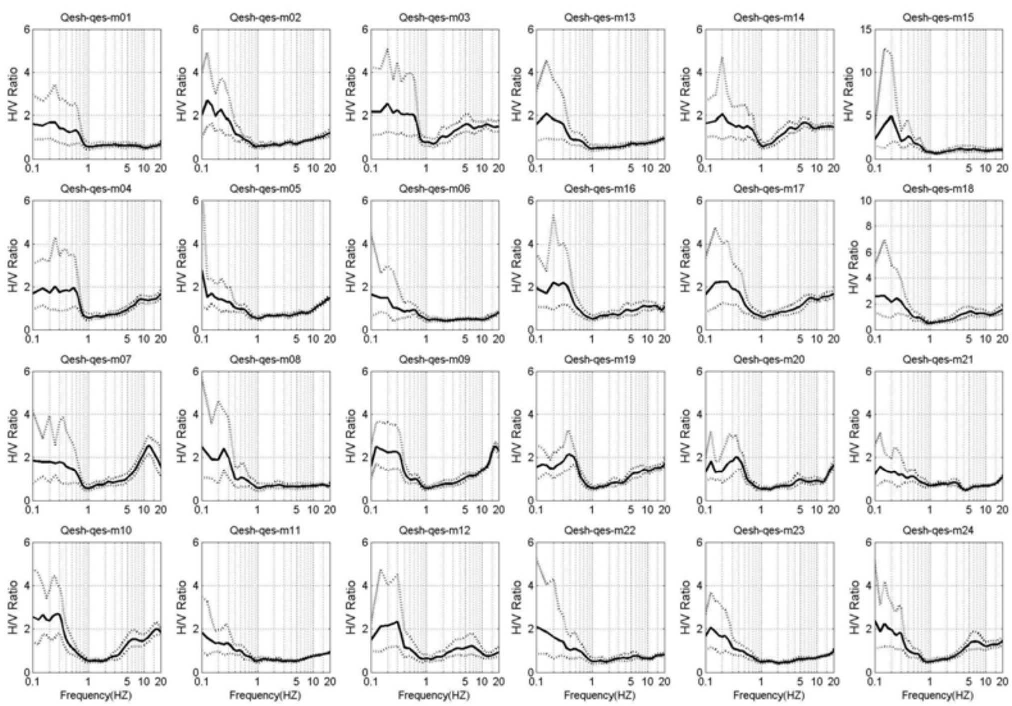


Figure 8. Amplification curves obtained by Microtremors in the Qeshm city.

7. Discussion

The effect of surface geology on the seismic motion is evaluated using the data of a temporary seismologic network and single station 30 minutes Microtremors measurements. The results show the clear amplification at least in the city of Dargahan and some other localities in the region like Gavarzin village (GAV) and Qeshm international airport (AIR). These 2 last localities are placed near to November 27, 2005 earthquake and were severely damaged (the total destruction in GAV) during that earthquake. For other seismological stations the amplification are not so clear despite to the weak surface geology of the region. This may be related to the absence of strong velocity contrast at depth but it should be also considered that the main objective of the seismological stations was the aftershock study. Thus the stations distribution was not very suitable for the aim followed in this paper.

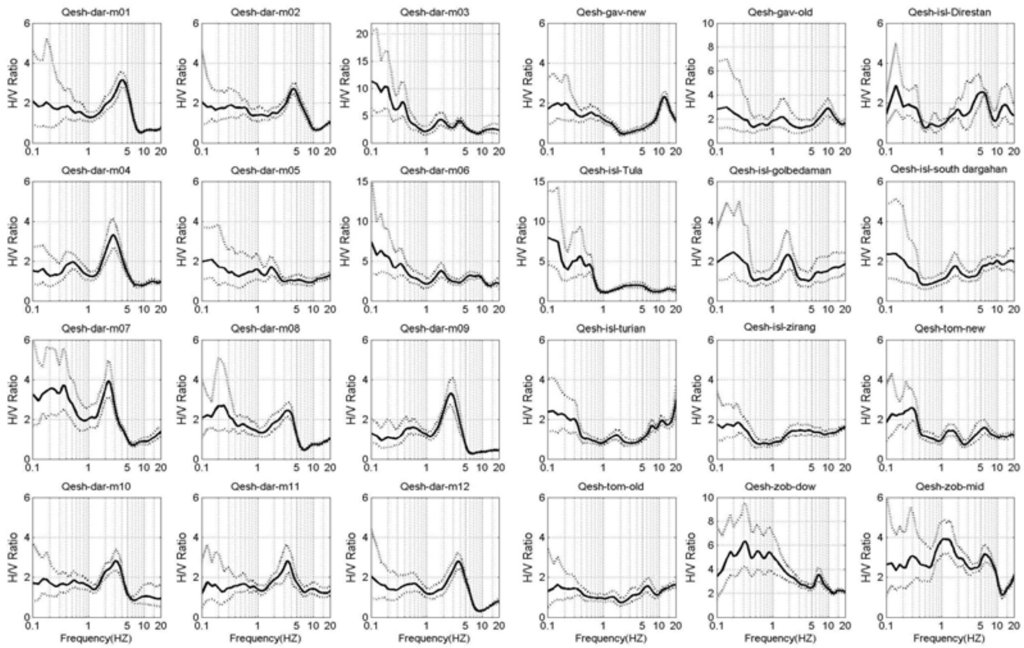


Figure 9. Amplification curves obtained by Microtremors in the Dargahan (3 left column) and the other stations across the Island (3 right column).

REFERENCES

Boatwright, J., J. B. Fletcher, and T. E. Fumal (1991). A general inversion scheme for source, site, and propagation characteristics using multiply recorded sets of moderate-sized earthquakes, *Bull. Seism. Soc. Am.* **81**, 1754 - 1782.

Borcherdt, R. D. (1970). Effects of local geology on ground motion near San Francisco Bay, *Bull. Seism. Soc. Am.* **60**, 29-61.

Gholamzadeh, A., Yamini-Fard, F., Ghasemi, M. (2007). The 2005 November 27 Qeshm Island earthquake (Iran), Mw 6.0, aftershock seismicity. *5th international conference on seismology and earthquake engineering,* **paper number:** ST4.

Hagipour A., A. Aghanabati (2005). Geological map of the Qeshm Island. Published by Free Trade Region of Qeshm.

Haghshenas,E., Hessami-Azar, K., Hazmelo, H., Javan, Gh. and M. Mostafazadeh, (2007). Earthquake and earthquake geotechnical hazard zonation in Qeshm island, part1: earthquake hazard zonation (IIEES professional report, in Persian)

Lermo, J., Chaves-Garcia, F.J. (1993). Site Effect Evaluation Using Spectral Ratios With Only One Station, *Bull. Seism. Soc. Am.* **83:5**, 1574-1594.