VIBRATION CHARACTERISTICS OF A FAR FIELD EARTHQUAKE AND ITS SHAKING EFFECTS ON DUBAI EMERGING SKYSCRAPERS

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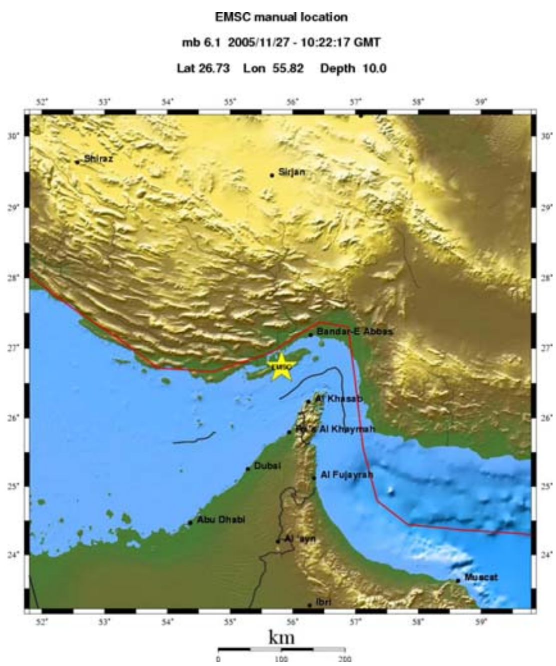
ABSTRACT :

On November 27, 2005, dominant long period earthquake has been recorded at Dibba, Fujairah station in the United Arab Emirates (UAE), generated on 150 kilometers distant epicenter of the seismic source zone at Qeshm island in Iran, known of generating large magnitude earthquakes in the past and recent history of seismic activity along the South-East coast of Iran. Preliminary analysis of time histories of the recorded earthquake motion at Dibba, Fujairah Station has been performed, and corrected acceleration, velocity and displacement time history of horizontal NS Component presented with the response spectra. Long period resonant effects of the recorded earthquake ground motions have been clearly identified, together with short period resonant effects on a firm soil conditions. Frequency and amplitude content of the obtained records have been discussed and relevant vibration characteristics presented with assessment of shaking effects experienced during the earthquake on Dubai high-rise buildings. It is concluded that the UAE could be exposed to frequent large magnitude earthquakes generated from distant seismic source zones (South Zagros Fault) on the South-East coast of Iran, with dominant long period content that may have damaging effect on Dubai rapidly increasing skyscrapers – coupled with the effects of soft soil and semi-reclaimed land on which some of these skyscrapers are built.

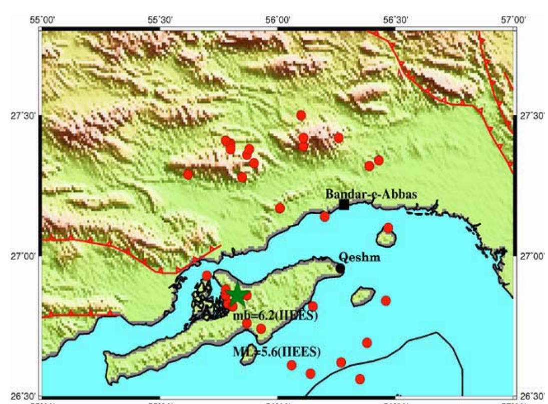
KEYWORDS: Far field earthquake, vibration characteristics, Dubai skyscrapers, Qeshm earthquake

1. CHARACTERISTICS OF NOVEMBER 27, 2005, QESHM EARTHQUAKE IN IRAN

According to the International Institute of Earthquake Engineering and Seismology (IIEES 2005) earthquake report and to USGS NEIC WDCS-D (USGS 2005) report on Sunday November 27, 2005 at 2:22:23 UAE Time (10:22:17 GMT) an earthquake with local magnitude M_l = 5.6 on the Richter scale occurred 44 km West of Qeshm Island in the Persian Gulf and 57 km South-West of Bandar Abbas and about 115 km (70 miles) North of Ras Al Khaymah, UAE. The magnitude of this earthquake according to the body wave scale is estimated at M_b = 6.2. According to the recorded seismograms, the location of this earthquake is at 26.87˚N and 55.83˚E (Figure 1a) and at a depth of approximately 10.0 km. Having been recorded by 14 of the Iranian National Broad-Band Seismic Network (INSN) at IIEES, over 400 aftershocks have followed the main earthquake in this region with 36 aftershocks of magnitude greater than 2.5. The biggest aftershock was of M_b = 5.9 which occurred few hours after the main event on the same day. Figure 1b shows the locations of some of these aftershocks. Several villages in the epicentral region have been destroyed and few casualties resulted from this earthquake, according to IIEES report (IIEES 2005).



(a)



(b)

Figure 1 (a) Epicenter of Nov. 27, 2005 Qeshm Earthquake (after EMSC 2005); (b) Aftershocks (after IIEES

2005)

2. VIBRATION CHARACTERISTICS OF THE NOVEMBER 27, 2005, QESHM EARTHQUAKE

2.1. Shaking Effects on Tall Buildings and Skyscrapers in the United Arab Emirates

The November 27, Qeshm Earthquake with M_b = 6.2 at 10:22 GMT, has been felt with strong shaking effects on the territory of the United Arab Emirates. Particularly strong earthquake shaking was pronounced and frightening in tall buildings and skyscrapers in Dubai and Northern Emirates. Safety officers across the Emirates evacuated thousands of office workers and residents from tower blocks and other tall buildings. Residents bombarded Civil Defense Centers with telephone calls upon experiencing frightening earthquake shaking in their apartments. None of the tall buildings and skyscrapers in the Emirates are provided with earthquake monitoring instrumentation system, widely implemented in Europe, United States of America, Japan, China, Iran and other earthquake prone countries in the World.

2.2. Vibration Characteristics of the Earthquake Recorded at Dibba, Fujairah in the UAE, on Epicentral Distance of 150 Kilometers

The November 27, 2005 Qeshm Earthquake has been recorded on the strong motion accelerometer installed at Dibba, Fujairah Station of the American University of Sharjah, on the east cost of the United Arab Emirates on a distance of about 150 kilometers from the earthquake epicenter on Qeshm island in Iran (Figure 2).

This is for the first time that an earthquake, generated from a distant seismic source zones in Iran, has been recorded on the strong motion accelerograph installed on the territory of the United Arab Emirates. Previous December 2002 Masafi Earthquake and October 21, 2004 Dibba Earthquake, with pronounced short period effects (Abdalla 2003), were generated (probably at Dibba Fault), from seismic source on a short distance of about 10 and 4 kilometers, respectively (Berberian 1976).

Figure 2 Epicenter of November 27, 2005 Qeshm Earthquake in Iran and location of the site of Dibba, Fujairah Station in the UAE

Three components of acceleration records of the main event with M_b = 6.2, and the strongest aftershock with M_b=5.9, which occurred around six hours later on the same day of November 27, 2005, have been analyzed in order to identify vibration characteristics of recorded earthquake ground motions, and very important long period presence in the records. Based on preliminary analysis performed of all components of the recorded acceleration time histories of the main event and strongest aftershock used for identification of vibration characteristics of the earthquake, presented are in this paper corrected acceleration, velocity and displacement time histories of horizontal NS Component of main event (Figure 3) and analyzed pseudo acceleration, pseudo velocity and displacement response spectra of the same component are shown in Figure 4, Figure 5 and Figure 6, respectively.

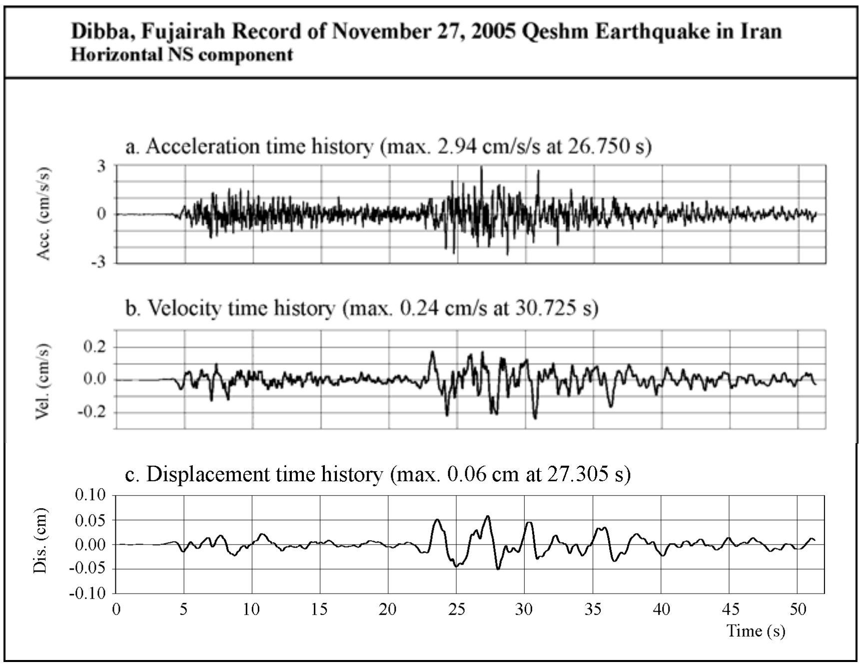


Figure 3 Corrected acceleration, velocity and displacement time history of horizontal NS Component of Dibba, Fujairah record of November 27, 2005 Qeshm Earthquake in Iran

Although, recorded maximum values of the amplitude of acceleration is only 2.94 cm/s², and calculated maximum amplitudes of velocity 0.24 cm/s and displacement 0.06 cm, are rather small, presented time histories are identifying clearly amplitude and dominant frequency content of the recorded ground motion (Figure 3). From the presented pseudo acceleration response spectra (Figure 4), pseudo velocity response spectra (Figure 5) and displacement response spectra (Figure 6) of horizontal NS component of the earthquake, the dominant presence of long period amplifications is evident and grouped at the periods of 1.0, 1.30 and 1.75 seconds as well as at the periods of 2.90, 3.20 and 4.00 seconds, for the spectral value with 2% damping. For these two groups of long periods, spectral displacements are 2 to 3 times larger with respect to the systems with vibration periods lower than 1.0 second. For period between 2.9 and 3.2 second the spectral displacement is more than 5 times as shown in Figure 6.

Due to rather firm surface soil conditions at the strong motion instrument site of Dibba, Fujairah Station, pronounced short periods of 0.20 and 0.40 seconds are also identified, with 4 times amplified pseudo acceleration response spectra to 12 cm/s² for 2% damping as indicated in Figure 4. Considering low amplitudes of vibration induces by the earthquake ground motions, amplification effects on long period as well as short period structural systems, are considered for the smallest value of 2% damping.

2.3. Vibration Effects on Buildings and Structures Due to Recorded Earthquake Ground Motions

Buildings and structures at the sites with rather firm surface soil conditions in the Emirates, similar to those at Dibba, Fujairah Station, have been exposed to amplified earthquake ground motions, vibrating into induced resonant conditions, for tall buildings in the range of 1.0 to 1.75 seconds and 2.90 to 4.00 seconds as well as low rise to medium rise buildings being into resonant conditions in the range of 0.20 to 0.40 seconds.

High-rise buildings and skyscrapers at the sites with softer surface soil conditions and deep pile foundation systems, have been exposed to significantly stronger earthquake ground motions, vibrating into strongly amplified resonant conditions (Petrovski 2003, Petrovski 2005). Frightening effects and evacuation of the inhabitants, were probably most pronounced in the Emirate of Dubai, on an epicentral distance of about 185 kilometers, and other regions with larger concentrations of tall buildings and structures.

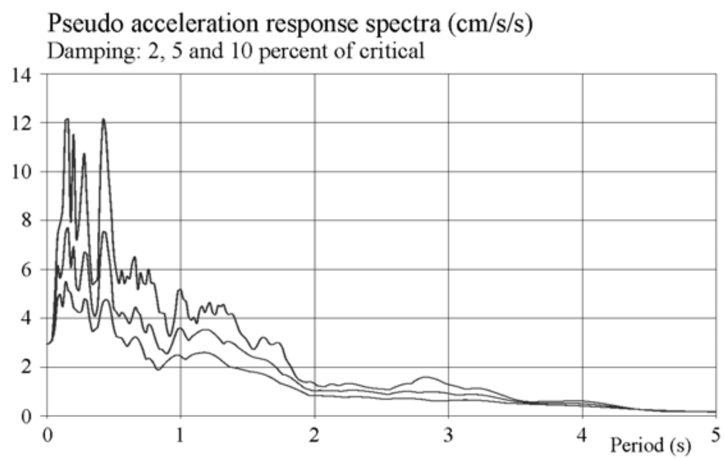


Figure 4 Pseudo acceleration spectra of horizontal NS Component of Dibba, Fujairah record of November 27, 2005 Qeshm Earthquake in Iran

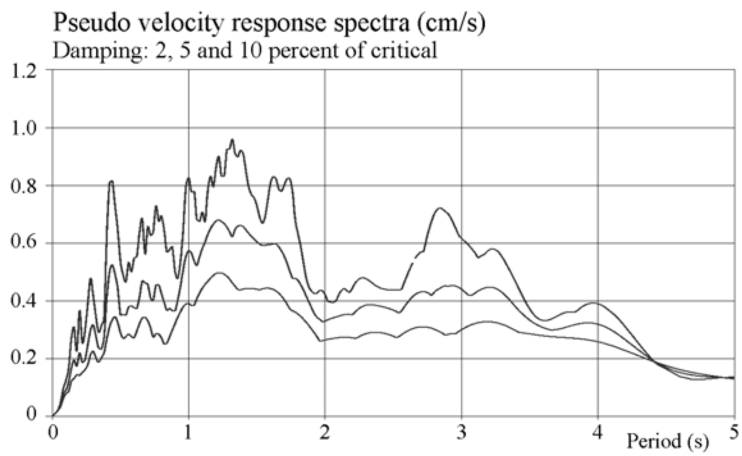


Figure 5 Pseudo velocity response spectra of horizontal NS Component of Dibba, Fujairah record of November 27, 2005 Qeshm Earthquake in Iran

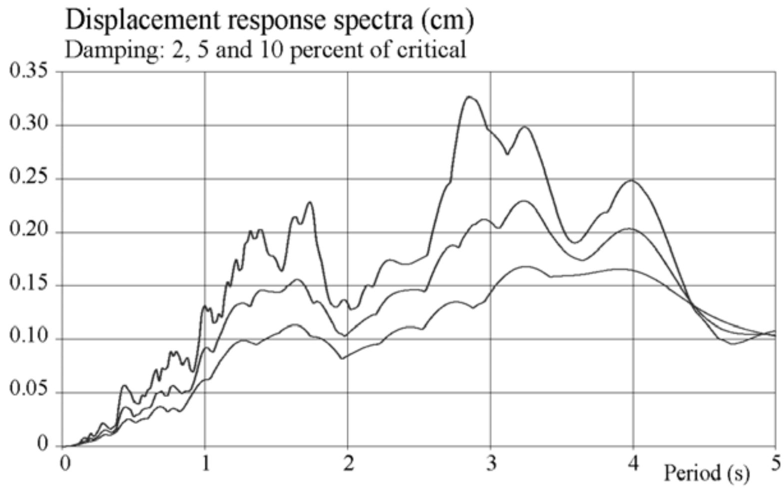


Figure 6 Displacement response spectra of horizontal NS Component of Dibba, Fujairah record of November 27, 2005 Qeshm Earthquake in Iran

3. SEISMIC HAZARD AND SEISMIC RISK OF DUBAI, UAE

The recent increase of seismic activities in the southern part of Zagros thrust fault and Makran subduction zone which is coupled with massive and rapid expansion of high-rise buildings and skyscapers in UAE warrant the consideration of earthquake forces in the analysis and design of such structures. From existing seismotectonic (Berberian 1976) and recent seismic hazard assessment studies (Abdalla 2006, Abdalla and Al-Homoud 2004, Petrovski 2005, Petrovski and Sereci 2005, Petrovski 1998, Roger 2005, Tavakoli and Ashtiany 1999), United Arab Emirates could be exposed to large magnitude earthquakes, (Tavakoli and Ashtiany 1999) from the South-East coast of Iran on a distance of 150 to 280 kilometers, producing peak ground accelerations in the range 240 to 320 cm/s² in the North Emirates (Petrovski 2005), or several times larger than those recorded at Dibba, Fujairah, due to Qeshm Earthquake with $M_l = 5.6$. This magnitude of peak ground acceleration, together with the amplification resulting from local site effect, can result in structural damage to key structures and lifeline systems. In addition, due to amplified long period effects of earthquake ground motions, soft soil surface conditions and implemented flexible pile foundation systems, tall buildings and skyscrapers, long span bridges, vital pipeline systems and other structures, could be exposed to resonant vibrations, producing large displacements and damage to non-structural elements and structural systems as well.

4. CONCLUSIONS AND RECOMMENDATIONS

As it has been shown in this study, long period earthquake ground motions has been recorded at Dibba, Fujairah station, on the North-East Coast of the United Arab Emirates, generated on November 27, 2005 by an earthquake with local magnitude $M_l = 5.6$. This earthquake occurred at a well known seismic source zone on Qeshm island in Iran, on an epicentral distance of about 185 kilometers from Dubai, UAE. From this study it can be concluded that:

1. Based on performed analysis of the recorded three component acceleration earthquake time histories of the main event and strongest aftershock, dominant long period content of the earthquake ground motions is well identified in the range of 1.0 to 1.75 seconds and 2.90 to 4.0 seconds with significant amplification in displacement response spectra.
2. Due to prevailing firm surface soil conditions at instrument site, amplified vibrations at short periods of 0.20 to 0.40 second are also identified.

3. On the North-West coast of the Emirates (Dubai, Sharjah, Ajman), at the sites with softer surface soil conditions, high-rise buildings and skyscrapers with flexible pile foundation systems, experienced much stronger resonant long period vibrations, with frightening effects and causing evacuation of thousand inhabitants.
4. It can be deduced from this event that earthquakes from the South-East coast of Iran may present serious threat to long period structures such as tall buildings, long span bridges, pipeline systems and other structures in the United Arab Emirates, especially those constructed on soft soil surface conditions and with flexible pile foundation systems.
5. It can be concluded that United Arab Emirates could be exposed to large magnitude earthquakes, from the South-East coast of Iran on a distance of 150 to 280 kilometers, producing peak ground accelerations several times larger than those recorded at Dibba, Fujairah, due to November 2005 Qeshm Earthquake with $M_l = 5.6$.
6. Considering described conditions, it could be inferred that earthquakes may present serious threat to the rapidly growing building industry of the United Arab Emirates and the gulf region. In order to study and control expected seismic risk it is recommended that earthquake monitoring systems on the territory of UAE be installed and seismic hazard maps and national seismic design codes be developed and implemented. Also, health monitoring systems should be installed on skyscrapers, important high-rise buildings, bridges, pipelines and other major structures.

5. ACKNOWLEDGEMENT

This paper is dedicated to the late Professor J. T. Petrovski (second author), who passed away late last year. This dedication, which is meant to serve as a small memorial, is to honor his contributions to the work presented here and to the enormous contributions he made to the field of earthquake engineering in general and to global seismic hazard assessment in particular.

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