Near field Uniform Seismic Hazard Spectra of Tabriz Zone

Javid Vafaie[1], **Touraj Taghikhany**[2], **Mohsen Tehranizade**[3]
[1] *MS student, Department of Civil and Environmental Engineering, Amirkabir University of Technology, Tehran, Iran*
[2] *Assistant Professor, Department of Civil and Environmental Engineering, Amirkabir University of Technology, Tehran, Iran*
[3] *Professor, Department of Civil and Environmental Engineering, Amirkabir University of Technology, Tehran, Iran*
Email: jvafaie@gmail.com, ttaghikhany@aut.ac.ir, tehz@govir.ir

Abstract:

Recent studies show when seismic sources is located in 10 to 15 km from urban area, the strong ground motions cause considerable damages on structures and result large fatalities. Indeed, seismic energy is accumulated in front of the propagating rupture and is expressed in the forward directivity region as a large velocity pulse.
Tabriz is capital of Azerbaijan province and one of the ancient cities in North-West of Iran. This city is surrounded by several active faults which caused many destructive earthquakes in history of Iran. One of the most active faults is in northern part of the city and is in close distance from urban area. Due to presence of several heavy industrial factories, financial centers and historical monuments, seismic hazard analysis of area with considering near field effect, is a national and regional project.
This study tries to generate uniform hazard spectrum of Tabriz zone caused considering active faults in vicinity of Tabriz. This paper compares generated seismic spectra for near field with conventional seismic spectra for far field in Tabriz zone. The difference of two spectra reveals the long-period pulses in near fault records are important factor in causing damage of structures.

Keywords: *Uniform Spectra, Near Field, Tabriz zone, Seismic Hazard.*

1- Introduction

For sites located in near field which is usually assumed to extend about 10 to 15 km from the seismic source, seismic records shows different results from far field [1]. Near field ground motions have caused much damage in the vicinity of seismic sources. The ground shaking near a fault rupture exposes structures to high input energy at the beginning of the record [2]. Where the fault rupture propagates toward the site at a velocity close to the shear wave velocity, casing most of the seismic energy to arrive at the site within a short time [3].
North-West Iran is a region of intense deformation and seismicity situated between two thrust belts of the Caucasus to the north and the Zagros Mountains to the south (Figure 1) [4]. Earthquake focal mechanisms suggest that the convergence between Arabia and Eurasia has been accommodated mainly through WNW-trending right-lateral strike-slip faults in this region (Figure 1) [5]. These strike-slip faults appear to be the southeastern continuation into NW Iran of the North Anatolian Fault and other right-lateral faults in SE Turkey [5]. However, right-lateral faulting in the SE Turkey-NW Iran region is not continuous but consists of several discontinuous fault segments (figures 1 and 2a). Three of these segments ruptured during earthquakes in 1930, 1966 and 1976 [5]. The most important fault of these discontinuous fault segments is North-Tabriz Fault. The North-Tabriz Fault segment, however, was seismically inactive during the last two centuries. The North-Tabriz Fault is one of the active faults in NW Iran that has a clear surface expression. It has an average strike of NW-SE over a length of about 150 km and appears to be generally close to vertical in dip [4].

Tabriz city is an economic and historic center in NW Iran. This city have been under destructive earthquakes and faced disastrous damages. To date, More than 12 historical earthquakes have been occurred in the Tabriz region. For example in earthquake 1779 with magnitude M_S=7.7, more than 50000 people died [6].

2- The Site Region

A review of the seismic history of Iran shows that this country is in a high seismic region. Geologically and structurally, the Iranian mountain ranges have long been known as part of the Alpine-Himalayan system in western Asia, between the Arabian Shield in the Southwest and the Eurasia plate in the north east. North-West Iran affected from three seismicity zones, Tabriz-Zanjan and Zarrinerood-Arak and Aras [6].

The North Tabriz Fault is the most prominent tectonic structure in the immediate vicinity of Tabriz city in NW Iran. It is extended 150km, from Mishu Mountain in the west to Bostanabad city in the east. The fault trace is approximately N 115° E and its dip is vertical [7].

The site considered for this study (longitude 46.05^0E. ~46.45^0E. , latitude 37.85^0 N.-38.25^0 N) is located in close distance from North-Tabriz Fault. In a region of about 200 km × 200 km of this site there are many active faults e.g. North Mishu, South Mishu, Sharafkhaneh-Sofian, Kenborchay, Ahmad-Abad, Barkashlu, Tasuj, North Bozgush, South Bozgush, Middle Bozgush, and Salmas faults [7]. Figure 2 is Small-scale regional map of active faults in NW Iran-Eastern Turkey and Figure 3 is location map of North-Tabriz Fault and Mazraeh Fault which both are main faults in close distance of considered site.

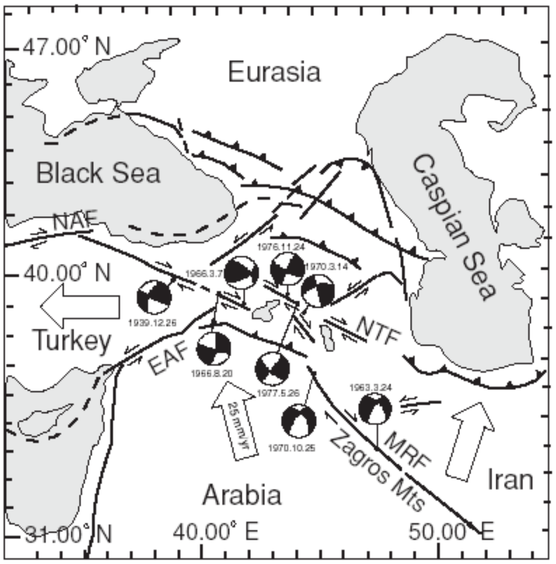

Figure 1 Location map of the NW Iran-Eastern Turkey, adapted, with focal mechanisms of some of the large earthquakes (*mb* > 5.3) in the Tabriz seismogenic zone. North Tabriz Fault (NTF), East Anatolian Fault (EAF), Main Recent Fault (MRF), North Anatolian Fault (NAF) [4].

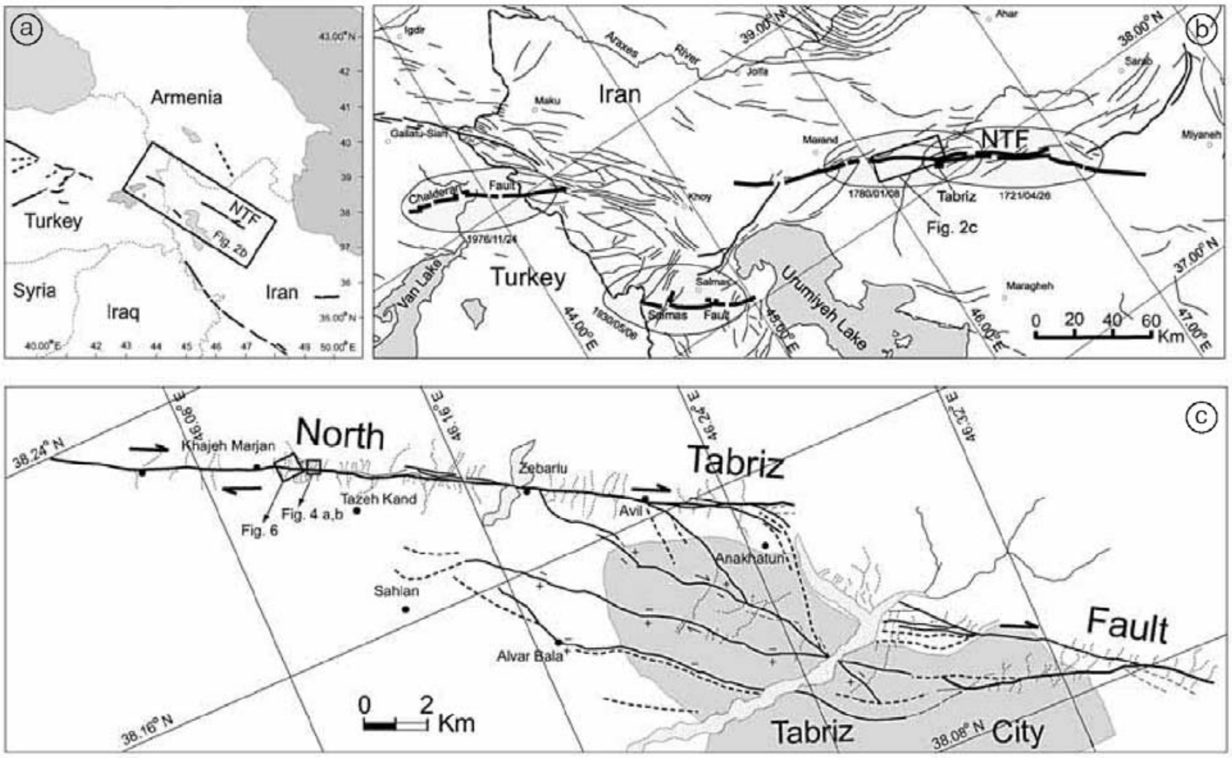

Figure 2 a) Small-scale regional map of active faults in NW Iran-Eastern Turkey. The rectangle encloses. b) simplified map of the NTF and location of historical earthquakes. Rectangle encloses c) NW section of the North Tabriz Fault [4].

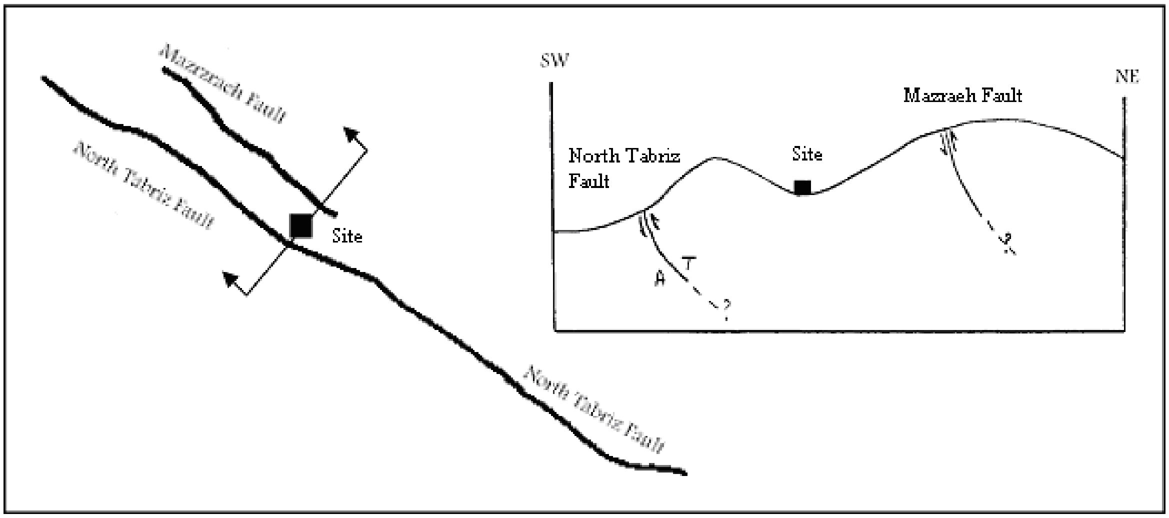

Figure 3 location map of North Tabriz faults and Mazraeh Fault which are two main faults in Tabriz boundary [8].

3- Near Field Effect

Destructive damages of structures in vicinity of seismic sources during San Fernando earthquake (1971) triggered off series of researches to understand the effects of near-source ground motions. Northridge (1994) and Kobe (1995) earthquakes provided new information concerning the behavior of engineered structures within close proximity to the rupture zone. These researches shows within near-fault zone, ground motions are characterized by long-period and high amplitude pulses of velocity and significantly influenced by the rupture mechanism. Furthermore, they understood ground motion is affected by direction of rupture propagation relative to the site, and possible permanent ground displacements resulting from the fault slip.

When the fault rupture propagates towards the site at a velocity close to the shear wave velocity, most of the seismic energy to arrive at the site within a short time. This velocity pulse is a narrow band pulse whose period increases with magnitude. This magnitude dependence of the period of the near fault pulse is expected from theory, because the period of the pulse is related to source parameters.

Moreover, Recent earthquakes have highlighted the importance of permanent ground deformation associated with surface rupture on the performance of buildings and lifelines that cross, or are situated close to, active fault traces. These factors result in effects termed herein as “rupture-directivity” and “fling step.” The estimation of ground motions close to an active fault should account for these characteristics of near-fault ground motions.

4- Probabilistic Seismic Hazard Analyzes

The methodology used to conduct PSHA was initially developed by Cornell (1968). PSHA allows the use of multi-valued or continuous events and models to arrive at the required description of the earthquake hazard. Ground motion levels are expressed in terms of probabilistic estimates such as the probability of exceedance of the PGA for a given period of time. The method also allows quantifying the uncertainty of the ground motion parameters. Evaluation of the frequency or probability of exceedance of ground motions at a site is a function of earthquake source definition (distance of the sources from the site, source geometries, and frequencies of occurrence (recurrence) of earthquakes of different magnitudes (on each source), and ground motion attenuation (amplitudes of ground motion as a function of earthquake magnitude and distance). These basic inputs to a PSHA are then combined in a probabilistic model to obtain hazard curves and equal-hazard response spectra as discussed above. PSHA may be conducted for peak ground acceleration and other ground motion parameters, such as peak ground velocity or response spectral values for specific periods of vibration and damping ratios [11].

The analysis requires ground motion attenuation relationships for the full range of magnitudes and distances considered. The ground motion attenuation is a mathematical model that indicates very parameters effect in response of earthquake. Developed attenuation relationships for peak ground acceleration and response spectral values of ground motion for near field are Bozorgnia&Campbell (2003) and Ambraseys&Douglas (2003). The uncertainties in the level of a ground motion parameter given a certain earthquake magnitude and distance are of considerable importance in influencing the results of a PSHA and should be included in the analysis [11].

A comprehensive database of near-source worldwide accelerograms is recorded between 1957 and 1998 used in Campbell and Bozorgnia (2003). The strong-motion parameters included in the analysis were peak ground acceleration and 5%-damped pseudo-acceleration response spectra (PSA) at natural periods ranging from 0.05 to 4.0 seconds. They uniformly defined the size of an earthquake in terms of MW and defined the source-to-site distance in terms of r_{seis}, the shortest distance between the recording site and the zone of the seismogenic energy release on the causative fault, referred to as the distance to seismogenic rupture [12]. Ambraseys & Douglas selected 186 free-field, chiefly triaxial strong-motion records from 42 earthquakes. They uses distance to the surface projection of the rupture, d, rather than the distance to the rupture [13]

The horizontal peak ground acceleration and response spectral values is computed for probabilistic occurrence %2 and %10 in 50 years. The results of analysis for Bozorgnia&Campbell (2003) and for Ambraseys&Douglas (2003) showed accordingly in Figure 4 and 5.

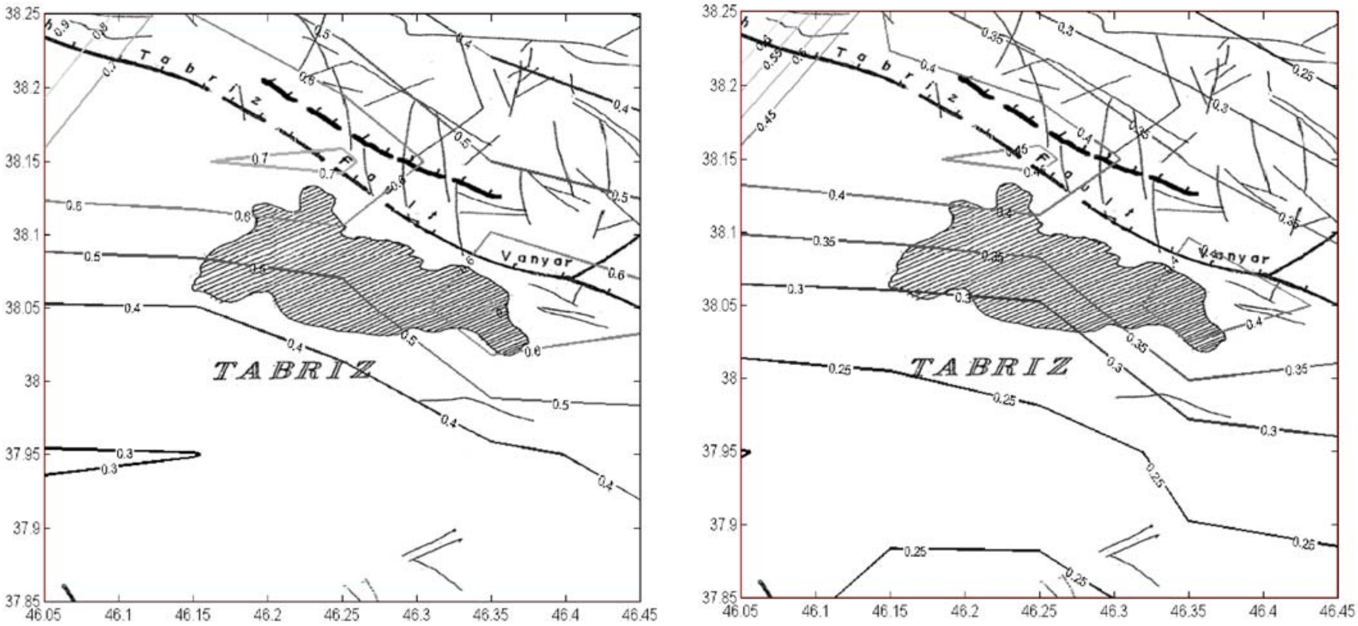

Figure 4 Peak ground acceleration (g) for %2 probability of exceedance (in left) and %10 probability of exceedance (in right) in 50 years using the attenuation relationship of Bozorgnia&Campbell (2003)

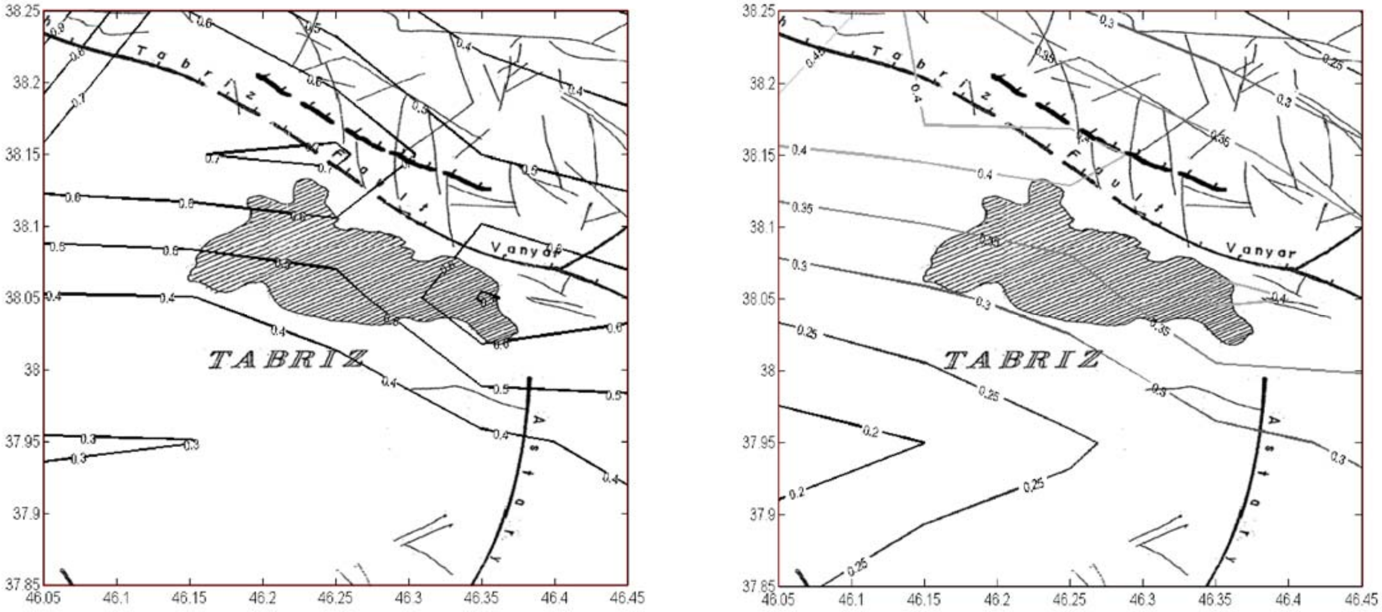

Figure 5 Peak ground acceleration (g) for %2 probability of exceedance (in left) and %10 probability of exceedance (in right) in 50 years using the attenuation relationship of Ambraseys&Douglas (2003)

5- Uniform Seismic Hazard Spectra

One of the common approaches in developing site-specific spectra on the basis of a probabilistic seismic hazard analysis is anchoring spectral shape to peak ground acceleration determined from PSHA. In this approach a probabilistic seismic hazard analysis is conducted to establish the relationship between peak ground acceleration and frequency of exceedance. The design peak acceleration level is specified by selecting an appropriate frequency, return period, or probability level. A site-specific spectrum could then be constructed by anchoring an appropriate spectral shape to this acceleration level. This spectrum does not reflect uniform seismic hazard level across structural frequencies [11].

In order to produce seismic demands with uniform hazard level across structural periods, in recent years another approach has been deployed by different researchers. In this approach, PSHA's are conducted for response spectral values covering the range of vibrational periods of interest for the project [11].

To obtain uniform seismic hazard spectra four steps should be done. First step is, define and characterize earthquake sources, then second step is, define attenuation relationships for peak ground acceleration (PGA) and response spectral amplitudes (SA) at different periods of vibration (T), third step is, conduct probabilistic analysis and develop hazard curve for peak ground acceleration (PGA) and response spectral amplitudes (SA) at different periods of vibration,(T), at last, construct response spectrum from hazard curve results. these steps were done for Tabriz boundary with these two attenuation relationships and with %2 and %10 probability of exceedance in 50 years. We obtain the uniform seismic hazard spectrums for each point of our boundary with these two attenuation relationships and for %2 and %10 probability of exceedance in 50 years. To compare in far field and near field affects only spectrums in one and ten kilometers of Tabriz Fault is shown in Figures 6 and 7.

Figure 6 shows the results of PSHA's for peak ground acceleration and for 5 percent-damped spectral ordinates at ten selected periods of vibration (0.10, 0.15, 0.20, 0.30, 0.40, 0.50, 0.75, 1.00, 1.50, and 2.00 seconds) for the site in the 1 kilometer and the 10 kilometers of North-Tabriz Fault with %2 and %10 probability of exceedance in 50 years for Bozorgnia&Campbell (2003) attenuation relationship. Figure 7 shows the results for Ambraseys&Douglas (2003) attenuation relationship.Then by passing line through these points draw the uniform seismic hazard spectrum that has the same probability of exceedance at each vibrational period. The uniform seismic hazard spectrum is the result of many possible earthquakes of different magnitude in different locations.

Spectra in one kilometer of Tabriz Fault is stronger than design spectra in Iranian code for very high seismic risk zones and this one for ten kilometers is similar to that.

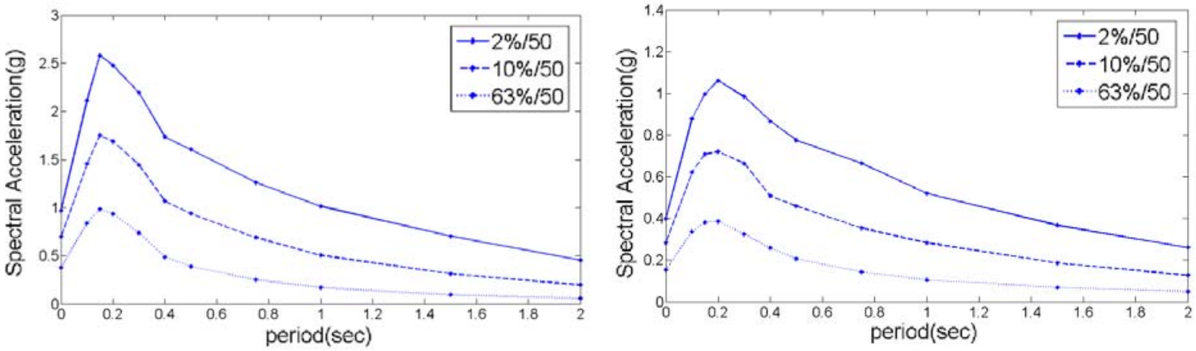

Figure 6 Uniform seismic hazard spectra for site in the 1 kilometer of North-Tabriz Fault (in left) and in the 10 kilometers (the right) for %2 , %10 and %63 probability of exceedance in 50 years using the attenuation relationship of Bozorgnia&Campbell (2003).

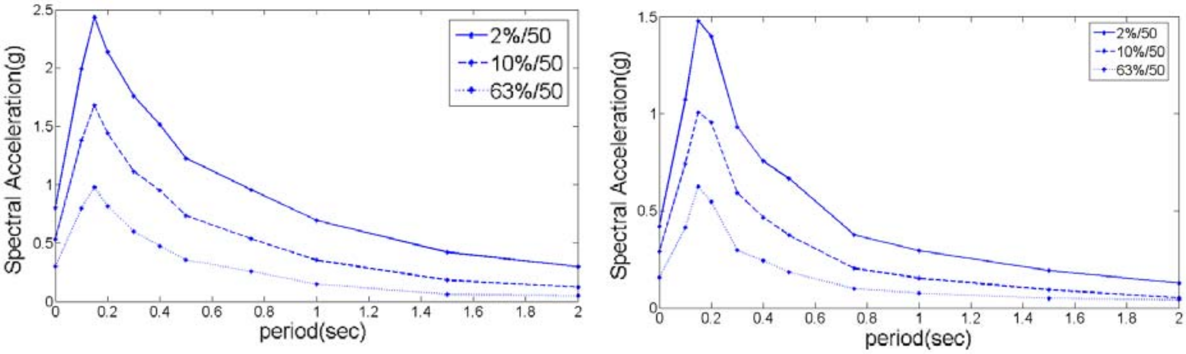

Figure 7: Uniform seismic hazard spectra for site in the 1 kilometer of North-Tabriz Fault (in left) and in the 10 kilometers (the right) for %2 , %10 and %63 probability of exceedance in 50 years using the attenuation relationship of Ambraseys&Douglas (2003) .

6- Conclusion

Tabriz as an economical and historical city in North West of Iran has been faced several destructive earthquakes and disastrous damages. In this study due to presence of several active faults in close distance of urban area, probabilistic seismic hazard analysis was carried out to evaluate the ground motion levels for design of structures considering near field effect.
Seismic hazard map in terms of peak ground acceleration for %2 and %10 probability of exceedance in 50 years indicated PGA has higher value in closer distance to North Tabriz Fault. Domination of near field effect of North Tabriz Fault delineated higher acceleration than design value recommended by National Iranian Code for Tabriz city (0.35g).
Uniform hazard spectra computed for two different site in one and ten kilometer distance from North-Tabriz Fault showed acceleration spectra in closer distance to seismic source is considerably higher than further one. Therefore demand of structures in vicinity of the North-Tabriz Fault is more than design value recommended by National Code.

References

1- SEAOC Blue Book. (1996) "Recommended Lateral Force Requirements and Commentary" Structural Engineers Association of California, sixth edition, Sacramento, California.

2- Alavi, B. and Krawinkler, H., (2001). "Effects of Near-Fault Ground Motions on Frame Structures", Ph.D. Department of Civil and Environmental Engineering Stanford University., California. USA.

3- Singh, j. (1985) "Earthquake Ground Motions: Implication for Designing Structures and Reconciling Structural Damage," *Earthquake Spectra*, Feb. 1985,239-270

4- Hessami, K. Pantosti, D. Tabassi, H. Shabanian, E. Abbassi, M. Feghhi, K. Solaymani, S. (2003) "Paleoearthquakes and slip rates of the North-Tabriz Fault, NW Iran: Preliminary Results" *ANNALS OF GEOPHYSICS*, VOL. 46, N. 5, October 2003

5- JACKSON, J. (1992) "Partitioning of Strike-Slip and Convergent Motion Between Eurasia and Arabia in Eastern Turkey and The Caucasus". *J. Geophys, Res.*, 97, 12471-12479.

6- Ambraseys, N.N. Melville, C. P. (1982) "A History of Persian Earthquake" Cambridge University Press.

7- Shahpasandzadeh, M. Zare, M. (1995) "Primary Study of Seismicity and Hazard Risk in Azarbaidjan Shargy State". International Institute of Seismology and Earthquake Engineering. (Farsi)

8- Omidi, .P. Hafezi Mogaddas, N. (1998) "Supplementary Report of Shahid Madani Dam (Vanyar) Project, Seismology and Seismcity" Power Ministry. Godsniro Consulting Engineering.(Farsi)

9- Hall,j. Heaton,T. Halling, M. Wald,D.(1995) "Near Source Ground Motion And Its Effects On Flexible Building" *Earthquake Spectra*, Vol.11, No, 4,Nov. 1995,569-605

10- Somerville PG, Smith NF, Graves RW, Abrahamson NA. (1997) "Modification of Empirical Strong Ground Motion Attenuation Relations to Include the Amplitude and Duration Effects of Rupture Directivity." *Seismo Res Lett*; V, 68.199–222.

11- "Response Spectra and Seismic Analysis for Concrete Hydraulic Structures". Department of the Army U.S. Army Corps of Engineers, (1999).

12- Bozorgnia,Y. Campbell, K, W. (2003) "The Vertical-to-Horizontal Response Spectral Ratio and Tentative Procedures for Developing Simplified V/H and Vertical Design Spectra" „*J. Earthquake Engineering*, Vol. 8, No. 2 ,2004. P.175-207.

13- Ambraseys, N.N., Douglas, J. 2003 ., "Near-field horizontal and vertical earthquake ground motions", *J. Soil Dynamics and Earthquake Engineering*, 23, 1-18