Developing the UHS and Iranian Seismic Code design spectrum for 1 Important Residential Building in Tehran

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SUMMARY:
A site investigation as well as a Seismic Hazard Analysis (SHA) has been carried out for one large residential building in new region in Tehran (capital of Iran). The aim has been estimating the level of seismic hazard for the site, developing the Uniform Hazard Spectra (UHS) for horizontal as well as vertical component to design against seismic ground motion more precisely and comparison among the UHS and Iranian Seismic Code design spectrum (Standard No. 2800-05, 3rd Edition). At first, it was tried to recognize all the active faults (sources) around the site. Secondly, by using the appropriate attenuation laws, the PGA values on the site were estimated. These values obtained for the site vary between 0.151g and 0.603g (horizontal) and 0.21g and 0.31g (vertical) for 10% probability of exceedence in 50 years ground motions depending on the applied attenuation laws such as Boore-joyner-Fummal, Ambraseys, Ambraseys-Bommer, Ambraseys-Simpson, and Zare-Ashtiany. By using logic tree idea and proposing reasonable weights for attenuation laws, the PGA values on the site were calculated. The values were 0.43g and 0.29g for horizontal and vertical component respectively. The UHS, which are more reliable for design purposes, were constructed for the 10% probability of exceedence in 50 years ground motions by using Zare-Ashtiany spectral attenuation law. Then the design spectrum, and 0.67 times of its values, for Life Safety Level was drawn based on the PGA values and Iranian Seismic Code. Finally, these spectra were compared each other. This comparison showed that design of this building with Iranian spectrum is often conservative.

Keywords: seismic hazard analysis, attenuation relationship, Uniform Hazard Spectra, Iranian Seismic Code design spectrum, IRAN

1. INTRODUCTION

As Iran is located in the high seismic area, reduction of seismic risk in different parts of the country by controlling the behaviour of structures, particularly the key structures is necessary. The best way for performing a reliable seismic hazard analysis is using probabilistic methods. This paper reports an actual case of applying this methodology for a large residential building in new region of Tehran. At first, it was tried to recognize all the seismic sources (faults) in a radius of about 110 km around the building, and to evaluate their seismic potential based on the seismic activities in recent centuries. Secondly, by using the appropriate attenuation relationships, the PGA values on the site were estimated by considering the focal depths of recorded earthquakes, horizontal site-to-source distance and the local soil conditions. Then the PGA values were calculated by using probabilistic method. Finally, the UHS in Horizontal and Vertical components were constructed for 10% probability of exceedence in 50 years ground motions based on spectral acceleration curves.

2. SITE LOCATION AND SEISMIC SOURCES PARAMETERS

The studied site in this paper corresponds to an important building in centre of Tehran, capital of Iran (51.150 T and 36.04 L). This building is located in a distance of about 6 km from North Tehran fault. Some important faults around the site in an area with radius of about 110 km are Mosha, Kandovan, North Alborz, and North Tehran. By using Iran Earthquake Catalogue, all of the ground motions with magnitude of more than 4.0, which were related to nearest active fault, were considered for hazard analysis. Faults and site location are shown in Fig. 1.

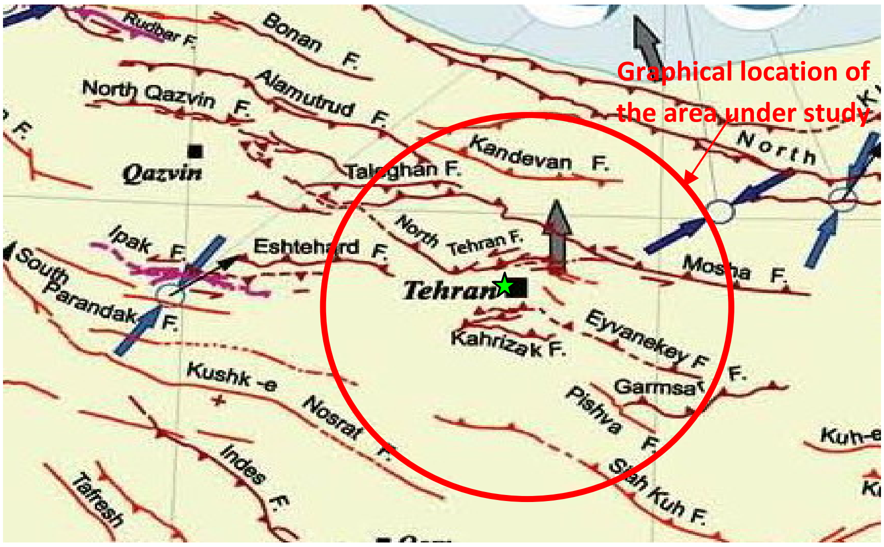


Figure 1. Faults and site location

3. ATTENUATION RELATIONSHIPS

The general form of attenuation expression used in most investigation can be characterized by the Eqn. 3.1:

$$y = b_1 \cdot f_1(M) \cdot f_2(R) \cdot f_3(M,R) \cdot f_4.(P_i) \cdot \varepsilon \tag{3.1}$$

Where y is the strong motion parameter to be predicted, b1 is a constant and

$$f_1(M) = e^{b_2 M} \tag{3.2}$$

$$f_2(R) = e^{b_4 R}\left[R + b_5\right]^{-b_3} \quad \text{or} \quad f_2(R) = e^{b_4 R}\left[\sqrt{R^2 + b_5^2}\right]^{-b_3} \tag{3.3}$$

$$f_3(M,R) = \left[R + b_6 e^{b_7 M}\right]^{-b_3} \tag{3.4}$$

$$f_4(P_i) = \sum e^{b_i R_i} \tag{3.5}$$

In Eqn. 3.1 to Eqn. 3.5, b6 is a constant and M, R, b2, b3, b4, b5, b7, Pi, and ε are respectively magnitude, site-to-source distance, magnitude attenuation rate, geometrical attenuation rate, the coefficient of elastic attenuation, the coefficient that limits the value of y at zero distance, negative coefficient that reduces the amount of magnitude scaling at short distances, site effect, random variable that is usually assumed to be log-normally distributed [Campbell, 1985]. Although an attenuation relationship that include all of the above factors are theoretically possible, two factors that are often represented in attenuation expressions are geometric spreading and magnitude.

4. HAZARD ESTIMATION BY PROBABILISTIC SEISMIC HAZARD ANALYSIS METHOD (PSHA)

This method considers all earthquakes with possible magnitude, on all significant sources, at all possible distances from the site, considering the likelihood of each combination. Therefore, using PSHA allows a desired facility to be designed for ground motion with a specified probability of exceedence [Green et al., 1994].

4.1. Steps Involved in a PSHA:

In the first step, all seismic sources that can produce damaging ground motion at the site were identified. Then each line source was divided into 3 to 5 segments.

The second step was the establishment of earthquake recurrence relationships, magnitude distribution and average occurrence rates which were obtained from Eqn. 4.1 to 4.3.

$$ln\, N = \alpha - \beta M \qquad \text{or} \qquad N(m) = e^{(\alpha - \beta M)} \tag{4.1}$$

$$\nu = [N(m_0) - N(max)] \times L \tag{4.2}$$

$$f(M) = C\beta e^{-\beta(M - m_o)} \tag{4.3}$$

Where α and β are Gutenberg-Richter coefficients, N is the number of earthquakes of magnitude greater than or equal to m_0 (the lower magnitude limit was supposed 4.0), M is the magnitude, L is part of length of line source and/or area of area source and C is as follows:

$$C = \frac{1}{1 - e^{-\beta(M_{max} - m_o)}} \tag{4.4}$$

The values of β are presented in table 4.1. In the third step, the PGA values were calculated from attenuation relationships mentioned above for various amount of R and M, between m_0 and M_{max} with a value of 0.5 for Δm.

Table 4.1. Seismicity parameter for the seismic sources

Seismic Sources	North Tehran	Mosha	North Alborz	Kandovan	Area source (south of Tehran)
β	1.00	1.23	0.526	0.971	1.02

Given the occurrence rate of an earthquake,ν, the probability that the site PGA will exceed an acceleration value (acc) of interest were determined for every combination of discretized magnitude and distance for each source by using Eqn. 4.5.

$$P(PGA \rangle acc | EQ : M, R) = 1 - \bar{\phi}\left(\frac{ln(acc) - \lambda}{\zeta}\right) \tag{4.5}$$

Where acc, varies from 0.05g to 0.65g with Δacc equal to 0.05g and

$$\lambda = E[ln(PGA)] = mean\ value\ of\ ln\,(PGA) \tag{4.6}$$

$$\zeta = \sigma_{ln(PGA)} \tag{4.7}$$

In the forth step by using Eqn. 4.8, the probability of exceedence for each fault was obtained.

$$P(PGA \rangle acc | EQ) = \sum_R \sum_M P(PGA \rangle acc | EQ : M, R) \cdot f(M) \cdot \Delta m \cdot f(R) \cdot \Delta R \tag{4.8}$$

Where value of f(R). ΔR is reverse of number of segments for all sources. The annual probability of exceedence for each fault was calculated by Eqn. 4.9.

$$P(PGA \rangle acc) = 1 - exp\left[-\nu\, t \cdot P(PGA \rangle acc | EQ)\right] \quad (4.9)$$

Where t equals 1.0.

In this study the following attenuation relationships have been used for the building.

a) Boore, Joyner and Fummal (H Comp.) [Boor et al., 1993]
b) Ambraseys & Simpson (H Comp.) [Ambraseys et al., 1996]
c) Ambraseys 1995 (H Comp.) [Ambraseys, 1995]
d) Ambraseys & Bommer (H & V Comp.) [Ambraseys et al., 1991]
e) Zare and Ashtiany (H & V Comp.) [Zare, 1999]

Fig. 2 and Fig. 3 indicate the annual probability of exceedence obtained by Zare-Ashtiany attenuation relationship (H & V Comp.). Similar curves were obtained by the attenuation relationships mentioned above, which can not be presented here.

Finally, as the fifth step, the results from the seismic faults were combined by Eqn. 4.10. The combined hazard curves for Zare-Ashtiany attenuation relationship in horizontal and vertical components and for the other attenuation relationships are shown in Fig. 4.

$$P(PGA \rangle acc) = 1 - \prod \left[1 - P(PGA \rangle acc)\right] \quad (4.10)$$

Table 4.2 presents the PGA values for horizontal and vertical components for 10% probability of exceedence in 50 years ground motions.

Table 4.2. PGA values for 10% probability of exceedence in 50 years (H & V Comp.)

Attenuation Relationship	PGA (in terms of g)			
	W.F.	H. Comp.	W.F.	V. Comp.
Boore-Joyner-Fummal	0.1	0.151	---	---
Ambraseys-Simpson	0.15	0.329	---	---
Ambraseys	0.15	0.211	---	---
Ambraseys-Bommer	0.15	0.426	0.25	0.21
Zare-Ashtiany	0.45	0.603	0.75	0.31
FINAL RESULTS	1.00	0.43	1.00	0.29

4. DEVELOPING THE UNIFORM HAZARD SPECTRA (UHS)

By definition the response at each discrete frequency of a UHS has an equal probability of being exceeded. The steps involved in computing a UHS are the same as those for the probabilistic hazard curve described above, except that the steps are repeated several times using different coefficients corresponding to each discrete frequency. The Zare-Ashtiany spectral attenuation relationships (H & V Comp.) have been used to compute the S_a. Fig. 5 indicates the UHS curves 10% probability of exceedence in 50 years (H & V Components) and Iranian Seismic Code design spectrum (Standard No. 2800-05) for life safety level separately.

In Fig. 6, UHS curves were drawn for horizontal and vertical components have been compared with Iranian Seismic Code design spectrum (Standard No. 2800-05). Comparison of 10% in 50 years and Iranian spectrum shows that design of this building with Iranian spectrum is non conservative.

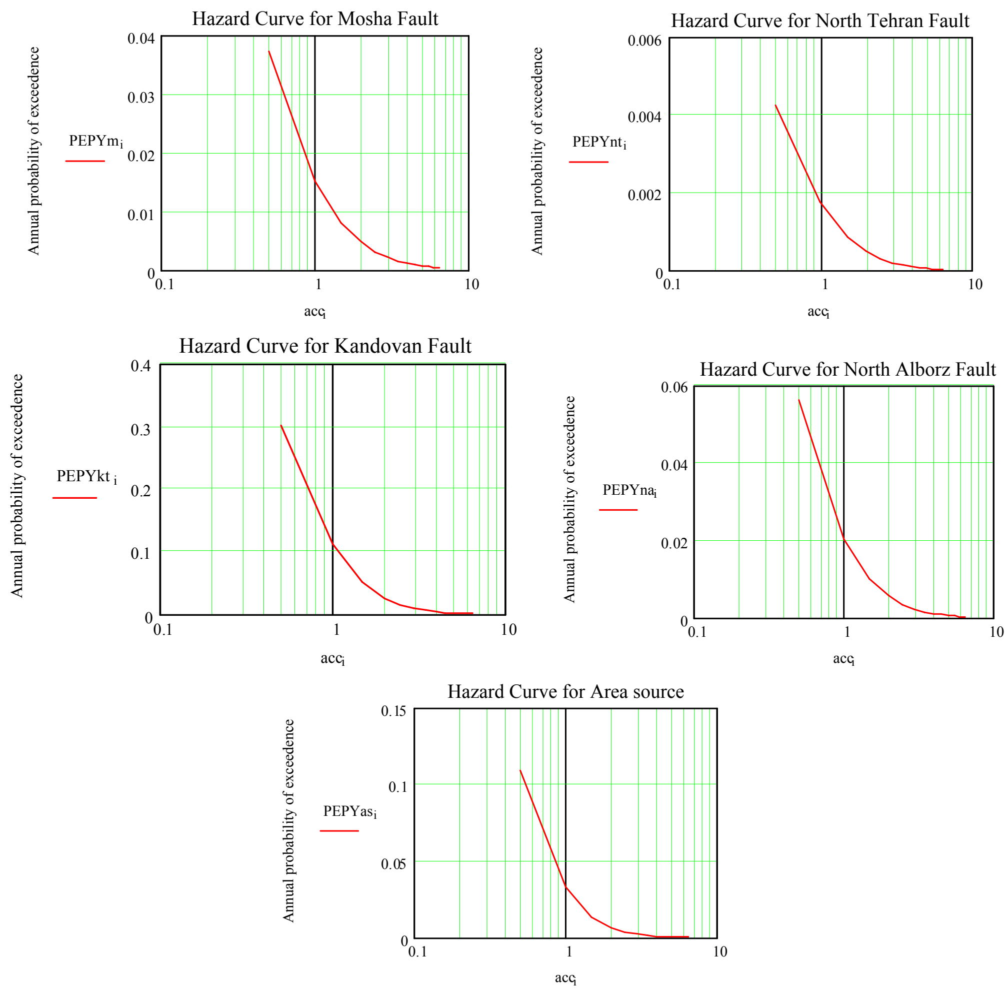
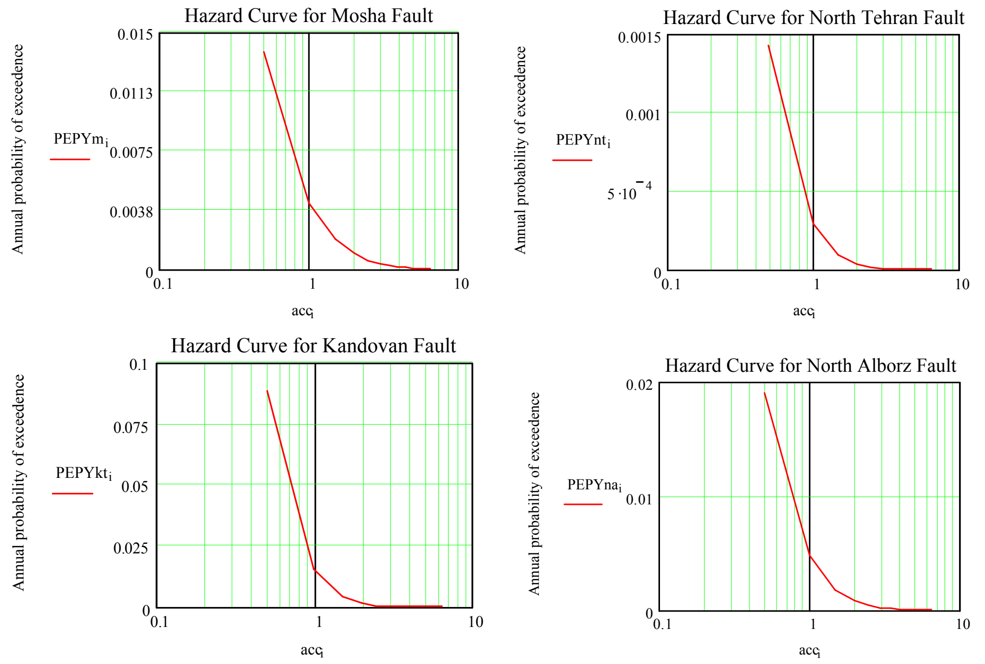


Figure 2. The hazard curve obtained for the seismic sources by Zare-Ashtiany attenuation relationship (H Component)



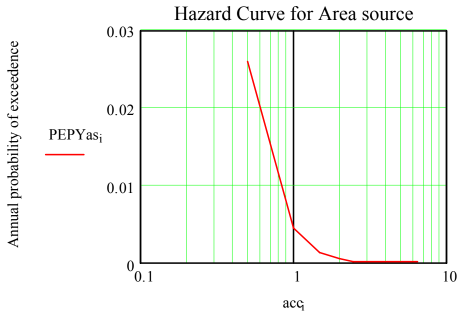


Figure 3. The hazard curve obtained for the seismic sources by Zare-Ashtiany attenuation relationship (V Component)

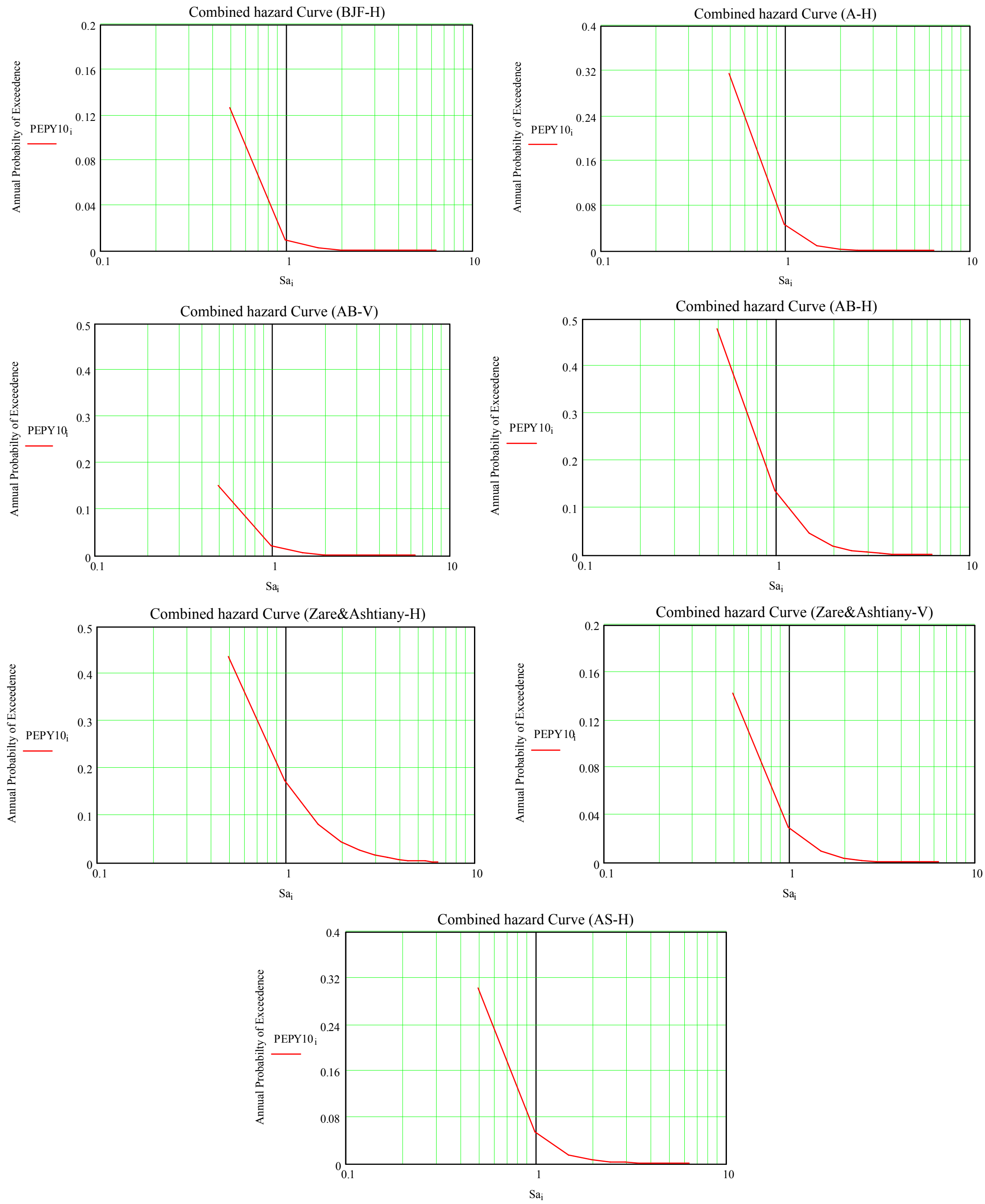


Figure 4. Combined hazard curves (all attenuation relationships)

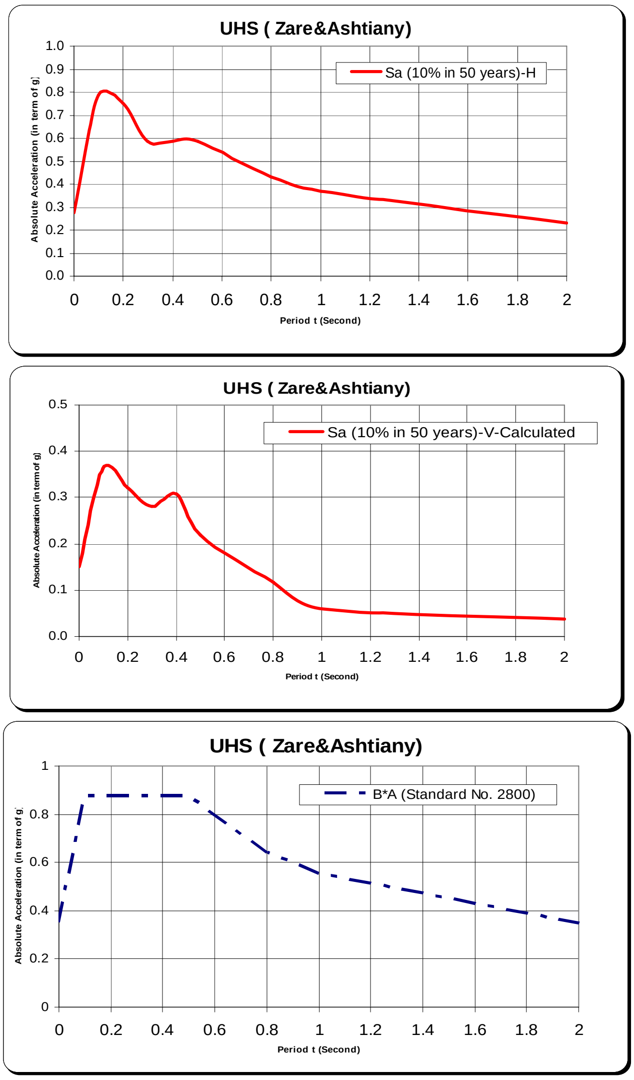


Figure 5. UHS curves for 10% probability of exceedence in 50 years (H & V Comp.) and Iranian Seismic Code design spectrum (Standard No. 2800-05) for Life Safety Level

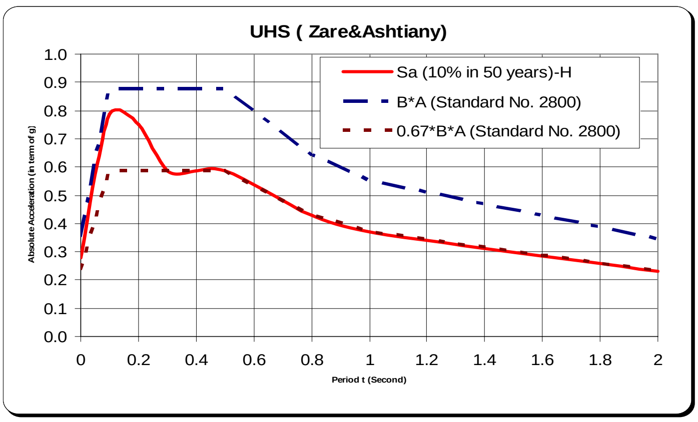


Figure 6. Comparison among UHS curves for different probability of exceedence and Iranian Seismic Code design spectrum (Standard No. 2800-05) for Life Safety Level

5. CONCLUSIONS

In this study Maximum PGA values obtained for the site from PSHA method (horizontal component) were 0.603g, for 10% probability of exceedence in 50 years ground motions and 0.31g (vertical component) depending on the applied attenuation laws. The average value factors (W.F.) were 0.43g and 0.29g respectively, based on defined weighting.

The results of PSHA method are reliable, because this procedure uses seismicity parameter and several site-to-source distances. Comparison of 10% in 50 years and Iranian Seismic Code design spectrum (Standard No. 2800-05) for life safety level shows that design of this building with Iranian spectrum is non conservative.

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