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Risk Analysis of Tehran through Deterministic and Probabilistic Methods

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ABSTRACT

In this study, the risk of earthquake is estimated onbase of deterministic and probabilistic method in Tehran, and zone ofthe Setareh Pars project was investigated in the relative risk of earthquakes.The study areawas an enclosed regional between 51 degrees 25 minutes and 40 seconds longitude and latitude 35 degrees 45 minutes and 30 seconds. Some lowering models were investigated, the investigations showed that all three of next generation attenuation(NGA) equations can be used to calculate of attenuation relations. However, BA model compared with the CB model is partly accurate for obtainingrelations regardless of the type of attitude and calculations.Generally, the BA and CB models fit better with the seismic datas of Iran. Contingency ofdifferent peak ground horizontal accelerations **(**PGVAs) was investigatedfor useful lifetime of 25, 50 and 100 yearsindistance of150 kilometers about the site. The risk of earthquakes is 10%in the 50-year period and 2% in the course of 100 years.

KEYWORDS: risk analysis, deterministic methods, probabilistic methods.

INTRODUCTION

Iran is located in the path of orogenic belt of the Alps-Himalayas. There is a high-level of seismic activity there and 130 earthquakes has happened with a magnitude of 7.5 on the scale of Richter up to day [1]. Iran had been among the six countries with high human casualties of earthquakes since 1900 - 2000 AD [2]. According to seismotectonic issue, Iran is divided to Zagros folded strip, Alborz, Kope Dagh and central Iran and Lut plain [3]. Seismic designing and retrofitting against ground movements of earthquakes should be done carefully and based on established criteria. For this purpose it is necessary to measure strong ground motion in terms of physical quantities and measures which represents a seismic loads applied to the structure by the land. The most important measure of strong ground motion which are intended in seismical designing with engineering application include the maximum amount of acceleration, acceleration response spectrum and the acceleration of mapping. The maximum of peak ground acceleration (PGA) is the most common measurement for designing of structures, while it can't explain dynamic structures status but the risk of seismic damage for structures will be increased by it's increasing. According to the by law No 2800 of structure designing against earthquake (updated 3), whenever 0.35 g is suggested for basis acceleration, the site surveyed exposure to high relative risk. There are two approaches to estimate the risk of earthquake. The most magnitude of expected earthquake is related to each spring in deterministic method and earth movement is estimated by attenuation relationships with assumption the earthquake occurs in nearest place to checkpoint. In the probabilistic approach, total odds of a certain level of ground motion parameters is intended around the point check parameters over a period of time. Based on previous work on neotectonics regime in Iran, Zagros in south Iran is the most active zone [4]. Then, Alborz in north Iran [6-8] and central Iran [5-7] have been situated in the next orders. In this research; the probabilistic method is used to estimate the earthquake in Tehran (district 22 of Tehran).

MATERIAL AND METHOD

Selection of attenuation model of strong motion ground

Attenuation relationships are functions which the measurement strong ground movement correlate to The variables that express the characteristics of an earthquake. In attenuation relationships of the strong ground movement are described on base of distance to project location and magnitude earthquake. The basis of process is the energy and domain of wave has been decreased by increasing the distance thus in attenuation relationships the acceleration has been decreased by increasing the distance. Also, acceleration is increased by increasing the magnitude of earthquake. For this purpose, the last of attenuation relations of research groups of earthquake was used in Berkeley university that is known as NGA. NGA attenuation relationships is briefly defined as follows:

Researchers who found NGA relations have provided a noteworthy model for the movement before the starting the project, that was highly regarded. The researchers are called as follows:
AS08: Abrahamson and Silva 2008 NGA Model
BA08: Boore and Atkinson 2008 NGA Model
CB08: Campbell and Bozorgnia 2008 NGA Model
AS08 and CB08 have used the most complex parameters. In addition the mentioned parameters hanging-wall, the effect of the failure and the effect of the sedimentary layers have been expressed.

1. The represented relationship by Abrahamson and Silva (2008) [8]

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$$\begin{aligned}\ln Sa(g) = {} & f_1(M, R_{rup}) + a_{12}F_{RV} + a_{13}F_N + a_{15}F_{AS} + f_5(P\hat{G}A_{1100}, V_{S30}) \\ & + F_{HW} f_4(R_{jb}, R_{rup}, R_x, W, dip, Z_{top}, M) + F_{RV} f_6(Z_{top}) + (1 - F_{RV}) f_7(Z_{top}) \\ & + f_8(R_{rup}) + f_{10}(Z_{1.0}, V_{S30})\end{aligned} \quad (1)$$

The parameters in Eq. (1) are defined in Table 1.

Table 1. Definition of parameters used in the regression analysis

Parameter	Definition	Notes
M	Moment magnitude	
Rrup	Rupture distance (km)	
Rjb	Joyner-Boore distance (km)	
Rx	Horizontal distance (km) from top edge of rupture	Measured perpendicular to the fault strike
Ztop	Depth-to -top of rupture (km)	
FRV	Flag for reverse faulting earthquakes	1 for reverse and reverse/oblique earthquakes defined by rake angles between 30 and 150 degrees, 0 otherwise
FN	Flag for normal faulting earthquakes	1 for normal earthquakes defined by rake angles between -60 and -120 degrees, 0 otherwise
FAS	Flag for aftershocks	1 for aftershocks, 0 for main shocks, foreshocks, and swarms
FHW	Flag for hanging wall sites	1 for sites on the hanging wall side of the fault, 0 otherwise. The boundary between the FW and HW is defined by the vertical projection of the top of the rupture. For dips of 90 degrees, FHW =0
Dip	Fault dip in degrees	
VS30	Shear-wave velocity over-the-top 30 m (m/s)	
Z1.0	Depth to VS=1.0 km/s at the site (m)	
PGA_{1100}	Median peak acceleration (g) for VS30=1100 m/s	
W	Down-dip rupture width (km)	

2. The represented relationship by Boore and Atkinson (2008) [9]

$$\ln Y = F_M(\mathbf{M}) + F_D(R_{JB}, \mathbf{M}) + F_S(V_{S30}, R_{JB}, \mathbf{M}) + \varepsilon\sigma_T, \quad (2)$$

In this equation, F_M, F_D, and F_S represent the magnitude scaling, distance function, and site amplification, respectively. **M** is moment magnitude, R_{JB} is the Joyner-Boore distance (defined as the closest distance to the surface projection of the fault, which is approximately equal to the epicentral distance for events of **M**<6), and the velocity V_{S30} is the inverse of the average shear-wave slowness from the surface to a depth of 30 m. The predictive variables are **M**, R_{JB}, and V_{S30}; the fault type is an optional predictive variable that enters into the magnitude scaling term as shown in Equation 5a and 5b below. ε is the fractional number of standard deviations of a single predicted value of ln *Y* away from the mean value of ln *Y* (*e.g.*, ε=−1.5 would be 1.5 standard deviations smaller than the mean value). All terms, including the coefficient σ_T, are period dependent. σ_T is computed using the equation:

$$\sigma_T = \sqrt{\sigma^2 + \tau^2}, \quad (3)$$

Where σ is the intra-event aleatory uncertainty and T is the inter-event aleatory uncertainty (this uncertainty is slightly different for cases where fault type is specified and where it is not specified; we distinguish these cases by including a subscript on T).

3. The represented relationship by Campbell and Bozorgnia (2008) [10]

$$\ln S_a(g) = f_{mag}(M) + f_{dis}(R_{rup}, M) + f_{flt}(F_{RV}, F_{NM}) + f_{hng}(M, F_{HW}) + f_{site}(V_{s30}) + f_{sed}(Z_{2.5}) \quad (4)$$

Where $f_{mag}(M)$: Presenter functions the effect of magnitude, $f_{dis}(M, R_{rup})$: Presenter functions the effect of distance, $f_{flt}(F_{RV}, F_{NM})$: Presenter functions the effects of fault mechanism, $f_{hng}(M, F_{HW})$: Parameter of effect hanging wall, $f_{site}(V_{s30})$: Presenter functions the effects of shear wave velocity of site, $f_{sed}(Z_{2.5})$: Presenter functions the effects of depth sediments

In general, the investigations showed that all three of NGA equations can be used to calculate of attenuation relations in Iran; however, BA model compared with the CB model is partly accurate for obtaining relations regardless of the type of attitude and calculations. Generally, the BA and CB models fit better with the seismic data of Iran.

RESULT AND DISCUSSION

Estimating the risk of earthquake through deterministic method

In this project, after determining the seismic sources by using the listed attenuation relations, maximum acceleration of ground was calculated and summarized in Tables 2 and 3.

Table 2. maximum horizontal acceleration ground of studied region in effect of strongest activity each fault

No	The name of fault	PGA max(g) AS-2008	PGA max(g) BA-2008	PGA max(g) CB-2008	PGA max(g) CY-2008
1	Mosha compressive fault	0.45	0.22	0.26	0.41
2	North of Tehran fault	0.88	0.36	0.55	0.57
3	Parchin-ivanekey fault	0.55	0.25	0.3	0.5
4	Garmsar fault	0.12	0.07	0.08	0.09
5	Khazar-Mazandaran run	0.17	0.07	0.09	0.11
6	Kahrizak fault	0.39	0.24	0.39	0.4
7	Telo fault	0.19	0.18	0.054	0.2
8	Kosar fault	0.19	0.18	0.054	0.2
9	North of Rey fault	0.42	0.21	0.26	0.38
10	South of Rey fault	0.4	0.2	0.24	0.35

Table 3. maximum vertical acceleration ground of studied region in effect of strongest activity each fault

No	The name of fault	PGA max(g) AS-2008	PGA max(g) BA-2008	PGA max(g) CB-2008	PGA max(g) CY-2008
1	Mosha compressive fault	0.36	0.18	0.23	0.32
2	North of Tehran fault	0.91	0.36	0.59	0.59
3	Parchin-ivanekey fault	0.41	0.19	0.22	0.38
4	Garmsar fault	0.07	0.04	0.05	0.05
5	Khazar-Mazandaran run	0.09	0.04	0.05	0.06
6	Kahrizak fault	0.27	0.18	0.24	0.26
7	Telo fault	0.13	0.13	0.04	0.14
8	Kosar fault	0.13	0.13	0.04	0.14
9	North of Rey fault	0.35	0.21	0.22	0.34
10	South of Rey fault	0.32	0.20	0.19	0.31

Probabilistic seismic hazard analysis

In probabilistic seismic hazard analysis method, analyzing is based on all possible modes obtained the seismic power of model seismic source in the area and in all the available distance to status check because of strong ground movement and exceedance probability. In this method, it is possible to estimate the uncertainty of each parameter quantitatively and the analyzing of earthquake risk can be calculated for more realistic estimating of the nature of seismic strong ground movement. To obtain the best estimating for the maximum value of strong ground motion, repeating the procedure and considering metrics will be possible include: uncertainty various measures, different models of seismic sources, seismic power and different attenuation relations. Estimating PGA through probabilistic method line area model of seismic sources. In this way, analyzing the risk of earthquake is done on base of introduced method by Kramer and NGA Attenuation relations. Peak ground acceleration (PGA) of desired parameter, the strong ground motion is calculated with respect to selected attenuation relations in studied origin (District 22 of Tehran). The magnitude of threshold, the related maximum and the nearest distance is studied according to depth of related focal to area search, and intended measurements of strong ground motion can be achieved by using all combined seismic sources for the possibility of increasing and the useful life of structure. Generally, three combinations of the possible function are used for each individual source. The probability of an earthquake occurs on a source with special magnitude at specified period. The probability of a failure of seismic source occurs with magnitude of this event and with special distance to place. The probability of a strong ground motion of earthquake be increased with magnitude and specified distance into special surface in origin. Calculating the probability of increasing for a special level strong ground motion in are available by considering all combined sources in desired origin and it's related useful life. Based on the written issues, there are 12 seismic sources as follows:

Mosha line seismic source
North of Tehran line seismic source
Parchin – Ivanekey line seismic source
Kahrizak line seismic source
Talegan line seismic source

Damavand Ghasran line seismic source
Kandovan line seismic source
North of Alborz line seismic source
Amiran line seismic source
Telo line seismic source
Kosar line seismic source
Ghasr-firuzeh line seismic source
The rate of return and the annual incidence rate maximum of horizontal and vertical acceleration values have been calculated for attenuation relations on the base of this method and by using the attenuation relations NGA which are shown in Figures 1 to 4.

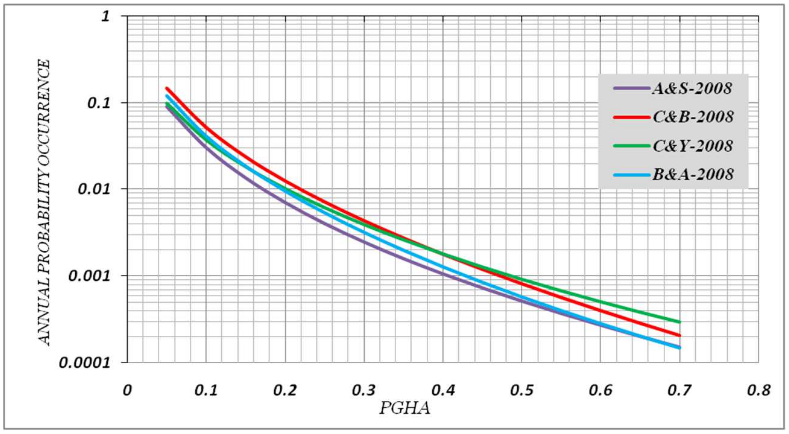

Fig. 1. The digram of annual rate occurrence of peak ground horizontal acceleration (PGHA) in distance 150 km around the site for different attenuation relations

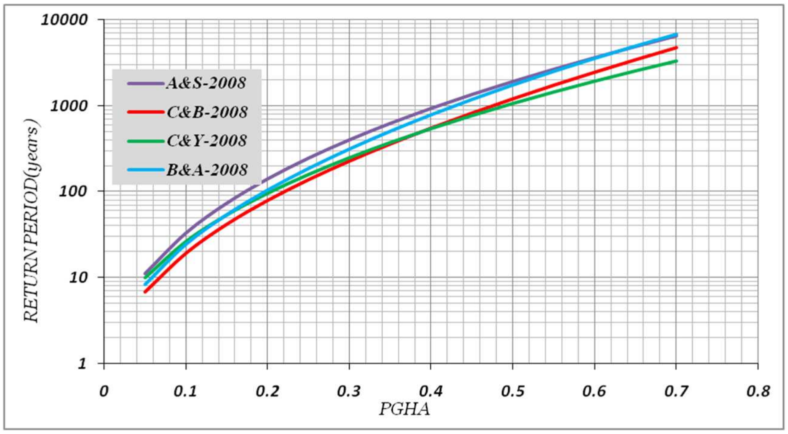

Fig. 2. The return period of peak ground horizontal acceleration (PGHA) in distance 150 km around the site for different attenuation relations

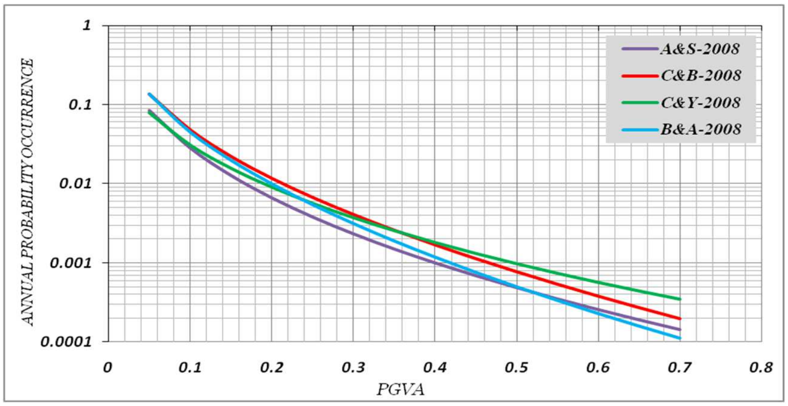

Fig. 3. The digram of annual rate occurrence of peak ground vertical acceleration (PGVA) in distance 150 km around the site for different attenuation relations

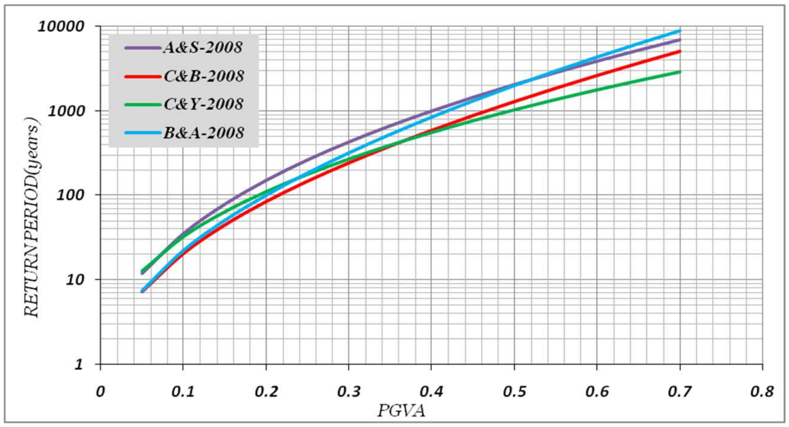

Fig. 4. The return period of peak ground vertical acceleration (PGVA) in distance 150 km around the site for different attenuation relations

Provided coefficients in logic tree are used for determination the curve of annual risk at studied origin. Summary results of the research were mentioned in attenuation relations. The logic tree is shown in figure 5 for estimating the peak ground horizontal acceleration.

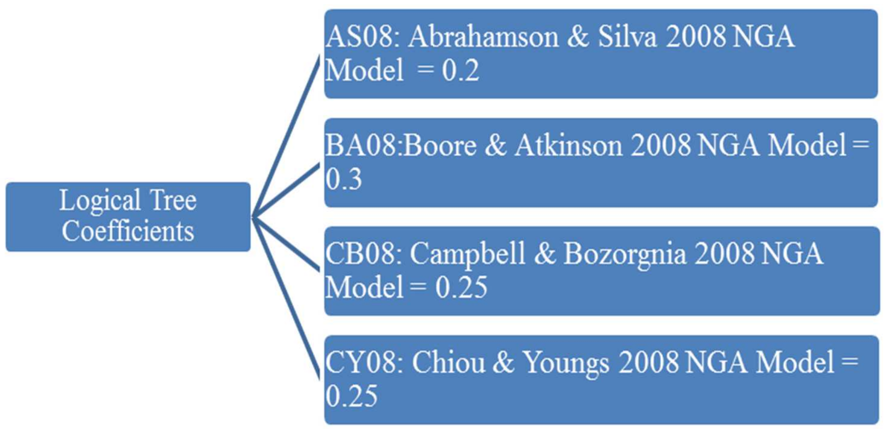

Fig. 5. The used logical tree in risk curve of structure

The digrams of annual rate occurrence of peak ground horizontal and vertical acceleration and also the digrams of the return period of peak ground horizontal and vertical acceleration are provided in Figures 6 to 9.

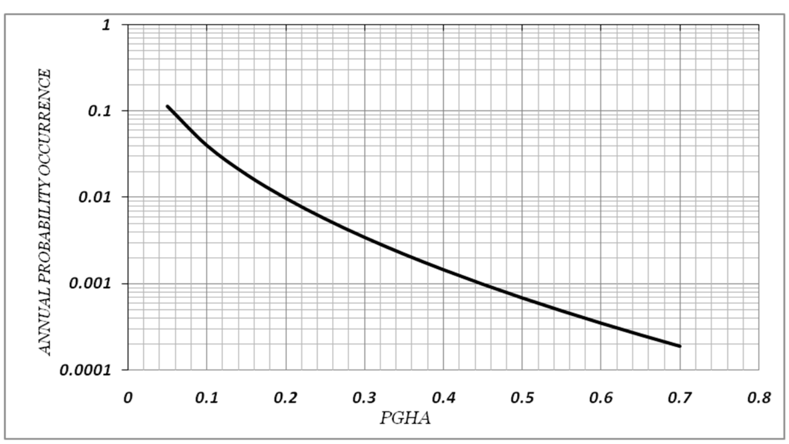

Fig. 6. The annual rate occurrence of peak ground horizontal acceleration (PGHA) in distance 150 km around the site

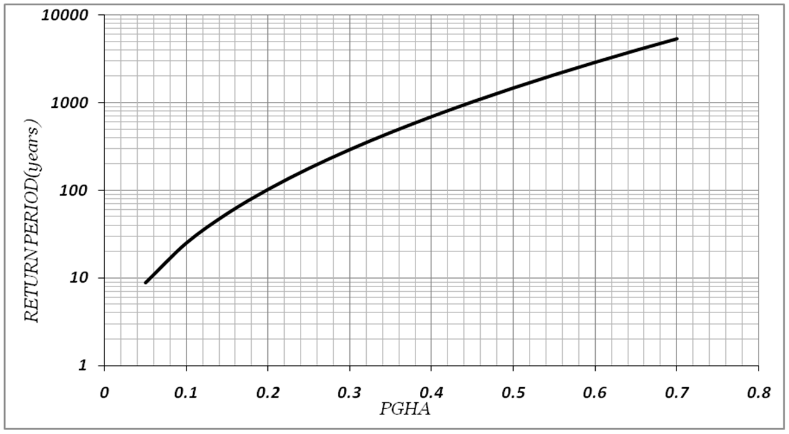

Fig. 7. The return period of peak ground horizontal acceleration (PGHA) in distance 150 km around the site

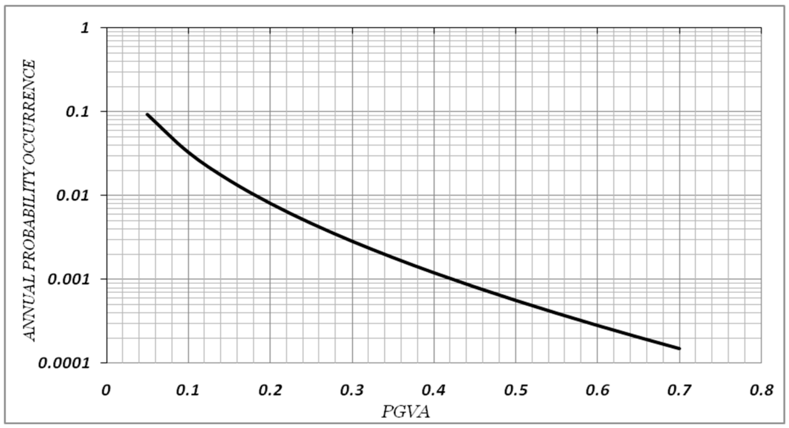

Fig. 8. The annual rate occurrence of peak ground vertical acceleration (PGVA) in distance 150 km around the site

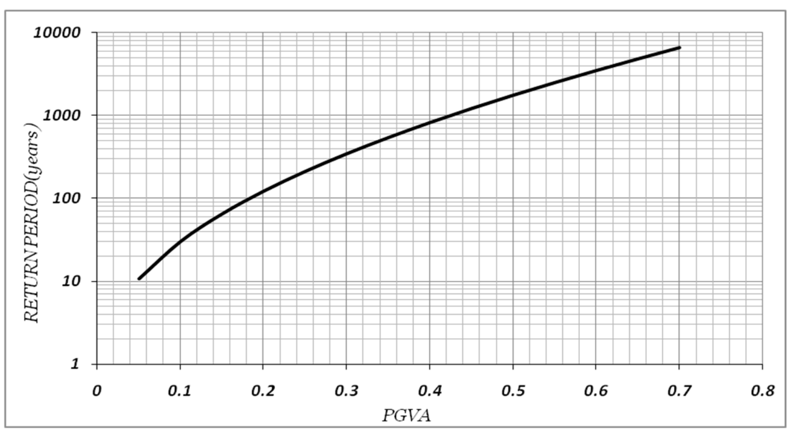

Fig. 9. The return period of peak ground vertical acceleration (PGVA) in distance 150 km around the site

The maximum acceleration of the earthquake with specified return period was determined on the seismic bedrock by using the equation P = 1- (1-p) n.

In this equation, parameter n "determines the useful life of the structure in a year, parameter" P "determines the probability of occurrence earthquake for n years, parameter" p "determines the annual probability of occurrence earthquake".

In Figure 10, 11 the possibilty of occurrence of peak ground vertical and horizontal acceleration are provided for useful lifetime 25, 50, and 100 years.

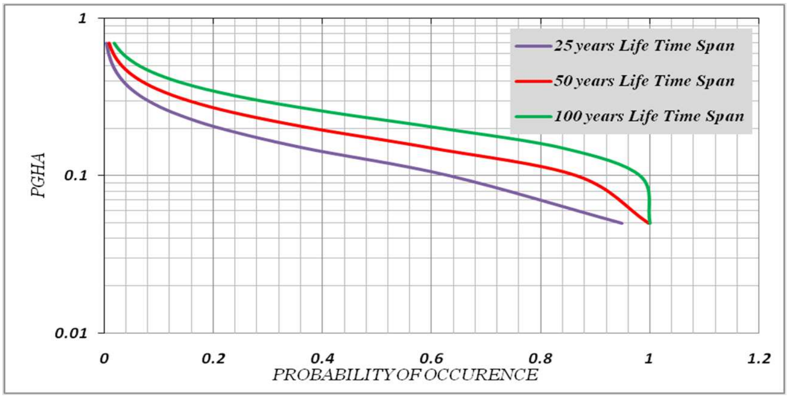

Fig. 10. the possibilty of occurrence different PGHAs in distance 150 Km around the site for useful lifetime 25, 50, and 100 years

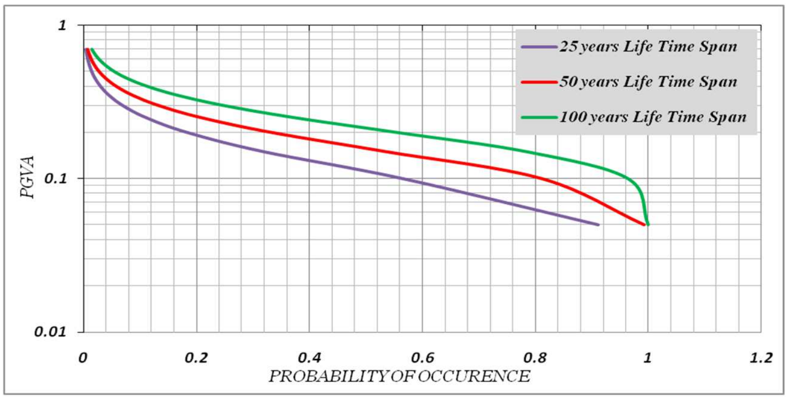

Fig. 11. the possibilty of occurrence different PGHAs in distance 150 Km around the site for useful lifetime 25, 50, and 100 years

Conclusion

In the by laws of designing the structures, the level of risk in structure designing should be identified for choosing the seismic forces. There are 3 risk levels in bylaws. The first risk level Earthquake is called operating basis earthquake (OBE). This kind of earthquake is weak or moderate and it is expected members of the structures have reactionary behavior. The spectrum of this risk level is called exploitation earthquake spectrum. The second risk level earthquake is called maximum design earthquake (MDE). It has relatively high magnitude and it's possibility of exceeding is 10% in site (an earthquake with a return period of 475 years). The result spectrum is called design earthquake spectrum. The third risk level earthquake is called maximum credible earthquake (MCE). It has very high magnitude and it's possibility of exceeding is 2% in site at period 100 years. The return period of this earthquake is 475 years. The spectrum of this risk level is called curious earthquake spectrum. Thus, according to the figures 10 and 11 and according to expert judgment, horizontal and vertical ground acceleration at the origin (District 22 of Tehran) on 3 levels for the structural design for earthquakes is presented in Table 4.

Table 4. Peak ground horizontal and vertical acceleration in different seismic levels in origin

The levels of seismic designing	Rturn period (year)	In useful lifetime 25 years		In useful lifetime 50 years		In useful lifetime 100 years	
		PGHA	PGVA	PGHA	PGVA	PGHA	PGVA
Exploitation level earthquake	10	0.04g	0.04g	0.05g	0.05g	0.08g	0.07g
Design level earthquake	475	0.28g	0.26g	0.36g	0.33g	0.45g	0.41g
Curious level earthquake	2475	0.48g	0.44g	0.58g	0.54g	0.7g	0.65g

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