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SEISMIC HAZARD ANALYSIS AND DEVELOPING THE WELL-KNOWN DESIGN SPECTRA FOR ONE IMPORTANT HOSPITAL IN IRAN

M. Firoozi Nezamabadi[1] and F. Yaghoobi Vayeghan[2]

[1] *Faculty Member and PhD. Student, Dept. of Civil Engineering, South Tehran Branch, Islamic Azad University (IAU), Tehran, Iran*
Email: m_firoozi_n@yahoo.com
[2] *PhD in Earthquake Engineering, Head of Retrofit Department, Transportation Research Institute (TRI), Tehran, Iran*
Email: fyaghoobi@yahoo.com

ABSTRACT :
A site investigation as well as a Seismic Hazard Analysis (SHA) has been carried out for one important hospital in Tehran (Capital of Iran). The aim has been estimating the level of seismic hazard for the site and developing the well-known Design Spectra for horizontal component to verify the performed seismic design of the building and preparing seismic rehabilitation process. At first, it was tried to recognize all the active faults around the sites. Secondly, by using the appropriate attenuation relationships and two methods for calculating seismicity parameter, direct and Kijko methods, the horizontal PGA values on the sites were estimated. These values obtained vary between 0.366g and 1.008g for 2%, 0.259g and 0.686g for 10%, 0.218g and 0.539g for 20% and 0.173g/0.387g for 50% probability of exceedence in 50 years ground motions depending on the applied attenuation laws such as Ambraseys, Ambraseys and Bommer, and Zare and Ashtiany. The more exact horizontal PGA values, obtained from mean of two mentioned methods, for 2%, 10%, 20% and 50% probability of exceedence in 50 years ground motions were 0.627g, 0.418g, 0.342g and 0.260g. Finally, the Newmark-Hall design spectra, which are more reliable for design purposes, were constructed for the 2%, 10%, 20% and 50% probability of exceedence in 50 years ground motions. The 10% and 2% spectra (first and second hazard level) compared with Iranian Standard Design Spectrum and 1.5 times of this spectrum respectively. This comparison showed that the values of Newmark-Hall design spectra are usually more than values of Iranian Standard Design Spectra.

KEYWORDS:
Seismic hazard analysis, Attenuation relationship, Newmark-Hall design spectrum, Hospital, 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 behavior of structures, particularly the key structures is necessary. The best way for performing a reliable seismic hazard analysis is using probabilistic methods. Some studies of this kind has been recently performed by the authors for buildings and bridges [Yaghoobi et. al., 2003], [Firoozi et. al. 2004], [Yaghoobi and Firoozi, 2004] and [Firoozi and Yaghoobi, 2006a, 2006b and 2006c].This paper reports an actual case of applying this methodology for an important hospital. At first, it was tried to recognize all the seismic sources (faults) in a radius of 150 km around the hospital, 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, calculating seismicity parameter and the local soil conditions. The attenuation relationships used in this study are Boore, Joyner and Fummal, Ambraseys and Sympson, Ambraseys, Ambraseys and Bommer, and Zare and Ashtiany. Seismicity parameter (beta) calculated through two methods, direct and Kijko methods [Kijko and Sellevol, 1992]. Then the PGA values and hazard curves for the site were prepared by using probabilistic method. Finally, the Newmark-Hall design spectra in horizontal component were constructed for the 2% and 10%, 20% and 50% 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 hospital in Tehran, North of the city. This hospital is located in a distance of at last 10 km from North Tehran fault. Some important faults around the site in an area with radius of about 150 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 Figure 1.

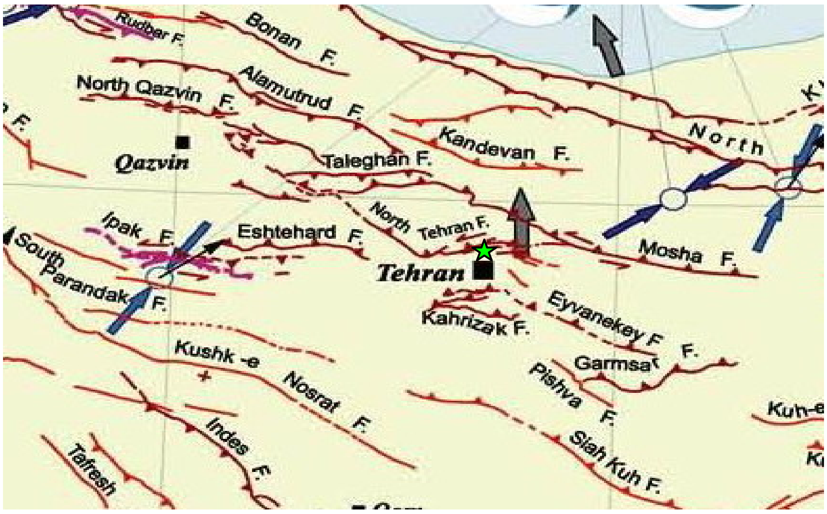

Figure 1 Faults and site location

3. ATTENUATION RELATIONSHIPS

The general form of attenuation expression used in most investigation can be characterized by the expression 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, b_1 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 expression (3.1) to (3.5), b_6 is a constant and M, R, b_2, b_3, b_4, b_5, b_7, P_i, 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.

In this study the PGA values were calculated from Ambraseys [Ambraseys, 1995], Ambraseys and Bommer [Ambraseys and Bommer, 1991], Ambraseys and Sympson [Ambraseys and Sympson, 1996], Boore, Joyner and Fummal [Boore, Joyner and Fummal, [Green and Hall, 1994], and Zare and Ashtiany [Zare, 1999] attenuation relationships have been used for the site.

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

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 and Hall, 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 based on fault specification.

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

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

$$\vartheta = N(m_o) - N(M_{\max}) \tag{4.2}$$

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

Where α and β are Gutenberg-Richter coefficients [Gutenberg and Richter, 1954], *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, 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.

Table 4.1 Seismicity parameter for the seismic sources (direct method)

Seismic Sources	North Tehran	Mosha	North Alborz	Kandovan	Area source
β	1.0	1.33	0.526	0.971	1.02

By using Kijko method, constant values for β and Lambda (Ms=4) are calculated. These values are presented in table 4.2. In this table, periods 1 to 4 are: 1930 and before with uncertainty equals 0.6 (historic data), between 1930 and 1963 with uncertainty equals 0.3; between 1964 and 2000 with uncertainty equals 0.2; and between 2001 and 2007 with uncertainty equals 0.1 respectively.

Table 4.2 Beta and Lambda parameters for the site (Kijko method)

Catalogue	Parameter	Value	period 1	period 2	period 3	period 4

Historical and Instrumental data	Beta Lambda(Ms=4)	1.51 0.655	64 12.5	14.3 23.2	16.8 39.3	5.0 25.0

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.

Given the occurrence rate of an earthquake, υ, 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 equation (4.5).

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

Where *acc*, varies from 0.5g to 0.65g with Δacc equal to 0.05g and

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

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

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

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

Where value of $f(R).\Delta R$ is 0.33 for all faults. The annual probability of exceedence for each fault was calculated by equation (4.9).

$$P(PGA\rangle acc)=1-\exp[-\vartheta t\cdot P(PGA\rangle acc|EQ)] \qquad (4.9)$$

Where t equals 1.0 and υ, the average occurrence rate of earthquake for North Tehran, Mosha, North Alborz, Kandovan, Area source is 0.0008, 0.03, 0.029, 0.061 and 0.07 respectively.

Finally, as the fifth step, the results from the seismic faults were combined by equation (4.10) to draw combined hazard curves.

$$P(PGA\rangle acc)=1-\prod[1-P(PGA\rangle acc)] \qquad (4.10)$$

Table 4.3 presents the PGA values for 2%, 10%, 20% and 50% probability of exceedence in 50 years using fault tree and weight factors for 2 methods and all attenuation relationships. Weight factors are usually based on data using to develop attenuation relationship and engineering judgment.

Table 4.3 PGA values for 2% 10%, 20% and 50% probability of exceedence in 50 years (Direct and Kijko methods)

Attenuation Relationship	Weight Factor	PGA (in terms of g)							
		2%		10%		20%		50%	
		Direct method	Kijko method	Direct method	Kijko method	Direct method	Kijko method	Direct method	Kijko method

		(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Boore, Joyner and Fummal	0.15	0.372	0.429	0.273	0.280	0.231	0.242	0.182	0.196
Ambraseys& Simpson	0.2	0.468	0.498	0.310	0.326	0.260	0.275	0.205	0.218
Ambraseys	0.2	0.366	0.413	0.259	0.272	0.218	0.231	0.173	0.185
Ambraseys & Bommer	0.2	0.708	0.764	0.463	0.477	0.379	0.406	0.292	0.307
Zare and Ashtiany	0.25	0.961	1.008	0.639	0.686	0.505	0.539	0.364	0.387
Final Results		**0.627**		**0.418**		**0.342**		**0.260**	

5. DEVELOPING SPECIAL DESIGN SPECTRA FOR SITE

Newmark-Hall suggested a design spectrum contains displacement, velocity and acceleration values with maximum ones (48in/sec, 36in, 1g respectively).

In this study, Newmark-Hall design spectra are drawn for earthquake with 2%, 10%, 20% and 50% probability of exceedence in 50 years ground motions and 10% and 2% spectra (first and second hazard level) compared with Iranian Standard Design Spectrum [BHRC, 2005] and 1.5 times of this spectrum respectively. These spectra are shown in figures 2 and 3. Figures 4 and 5 indicate Newmark-Hall design spectra for 20% and 50% probability of exceedence in 50 years ground motions respectively.

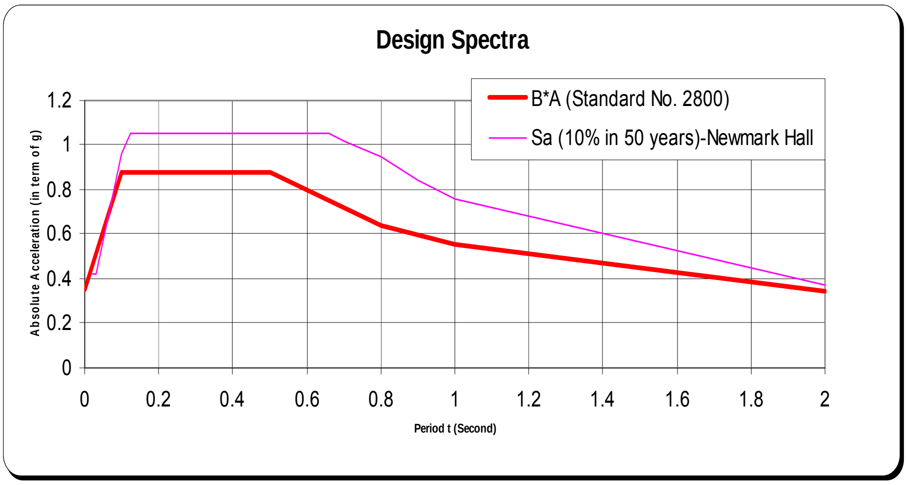

Figure 2 Comparing between Newmark-Hall and Iranian Standard Design Spectrum (10% in 50 years)

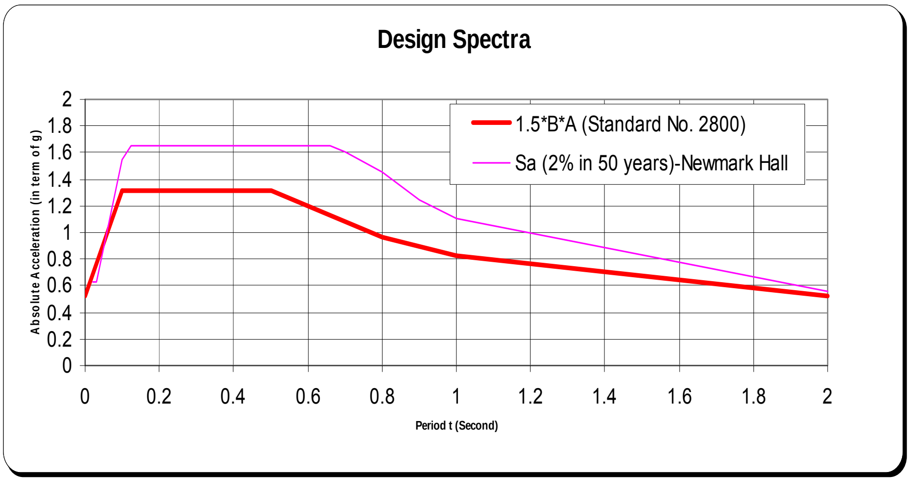

Figure 3 Comparing between Newmark-Hall and 1.5 times Iranian Standard Design Spectrum (2% in 50 years)

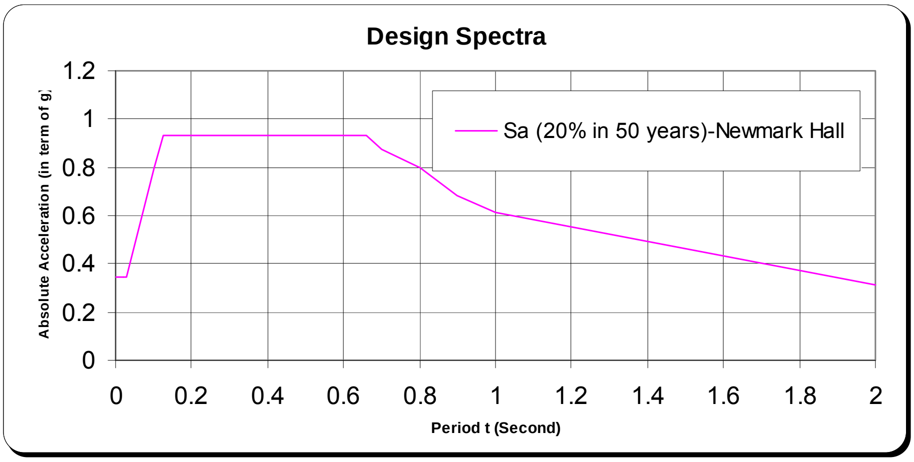

Figure 4 Newmark-Hall design spectrum (20% in 50 years)

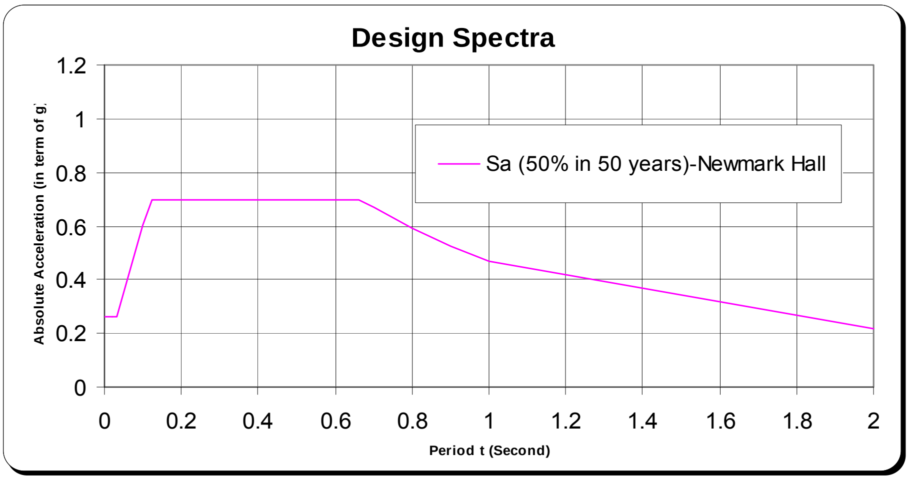

Figure 5 Newmark-Hall design spectrum (50% in 50 years)

All Newmark-Hall design spectra are shown in one figure (figure 6).

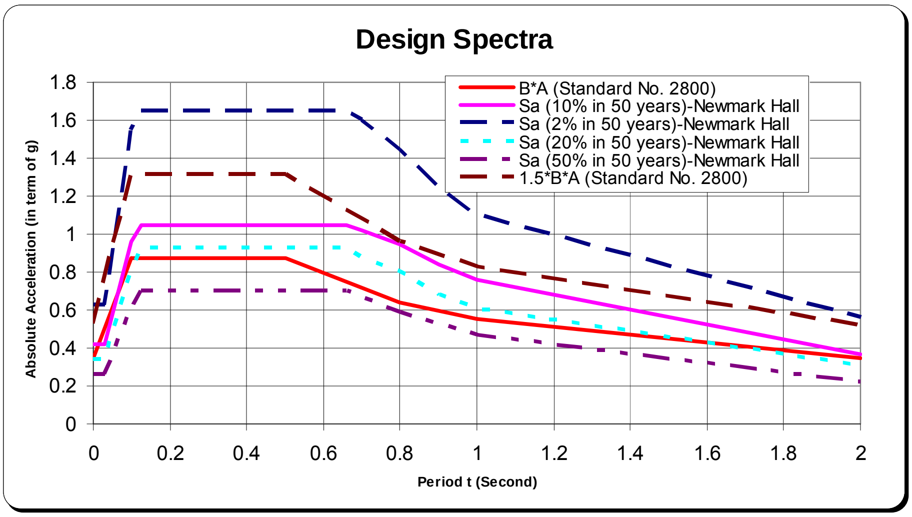

Figure 6 Comparing between all Newmark-Hall design spectra

6. CONCLUSIONS

A site investigation as well as a Seismic Hazard Analysis (SHA) has been carried out for one important hospital in Tehran (Capital of Iran). By using the appropriate attenuation relationships, considering weight factor (fault tree) and two methods for calculating seismicity parameter, direct and Kijko methods, the more exact horizontal PGA values on the sites were estimated. These values for 2%, 10%, 20% and 50% probability of exceedence in 50 years ground motions were 0.627g, 0.418g, 0.342g and 0.260g. Finally, the Newmark-Hall design spectra, which are more reliable for design purposes, were constructed for the 2%, 10%, 20% and 50% probability of exceedence in 50 years ground motions. The 10% and 2% spectra (first and second hazard level) compared with Iranian Standard Design Spectrum and 1.5 times of this spectrum respectively. This comparison showed that the values of Newmark-Hall design spectra are usually more than values of Iranian Standard Design Spectra.

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