Determination and Assessment of Ground Motion and Spectral Parameters for Iran

G. Ghodrati Amiri, M. Khorasani, Razavian Ameri, M.Mohamadi Dehcheshmeh, S.Fathi

Abstract**—**Many studies have been conducted for derivation of attenuation relationships worldwide, however few relationships have been developed to use for the seismic region of Iranian plateau and only few of these studies have been conducted for derivation of attenuation relationships for parameters such as uniform duration. Uniform duration is the total time during which the acceleration is larger than a given threshold value (default is 5% of *PGA*). In this study, the database was same as that used previously by Ghodrati Amiri et al. (2007) with same correction methods for earthquake records in Iran. However in this study, records from earthquakes with M_S< 4.0 were excluded from this database, each record has individually filtered afterward, and therefore the dataset has been expanded. These new set of attenuation relationships for Iran are derived based on tectonic conditions with soil classification into rock and soil. Earthquake parameters were chosen to be hypocentraldistance and magnitude in order to make it easier to use the relationships for seismic hazard analysis. Tehran is the capital city of Iran witha large number of important structures. In this study, a probabilistic approach has been utilized for seismic hazard assessment of this city. The resulting uniform duration against return period diagrams are suggested to be used in any projects in the area.

Keywords**—**Attenuation Relationships,Iran,Probabilistic Seismic Hazard Analysis,Tehran, Uniform Duration

I. INTRODUCTION

THE purpose of this study is to pursue the previous research publications of the first author on the subject of attenuation relationships for Iran (Ghodrati Amiri et al., 2007) [1] and derive new relations for uniform. Peak ground motion, frequency content and duration of ground motion are three characteristics of ground motion, which are important in earthquake engineering applications.

Iran is located in one of the seismic regions of the world. The occurrence of many destructive earthquakes in recent years has emphasized the urgent need to assess earthquake hazards in this part of world [2]. Several studies have been conducted to link structural damage to parameters related either directly or indirectly to the duration of strong ground motion (Jalali and Hakimvand, 2006) [3].

Several studies have been conducted to propose procedures for estimating the strong motion duration of an accelerograms. Naeim (2001) has explained some of these definitions for duration of an earthquake record. According to this reference, "bracketed duration" is the time interval between the first and the last acceleration peaks greater than a specified value (usually 0.05g) [4]. Others definitions are based on the integral of the square of acceleration referred to as the accelerograms intensity or on the average energy arrival rate. As it has been mentioned in this reference, the comparisons show that different procedures result in different durations of strong motion. Therefore, since there is no standard definition of strong motion duration, the selection of a procedure for calculation of the duration for a certain study depends on the purpose of the intended application.However, Jalali and Hakimvand (2006) concluded that nearly all of the definitions could be classified into three generic groups, namely, bracketed durations, uniform durations and significant duration [3]. Uniform duration defined as the sum of the time intervals during which the acceleration is greater than the threshold. The concept of uniform duration is illustrated in Figure 1. This definition is less sensitive to the threshold level than the bracketed duration, but it has the disadvantage that it does not define a continuous time window during which the shaking can be considered strong.

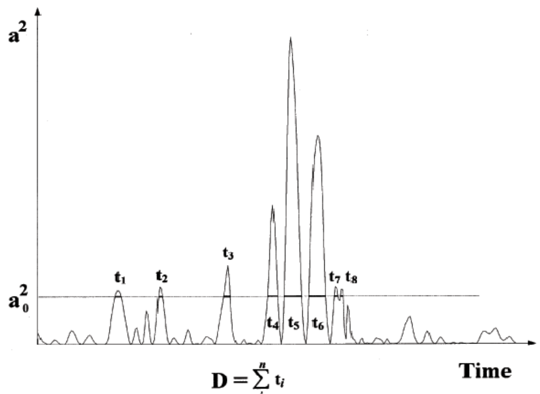

Fig. 1 Uniform duration of an accelerogram (Jalali and Hakimvand, 2006) [3]

As a case study, using the proposed relationships in this article, a probabilistic approach has been utilized for seismic hazard assessment of the capital city of Iran.

II. THE INPUT DATABASE AND THE INPUT PARAMETERS

The database used as the input for this study consists of 381 earthquake events including 663 earthquake records. This suitable catalog of earthquake records has enough number of data components that allow for regression of a curve and is necessary for development of an attenuation model. The preliminary catalog was gathered by the first author of this article (Ghodrati Amiri et al., 2007) [1], using different

G. Ghodrati Amiriis withcenter of excellence for fundamental studies in structural engineering,college of civil engineering, iran university of science& technology, tehran, iran,(email:ghodrati@iust.ac.ir)

M. Khorasani is withcollege of civil engineering, iran university of science & technology, tehran, iran(email: khorasani@iust.ac.ir)

S. A. Razavian amreiis withcollege of civil engineering, iran universityofscience&technology,tehran,iran(email: ali_razavian@iust.ac.ir)

M.mohamadi dehcheshmeh is with college of civil engineering, iran universityofscience&technology,tehran,iran(email: mohamadi_dehcheshmeh@civileng.iust.ac.ir)

S.fathi is withcollege of civil engineering, iran university of science & technology, tehran, iran(email: soheil.f989@gmail.com)

resources. The processing of data consisted of correction and conversion of magnitude, calculation and correction of distance of epicenter to the recording station and determination and correction of the ground type of the recording station are all the same as what has been done in the previous study of the author (Ghodrati Amiri et al., 2007). The details of the data set are not repeated here in order to save space [1].

All the values for magnitude are used in terms of surface wave. Most of values for large-magnitude earthquakes in Iran have been reported in terms of surface wave magnitude. For other cases, the magnitude converted from other terms into surface wave terms. Here, geometric methods were used together with the geographic coordinates of epicenter and accelerograph, and focal depth to calculate the hypocentral distance. Hypocentral distance (*R*) is assumed the hypotenuse of a right-angled triangle in which focal depth (*D*) and distance between epicenter and accelerograph (*r*) are the other sides.

Ground type is used for categorization according to the properties of subsoil and shear wave velocities. The ground type affects all the characteristics of ground motion such as amplitude, frequency content and period. The extent of this effect is related to the geometry and properties of sub-surface layers and the topographic characteristics of construction site. Based on this definition, one can consider the rock type equivalent to shear wave velocities more or equal to 375 m/sec and the soil type equivalent to shear wave velocities less than 375 m/sec.

III. Attenuation Model

One of the important elements in seismic hazard assessment is attenuation relationships. With regards to the acquired data in this study, the two parameters of magnitude and hypocentral distance were directly used in the models. Similar to the previous study of the first author (Ghodrati Amiri et al., 2007) [1], in order to consider the ground type, two separate models were developed for rock and soil ground types. This classification is comparable to the classification of Iranian Code of Practice for Seismic Resistant Design of Buildings (2005) [5].

Moreover, concerning the data acquired in this study and categorization of Iran in two regions of Zagros, and Alborz-Central Iran, the attenuation relationships for these regions were derived. The polygon with the coordinates in Table 1 was considered Zagros region and the rest of Iran as Alborz-Central Iran region. It is to be noted that categorization of the records in different regions was performed based on the causing earthquake.

TABLE I
PROPERTIES OF ZAGROS REGION POLYGON

E	42.0	51.0	51.0	53.5	55.8	57.0	56.4	54.0	43.8	42.0
N	36.0	29.0	27.5	26.3	26.2	27.5	28.3	30.2	37.5	38.2

It should be added that due to this coordinates, Tehran is located in the Alborz-Central Iran region. The proposed attenuation relationships provide good results for the focal distance from 5 to 200 kilometers and the surface wave magnitude from 4.0 to 7.7.

IV. Predictive Equations for Uniform Duration

The functional form of the predictive equations for uniform duration could be determined through non-linear regression analysis to be:

$$\ln(D_u) = C_1 + C_2 M_s + C_3 \ln(M_s) + C_4 \cdot \ln(R) \quad (1)$$

Where, *R* is the hypocentraldistance for an earthquake of given magnitude M_S. $D_u$is uniform duration and the coefficients used in the final model are shown in Table 2.

TABLE II
COEFFICIENTS OF THE PROPOSED ATTENUATION MODEL FOR UNIFORM DURATION

		C1	*C2*	*C3*	*C4*	*R*	*σ*
Alborz and Central Iran	Rock	-4.414	-0.103	3.543	0.301	0.827	0.412
	Soil	-6.177	-1.159	8.636	0.120	0.807	0.331
Zagros	Rock	1.655	0.767	-2.685	0.302	0.812	0.207
	Soil	-9.567	-2.577	15.483	0.046	0.808	0.268

In addition, In Figure 2, D_u diagrams are obtained based on R for the different rates ofM_S (5,6,7). According to these diagrams, by increasing theM_S,D_u is also increased based on R.

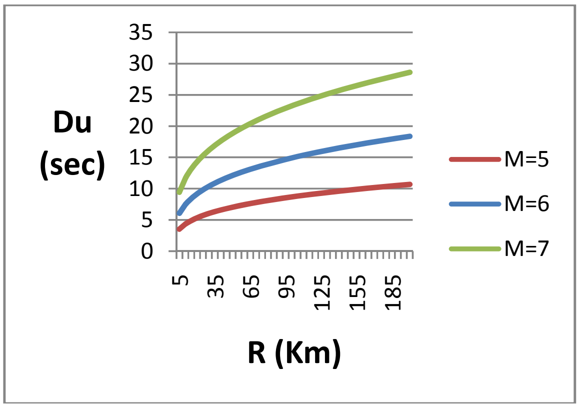

Fig. 2 Diagrams of Uniform Duration (Du) based on Radius (R) for the different rates of MS (5, 6, 7) – Alborz, Rock

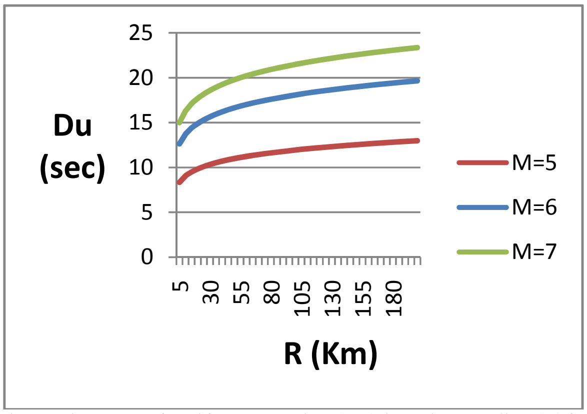

Fig. 3 Diagrams of Uniform Duration (Du) based on Radius (R)for the different rates of MS (5, 6, 7) – Alborz, Soil

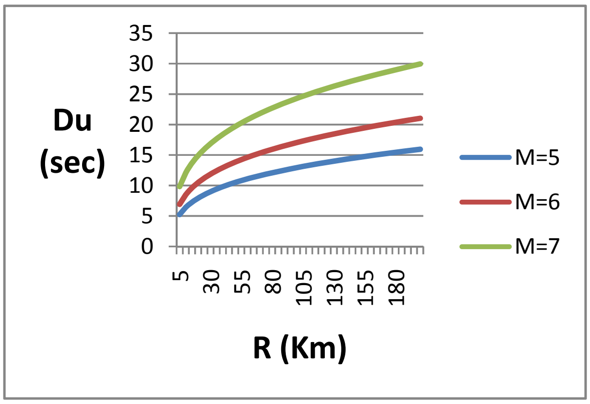

Fig. 4 Diagrams of Uniform Duration (Du) based on Radius (R)for the different rates of MS (5, 6, 7) – Zagros. Rock

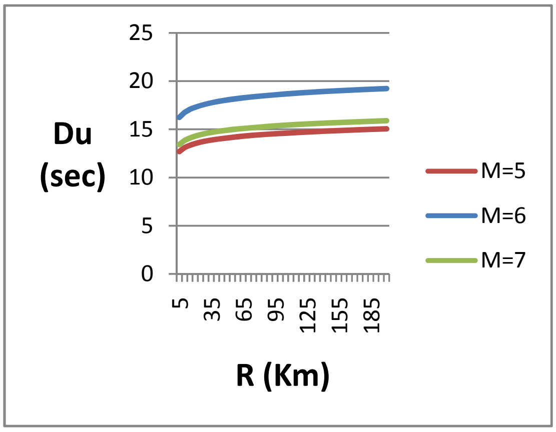

Fig. 5 Diagrams of Uniform Duration (Du) based on Radius (R)for the different rates of MS (5, 6, 7) – Zagros. Soil

V. Probabilistic Seismic Hazard Analysic

As it has been mentioned in the article written by the first author (Ghodrati Amiri et al., 2006) [2], a variety of factors influence the choice between these two approaches. These factors are the purpose of the hazard assessment, the seismic environment (whether the location is in a high, moderate or low seismic risk zone), and the scope of the assessment (whether one is assessing a site risk, a multi-site risk, or risk to a region). As for the earthquake decision, a general rule states the more quantitative the decision to be made, the more appropriate is the PSHA approach (McGuire, 2001) [6]. As the result of these three criteria, only PSHA approach has been followed in the study.

VI. Seismicity Of Tehran

Being surrounded by young faults, Tehran is located in one of the active seismic regions of Iran. There is a harsh topographic discrepancy in the city of Tehran, particularly in the northern area, that is of high importance to seismotectonic studies. To evaluate the earthquake hazard for an area or a district, all the quaky resources and their capability in motivating the earth movements shall be identified in future. From the important faults of Tehran district and its surroundings are the faults of North Tehran, Mosha, Niavaran, North Rey, South Rey, Kahrizak, Garmsar and Pishva [7]. The names and specifications of these faults are listed in Table 3. In addition, the location of these faults toward Tehran is demonstrated in Figure 3.

TABLE III
IMPORTANT ACTIVE FAULTS OF TEHRAN DISTRICT AND ITS SURROUNDINGS [8]

No.	Fault	Type	Length (Km)	Ms
1	Mosha	Thrust-Inverse	200	7.5
2	North Tehran	Thrust-Inverse	75	6.9
3	Garmsar	Thrust-Inverse	70	6.9
4	Kahrizak	Thrust-Inverse	40	6.9
5	Pishva	Thrust-Inverse	34	6.9
6	South Rey	Thrust-Inverse	18.5	6.2
7	North Rey	Thrust-Inverse	17	6.1
8	Niavaran	Thrust-Inverse	13	6

The former earthquake history of any region shows the conditions of seismicity in that region. To get the specifications of seismotectonic conditions, there is a need to gather a complete list of earthquake events of that area or district and to study on that information. The earthquakes occurred in Tehran can be divided into two groups:

A) Historical earthquakes (earthquakes happened before the year 1900)

B) Instrumental earthquake (earthquake events after the year 1900 till now)

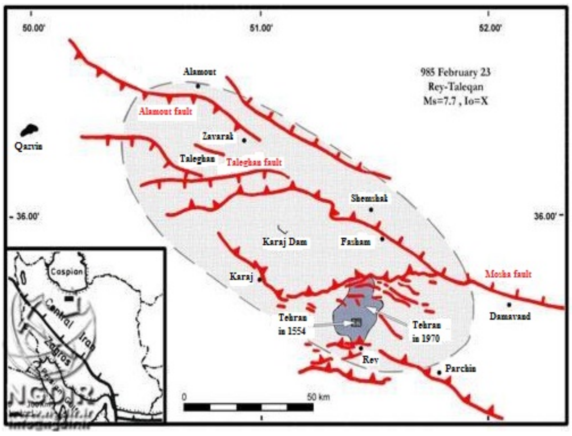

Fig. 6 The location of faults of Tehran and its surroundings [9]

Acquaintance with the earthquake events before the 20th century is based on data gathering out of ancient and historical inscriptions. Therefore, it may contain overstatement or exaggeration about the rate of destructiveness and the damage. The first earthquake happened in this area returns to 400 BC that destroyed the whole areas of Tehran and Rey.Researchers like Berberian [10], Nabavi [11], and Ambraseys and Melville [12] have done several researches on this subject. About the historical earthquakes of Iran, among these researches, Ambraseys and Melville's [12] catalogue is more complete.

VII. Seismic Parameters Of Tehran

Evaluating the seismic parameters is based on the data of earthquake events happened in the area and using the probabilistic methods. Earthquake catalogue around 200 km is gathered with knowing that the earthquakes follow the Poisson distribution. Seismic parameters, rate of event, and earthquake probability are calculated by Kijko method [13].The basic assumption in evaluating the seismic parameters is that the earthquake events shall be independent from others and that they shall follow Poisson distribution. Usually, the complete list of earthquake events doesn't contain Poisson distribution. Therefore, excluding the pre-earthquake and the aftershocks from the list is mandatory for each of the main earthquakes. The method used here to exclude the pre-earthquake and the aftershock is space-time window method. [14]In this study, for the lack of earthquakes containing both M_b and M_S records, the method presented by the National Committee of Big Dams introduced to the whole of Iran is used [15]. The relation is:

$$M_s = 1.21(M_b) - 1.29 \qquad (2)$$

In track record probability estimation method, the corresponding usage of historical and instrumental data is permitted. The basic level depends on using historical date containing low accuracy and wide range and the Gutenberg–Richter function for instrumental earthquakes and the method of probability estimation.According to these previews and the calculated computations by Kijko method, the annual event rate of the earthquake based on the magnitude of earthquakes with M_S> 4.0 in the distance of 200 km of Tehran is presented in Figure 4.

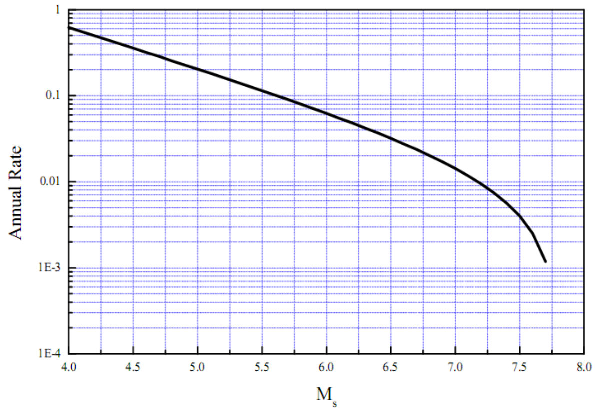

Fig.7 The annual event rate of earthquakes with MS > 4.0 in the distance of 200 km of Tehran

VIII. Seismic Hazard Assessment

To evaluate the D_u parameter, the probabilistic seismic hazard analysis, which produced by attenuation relationships, has been used. [16],[17]

For the earthquake magnitude function and the fault separation length, the Nowroozi method [14] has been used.

In this section, based on modeled and obtained seismic sources and because of that the quaky data is incomplete and also low accuracy of earthquake data (lack of accurate seismic network), the software SEISRISK III [18] is used to obtain the D_u parameter during the effective lifetime of the construction (based on 10% probability of the event in 50 years, equal to the return period of 475 years, the design earthquake in 2800 standard [19]) for a 12×11 network covering different parts of Tehran. The calculated rates by the software are presented as equal lines for the rock (1 and 2 tectonic conditions in standard No. 2800) and soil (3 and 4 tectonic conditions in standard No. 2800) specifications in Figures 5 and 6.

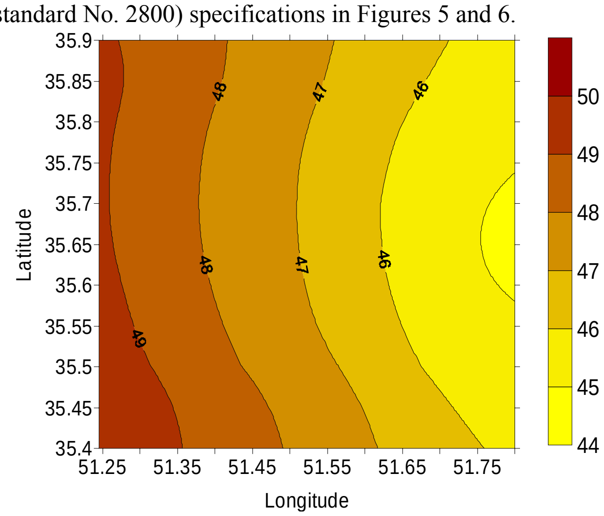

Fig. 8 The equal lines of Du parameter for different regions of Tehran based on 10% probability of the event in 50 years, Rock condition

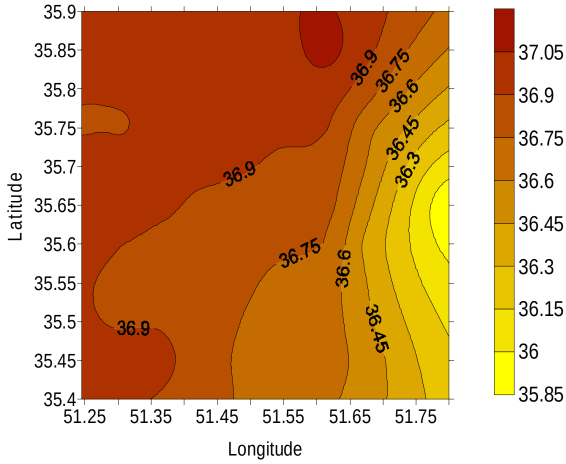

Fig. 9 The equal lines of Du parameter for different regions of Tehran based on 10% probability of the event in 50 years, Soil condition

IX. Conclusions

In this paper a probabilistic seismic uniform durationassessment of metropolitan Tehran and its vicinity is conducted. Also, according to division of seismic regions, soil types and used records, the comprehensibility of these relationships is singular for Iran region up to present. The significant results of this study can be summarized as:

- With increasing the magnitude and focal distance, uniform duration is also increased and decreased respectively.
- The contour levels of the uniform duration maps range from 44 to 50 sec in 475 years for rock condition and 35.85 to 37.05 sec in 475 years for soil condition.
- The highest uniform durationcontours encompass the West North-West and South-West of Tehran.
- The smallest uniform duration are expected in East of the city.

References

[1] Ghodrati Amiri, G., Mahdavian, A. and Manouchehri Dana, F. (2007), Attenuation Relationships for Iran, Journal of Earthquake Engineering, 11(4), 469-492.
[2] Ghodrati Amiri, G., Rokneddin, K., KarimpourFard, M., JafarianMarzouni, Y. and RazavianAmrei, S.A. (2006), Seismic hazard assessment of southern Iran dry docks, 1st European Conference on Earthquake Engineering and Seismology, Geneva, Switzerland.
[3] Jalali, A. and Hakimvand V. (2006), Effect of ground motion duration on seismic response of steel MRF structures, 4th International Conference on Earthquake Engineering, Taipei, Taiwan.
[4] Naeim, F. (2001), the seismic design handbook, Second edition, Kluwer Academic Publishers, United States of America.
[5] Iranian Code of Practice for Seismic Resistant Design of Buildings (2005) Standard No. 2800, Third Revision, Building & Housing Research Center, Iran (In Persian)
[6] McGuire, R.M. (2001), Deterministic vs. Probabilistic Earthquake Hazards and Risks, Journal of Soil Mechanics and Earthquake Engineering, 21, 377-384.
[7] Berberian, M., Ghoreishi, M., Ravesh, B.A., and Ashjaei, A.M., 1983, Seismotectonic and Earthquake Fault Hazard Investigations in the Tehran Region, Geological Survey of Iran, Report No. 56. (In Persian)
[8] Nowroozi, A., 1985, Empirical relations between magnitude and fault parameters for earthquakes in Iran, Bulletin of the Siesmological Society of America 75(5), 1327-1338.
[9] Iranian Geological Survey, http://www.ngdir.com.
[10] Berberian, M., 1994, Natural Hazards & the First Earthquake Catalogue of Iran, Vol. 1: Historical Hazards in Iran Prior to 1900, International Institute of Earthquake Engineering and Seismology, (IIEES).
[11] Nabavi, S.M., 1978, Historical earthquakes in Iran, 300BC - 1900 AD, Journal of Earth and Space Physics 7, 70-117.
[12] Ambraseys, N.N. and Melville, C.P., 1982, A History of Persian Earthquakes (Cambridge University Press, Cambridge, Britain).
[13] Kijko, A., 2000, Statistical estimation of maximum regional earthquake magnitude Mmax, Workshop of Seismicity Modeling in Seismic Hazard Mapping, Poljce, Slovenia, Geological Survey, 1-10.
[14] Gardner, J. K. and Knopoff, L., 1974, Is the sequence of earthquake in southern California, with aftershocks removed, Poissonian?, Bulletin of the Siesmological Society of America 64(5), 1363-1367.
[15] IRCOLD, Iranian Committee of Large Dams, 1994, Relationship between MS and Mb , Internal Report. (In Persian)
[16] Cornell, C.A., 1968, Engineering seismic risk analysis, Bulletin of the Siesmological Society of America 58(5), 1583-1606.
[17] Green, A.R. and Hall, W.J., 1994, An Overview of Selected Seismic Hazard Analysis Methodologies, A Report on a Research Project, Department of Civil Engineering, University of Illinois at Urbana-Champaign.
[18] Bender, B. and Perkins, D.M., 1987, SEISRISKIII: A Computer Program for Seismic Hazard Estimation, U.S. Geological Survey, Bulletin 1772.
[19] Iranian Code of Practice for Seismic Resistant Design of Buildings, 2005, Standard No.2800, Third Revision, Building & Housing Research Center, Iran. (In Persian)