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UNIFORM SEISMIC HAZARD SPECTRA OF MARIVAN, IRAN

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ABSTRACT

This paper presents uniform seismic hazard spectra of Marivan city of Iran. Marivan is a touristy city in Kurdistan province, in which there is much beautiful and wonderful scenery.
A collected catalogue, containing both historical and instrumental events and covering the period from the 10^{th} century BC to the year 2009, is used. Then seismic sources and the seismotectonic model of the considered region have been modeled within the radius of 200 km and the recurrence relationship is established. After elimination of the aftershocks and foreshocks, the main earthquakes were taken into consideration to calculate the seismic parameters. For this purpose the method proposed by Kijko [2000] was employed considering uncertainty in magnitude and incomplete earthquake catalogue.
Marivan and its vicinity has been meshed as a 5(vertical lines)* 4(horizontal lines) and the calculations were performed using Ambraseys and et al. [1996] spectral acceleration attenuation relationship. These calculations have been performed by the Poisson distribution of two hazard levels. Seismic hazard assessment is then carried out for a 5×4 grid points using SEISRISK III [1987]. The evaluation of the probabilistic occurrence of earthquake for the specific area is shown by horizontal spectral acceleration maps with the probability of 2% and 10% occurrences in 50 years.
The results showing the spectral accelerations calculated in this paper are greater than those of proposed by Iranian code of practice for seismic resistant design of building.

Keywords: Hazard, Spectra, Attenuation Relationship, Marivan

INTRODUCTION

The aim of seismic hazard assessment is to estimate strong ground motion. In this paper in order to estimate ground motion parameters uniform hazard spectra are calculated by a probabilistic method.

Many disasters have been occurred in Iran due to the occurrence of earthquakes, causing large economic and life losses. The specifications of some catastrophic earthquakes like Bouin-Zahra (1962), Dashte Baiaz (1967),Tabas (1978) , Manjil_Roudbar (1990) and Bam (2003) demonstrate lack of our knowledge about the earthquakes. Marivan city which are near the faults are along the Zagros faults.

Marivan city is very beautiful that is located in the west of Kurdistan province, Iran. The city has attractive places for tourists and its many other potentialities for development can make it one of the significant centers of the country. Any strong earthquake may then make considerable damages in there. So, the importance of such studies is apparent. The existence of active faults of Morvarid, Piranshahr, Dinvar, Sahneh, Marivan and the fault of the Zagros edge in the vicinity and the occurrence of severe earthquakes in the past show that the region has high seismicity and severe earthquakes which are probable in the future. Fig. 1 represents the faults of the region.

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The studied region encircles Marivan city with the radius of 200 km.

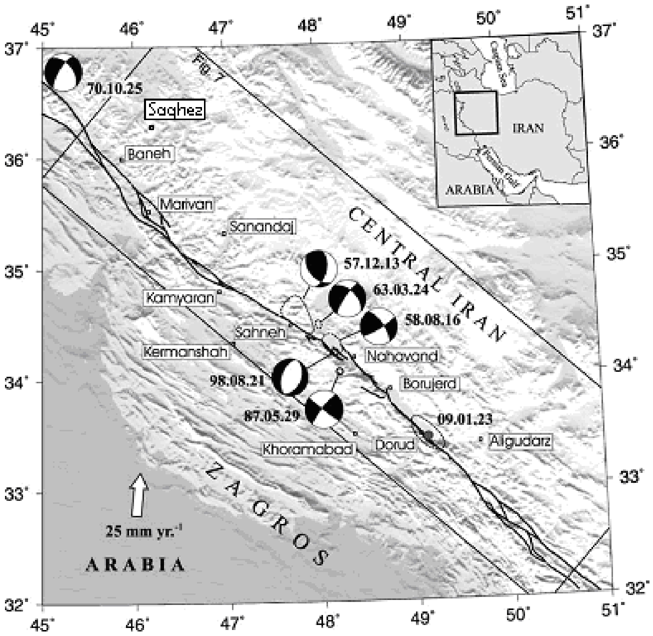

Figure 1. Map of active faults

GEOLOGIC BACKGROUND

Based on geological and geotectonical references Marivan city is situated in the zone of Sanandaj-Sirjan band [as an independent region of the central Iran] and also located near to the zone of high Zagros.

The actively deforming Zagros fold–thrust belt is a result of the collision of Arabia with continental Eurasia (Fig. 2).The separation of Arabia from Africa and its subsequent collision with Eurasia were the last of a series of separation collision events, all of which combined create the extensive Alpine–Himalayan orogenic system. The Zagros fold–thrust belt is bounded on the northeast by both the Main Zagros Reverse fault and Main Recent fault. The Main Zagros Reverse fault is a proposed suture zone between the Arabian plate and Eurasia. The Main Recent fault, a young, active, right lateral fault, follows the trace of the Main Zagros Reverse fault from Turkey to approximately 328 S (Fig. 2). The Main Zagros Reverse fault is also the southern margin of the Sanandaj–Sirjan zone. The Sanandaj–Sirjan zone is a region of polyphase deformation, the latest reflecting the collision of Arabia and Eurasia and the subsequent southward propagation of the fold–thrust belt. At the northeastern edge of the Sanandaj–Sirjan zone is the Urumieh Dokhtar arc (Fig 2). Interpreted to be an Andean type magmatic arc that has been active from the late Jurassic through present, the Urumieh Dokhtar Arc represents the subduction of the Neotethys ocean as Africa moved northward with respect to Eurasia.

The interpretations presented in the balanced crosssections are based on 1:100,000 and 1:250,000 geologic maps from the National Iranian Oil Company and Iranian Geological Survey. Although the maps show detailed surface geology, important aspects of the Zagros orogen are not known, such as the dip of the basement surface and the stratigraphic level (base of Cambrian section or within the basement) of the master de´collement. The following iscussion describes and provides the rationale for the interpretations of the structures that are shown in the balanced cross-sections. The interpretations are based on map patterns, strike and dip data, changes in stratigraphic thicknesses across strike and select borehole data. The lack of published seismic data inhibits knowing completely the geometry of structures at depth, the depth to basement or how basement topography may change through the orogen. Even with these handicaps, knowing the undeformed thickness of strata (,12 km, and depth to basement (,11 km) determined from travel times for local earthquakes) at the front of the Zagros fold thrust belt, provide a minimum depth to basement. In addition, using the constraints of equal line lengths, kinematic compatibility and detailed analysis of the geometry of rocks at the surface can provide insight into a wide variety of structures present at depth, including detachment folds, fault propagation folds, fault-bend folds, imbricate fans, and duplexes.(McQuarrie, M. 2004).

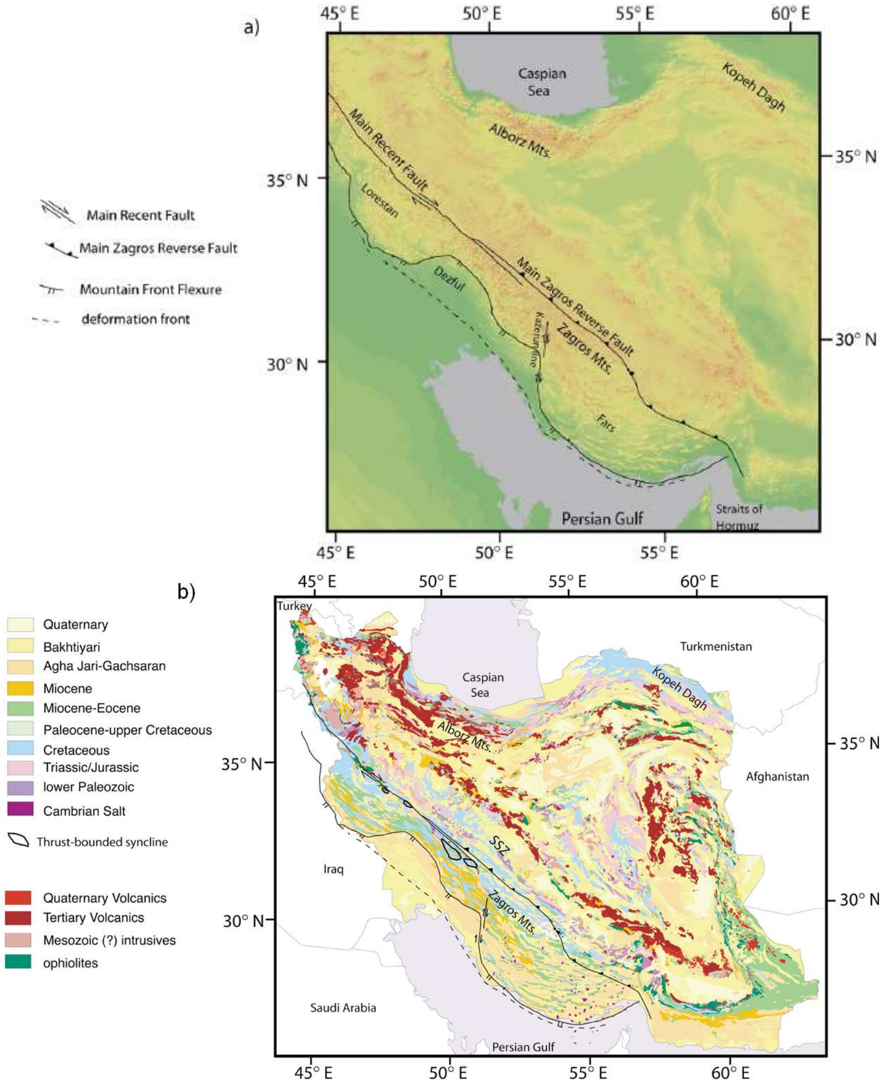

Figure 2. **(a) Topographic map of the Arabia /Eurasia collision zone in Iran. Reds indicate topography .1.5 km. (b) Geologic map of Iran. SSZ represents the Sanandaj–Sirjan zone. Open ovals south of the Main Zagros Reverse fault represent thrust-bounded synclines. (McQuarrie, M. 2004).**

MODEL OF SEISMOTECHTONIC OF STUDIED REGIONS

Based on seismotectonic, the studied region contains the seismotectonic units of Maraghe-Sirjan (including two tectonic zones: Sanandaj-Sirjan and Oroumiye-Dokhtar in the middle of Zagros and central Iran), the high Zagros , the driven folded thrust of Zagros and Central Alborz.

Based on the performed studies, the studied region, a part of Zagros, is situated in the collided part of Iran, Arabia and Caucasus and mainly has got involved in vertical strike-slip and transitional motions. Structural elements of studied region consist of faults with north-west; south-east direction and reverse strike-slip reverse mechanism. Vertical component along these structures is mainly reversed (compressive) [Harvard Seismology education, (2007); Hesami, K., et. al, (2001); Berberian, M., (1981)]. Release rate analysis of seismic moment of earthquakes in the studied region shows that main part of energy releases along the strike-slip moving faults. But this is incompatible with the expected shortening of the region. So, this is the fact that increases the probability of moderate and severe earthquakes [Tchalenko, J. S.,et. al, (1974)]. Most of the past earthquakes in the region were those having small depth and in many cases the bedrock is involved in deformations. The mean Moho depth is about 50 km and the depth of the seismic stratum has been assessed 8-12 km. [Maggi, A., et. al, 2002], According to focal mechanism of past earthquakes and tectonic evidences, the mechanisms of the reverse faults are predominant in the studied region but the effect of the reverse strike-slip faults can't be ignored. Groups of young faults of Zagros as reverse strike-slip faults are most active faults of the region which encircle its young and principal deformations. Figure 3 shows tension and compression region in the system of faults in marivan region.

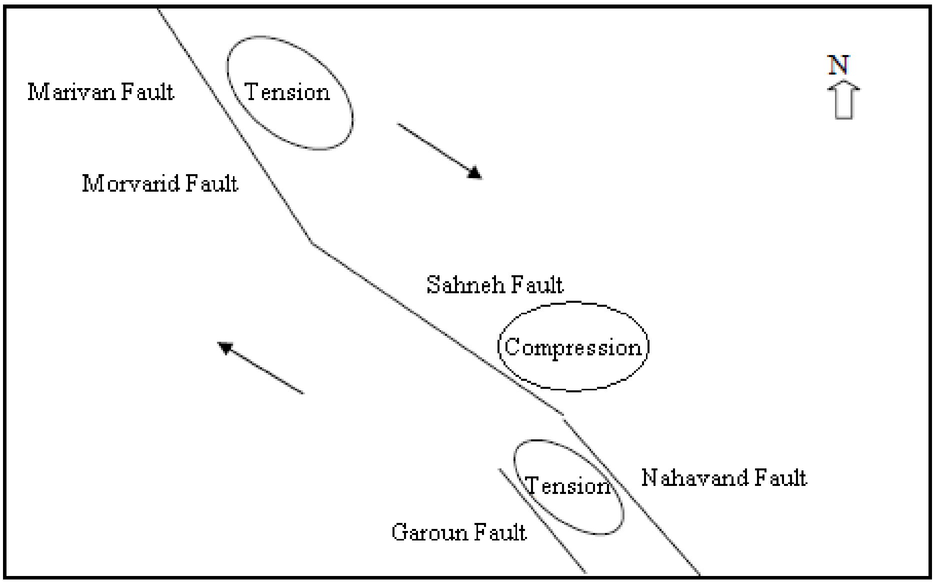

Figure 3. tension and compression region in the system of faults in marivan region

Earthquake Data

In this paper a list of earthquakes containing both historical and instrumental events and covering the period from the 17^{th} century BC to 2009 is used. According to the available information of the historical earthquakes, the oldest earthquake of the studied region is Goudin earthquake that has been occurred about 1600-1650 BC [Berberian, M., et. al, 2001]. The nearest historical city to Marivan was Dinvar, that has been destroyed twice by earthquake. The most severe historical earthquake with the magnitude of Ms7 has been occurred in this city, that made the city completely destroyed and more than 16000 people lost their lives. [Ambraseys, N. N., et. al, 1982]. The most severe earthquake of the region has occurred in the south of Sahneh with the magnitude of mb7.2 [Moinfar, A., et. al, 1994] and is known as Farsineh earthquake. According to official reports 1130 people died and 211 villages were destroyed.

Since all magnitudes reported for historical earthquakes are in the form of surface wave, Ms, also instrumental earthquakes are based on surface wave, Ms, or volumetric wave (mb). Then, the magnitude of the surface wave, Ms, is used for all data. Using the relationship presented by Iranian Committee of Large Dams [IRCOLD, 1994], the magnitude of mb is converted into Ms. In seismic hazard analysis of a region it is assumed that occurred earthquakes are location and time independents. Regarding the mentioned limitations, foreshocks and aftershocks that are related to principal earthquakes should be eliminated from the data base. In this study Gardner and Knopoff [Gardner, J.K., et. al, 1974] method is used to eliminate aftershocks and foreshocks.

Depth Mechanism of the Earthquakes

Using the mechanism of the epicenter of the occurred earthquakes is one of the approaches to study the active tectonic in the studied region. By using this method we can gather some information about the positions of the fault planes, the direction of the slip vector and principal stresses in the region. The depth mechanism of eight earthquakes in a radius of 200 km of Marivan city has been presented on the basis of the information of the Harvard University by Centroid Moment Tensor (CMT) method [Harvard Seismology education,2007]. Among the five earthquakes that their mechanisms have been presented, three of them are straight-slip. Two earthquakes have compressive mechanisms. Statistically, the main mechanism in the studied region can be assumed compressive up to straight-slip. In Fig. 4 the mechanism is represented.

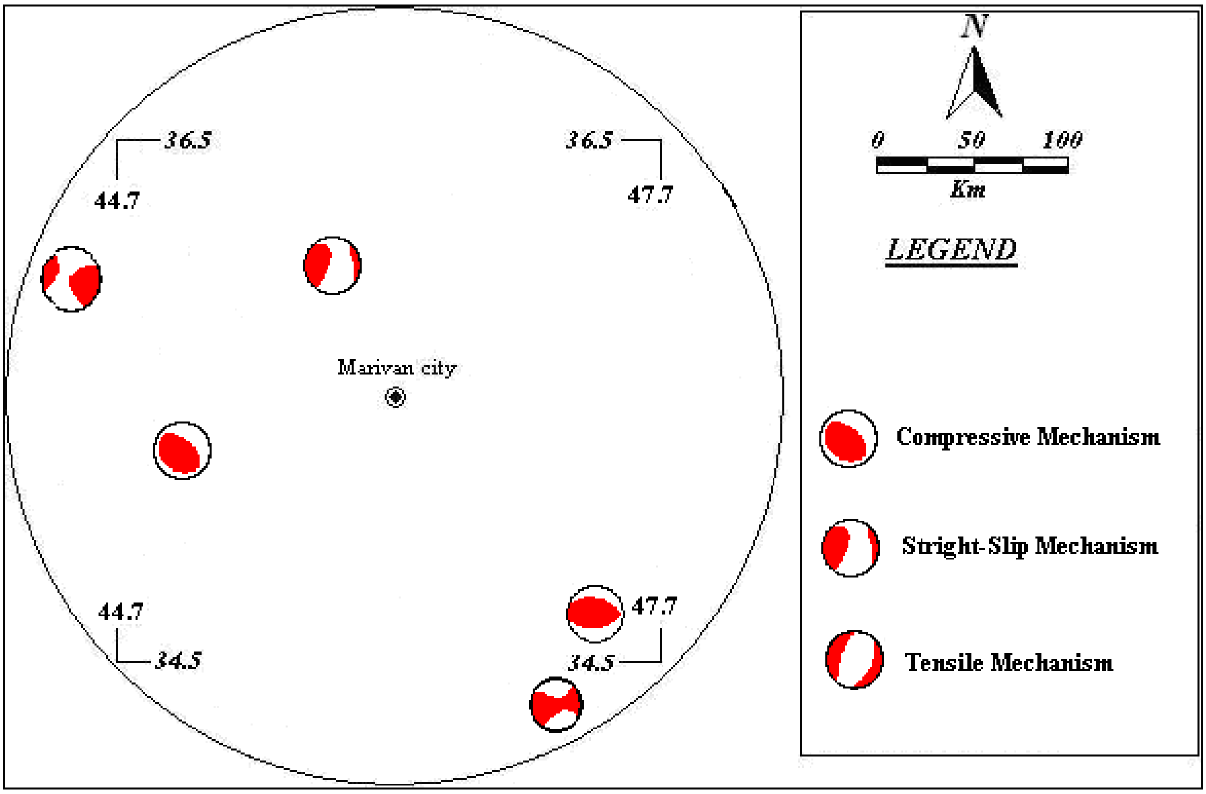

Figure 4. The depth mechanism of five earthquakes in the vicinity of marivan by CMT method

ASSESSMENT OF EARTHQUAKE HAZARD PARAMETERS

As it is known the error in recording the earthquakes magnitudes in different time differs then it does not seem that initial Guttenberg Richter relationship has a good output. Therefore, a method which matches more with Iran tectonic is used.

In this method, with assumption different error values in different periods and considering Kijko [2000] method, Earthquake hazard parameters such as, maximum expected magnitude, *Mmax*, the rate of earthquake occurrence with different magnitudes (activity rate), λ, and b have been evaluated using maximum likelihood method [Kijko, A., and Sellevoll, M.A., 1992]. Besides, the return period and the occurrence probability of each magnitude have also been calculated by the Kijko [Kijko, A., 2000] software. Calculation results of the seismic hazard parameters for each of three time periods are represented in Table 1 for comparison.

Table 1. result values of the calculated seismic hazard parameters in different time periods by Kijko method

Catalogue	Parameter	Value	Data Contribution to the		
			Period#1	Period#2	Period#3
Historical and 20th Century Data	Beta	2.09	55.4	16.9	27.7
	Lambda(for Ms=4)	0.88	9.4	17	73.6

Seismic Hazard Assessment of Marivan City

In this paper in order to evaluation of seismic hazard, the model of linear sources is used and it is also assumed that the seismic power of all the active faults in the region is equal, and the occurrence relationship of Gutenberg and Richter and Poisson model are used as the function of the probability prediction of the earthquake occurrence in the future. Nowroozi [Nowroozi, A., 1985] relationship was used to express the relationship between fault rupture and the earthquake magnitude. Attenuation relationships are one of the most important elements in the seismic hazard analysis which represent the relationship between spectral acceleration, the distance from the surface epicenter of the earthquake and the magnitude. In this study, after assessing different spectral attenuation relationships to select proper relationship, Ambraseys and et al. [1996] attenuation relationship was selected. The type of soil for different regions of Marivan has been reported III type and IV type according to soil type represented by Iranian Code of Practice for Seismic Resistant Design of Buildings [BHRC, 2005]. Table 2 shows characteristics of soil type proposed by Iranian code. Based on technical reports on previous works about soil type of different regions of Marivan city, spectral acceleration was computed for soft soil type represented in the used attenuation relationship that is equal to the III type and IV type soil. In this Research the structure of Marivan city and its vicinity are subdivided into a grid of 5×5, total of 25 sites, with five vertical and five horizontal lines that the distance between every two subsequent vertical lines is 1.65 km and the distance between every two subsequent horizontal lines is 1.365km. Probabilistic seismic hazard analysis is then carried out for each site by SEISRISK III [Bender, B., et. al, 1987], based on 10%, and 2% probability of being exceeded during life cycles of 50 years or the return periods of 475 and 2475 years respectively, and eight period including 0.1sec, 0.2sec, 0.3sec, 0.5sec, 0.75sec, 1sec, 1.5sec, and 2sec.

Table 2. Characteristics of different soil types proposed by Iranian code

Soil type	Soil Type I	Soil Type II	Soil Type III	Soil Type IV
Average rate of shear wave measured in depth of 30m under earth surface ,V_s(m/s)	$V_s > 750$	$375 \le V_s \le 750$	$175 \le V_s \le 375$	$V_s < 175$

Uniform Hazard Spectra

In order to provide uniform hazard spectra, spectral acceleration is computed for all 25 identified sites based on probabilistic seismic hazard assessment for a specific hazard level, a soil type represented in attenuation relationship, and a specific period. The maximum, average, and minimum values of spectral accelerations correspond to the represented period are then identification. Using a different period and same hazard level and same soil type, spectral acceleration is computed for all 25 identified sites, and the maximum, average, and minimum values of spectral accelerations are identified among the computed spectral accelerations. This process is continued and the maximum, average, and minimum values of spectral accelerations correspond to all different periods are computed, and maximum, average, and minimum uniform hazard spectra are provided using them. The provided uniform hazard spectra show spectral acceleration (SA) versus period (T) for the specific hazard level and the specific soil type. The uniform hazard spectra are calculated for soft soil type and two represented hazard levels. Figures 5 and 6 show maximum, average, and minimum values of uniform hazard spectra, calculated for Marivan city, for the return period of 475 and 2475 years, and for soft soil site.

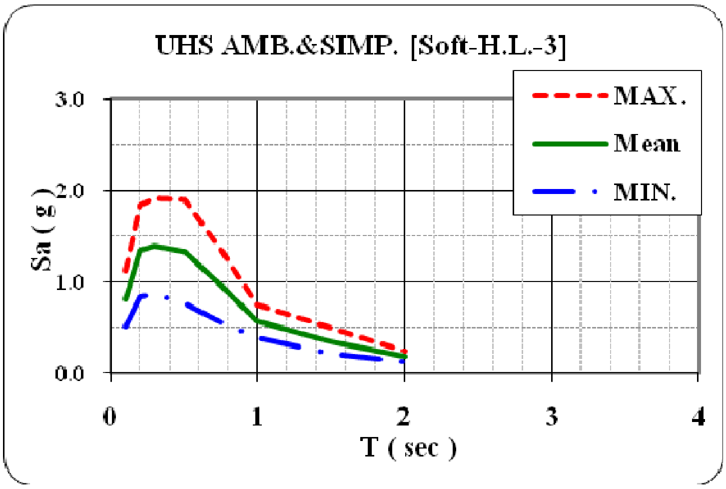

Figure 5. Uniform Hazard Spectra for 475-year return period with soft soil site

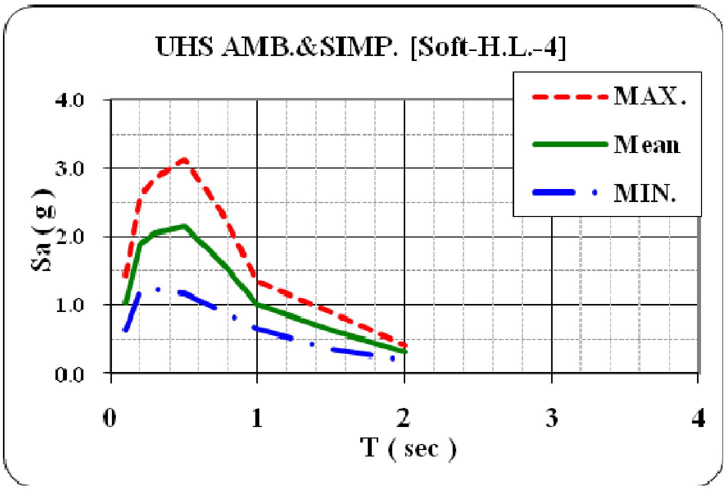

Figure 6. Uniform Hazard Spectra for 2475-year return period with soft soil site

CONCLUSIONS

The results show maximum, average, and minimum values of uniform hazard spectra for the return period of 475 and 2475 years, in soft soil site. The comparison of the calculated values of acceleration spectral in this study in the return period of 475 years with the proposed spectral acceleration of the Iranian Code of Practice for Seismic Resistant Design of Buildings [BHRC, 2005] (A*B) shows that the calculated values by this research, for periods less than $1_{sec,}$ is much higher than proposed values of spectral acceleration of the 2800 manual. Figure 7 shows comparison maximum uniform hazard spectrum, related to the nearest site to an active fault, for the return period of 475 years with proposed values of spectral acceleration of the Iranian code Standard No.2800-5. The significant reason for this difference is that the Marivan city is situated near active faults and the Iranian code does not consider near-faults effects.

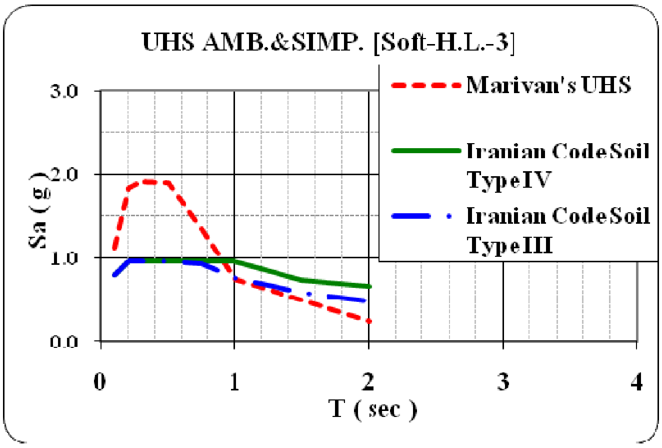

Figure 7. Comparison Marivan's Uniform Hazard Spectrum with Iranian Code

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