Seismic Hazard Maps of Iran

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SUMMARY:
A new seismic hazard maps have been developed for Iran based on probabilistic earthquake hazard analysis. The hazard map, depict peak horizontal ground acceleration and spectral response at period of 0.2 sec and 1.0 sec with 50%, 10%, 5% and 2% probability of exceedence in 50 years, corresponding to return period of 75, 475, 975 and 2475 years, respectively. Finally, we presented the disaggregation and uniform hazard plots showing the contribution of hazard for major cities in Iran.

Keywords: Seismic hazard, Deaggregation, Response spectra, Ground motion

1. INTRODUCTION

The Alpide - Himalayan seismic belt is recognized as one of the seismically active areas of the world. Major development activities are taking place along this belt. The Iranian plateau (Fig.1), situated on this belt has experienced several major and destructive earthquakes in the recent past. It is therefore necessary to estimate characteristics of strong ground motion that can take place during a hypothetical destructive earthquake in an area where development is taking place, or is likely to take place. Berberian (1976) has divided Iran into four major seismotectonics zones, viz., Zagros active folded belt, Central Iran, Alborz, and Koppeh Dagh (Fig.1).

The Alpide- Himalayan belt in Iran is defined by a broad band of diffused seismicity and contains several mobile belts surrounding small, relatively stable blocks. In the opinion of Shojah- Taheri and Niazi (1981), the major zones of mobility, in decreasing order of activity are Zagros, Alborz, East-Central Iran and the Caucasus and Eastern Turkey, although some small aseismic blocks in central Iran, Azarbaiejan and the south Caspian sea exhibiting noticeable stability has also been identified. The distribution of epicenters indicates that seismicity of the Zagros Active Folded Belt (Fig.2) is very high and characterized by a large number of shocks in the magnitude range 5 to 6 and a small number of shocks with magnitudes equal to or greater than magnitude 7. Central Iran has scattered seismic activity with large magnitude earthquakes. The earthquakes in Central Iran are generally of shallow nature with few intermediate earthquakes. The pattern of Seismicity in the Alborz region is discontinuous but with gaps filled in gradually by relatively large events. Most of the strong earthquakes of the region are in eastern and central Alborz. The earthquakes in Alborz Mountains are mostly of shallow type while some are intermediate. Koppeh Dagh is seismically active and the shocks have shallow focus (Berberian, 1976). The southern limit of this activity is not well defined and extends south to the Alborz and Central Iran.

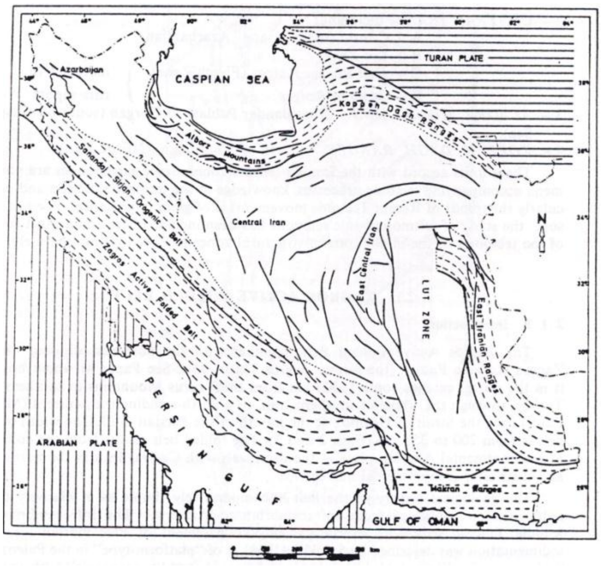

Figure 1. Seismotectonic province of Iran (Berberian, 1976).

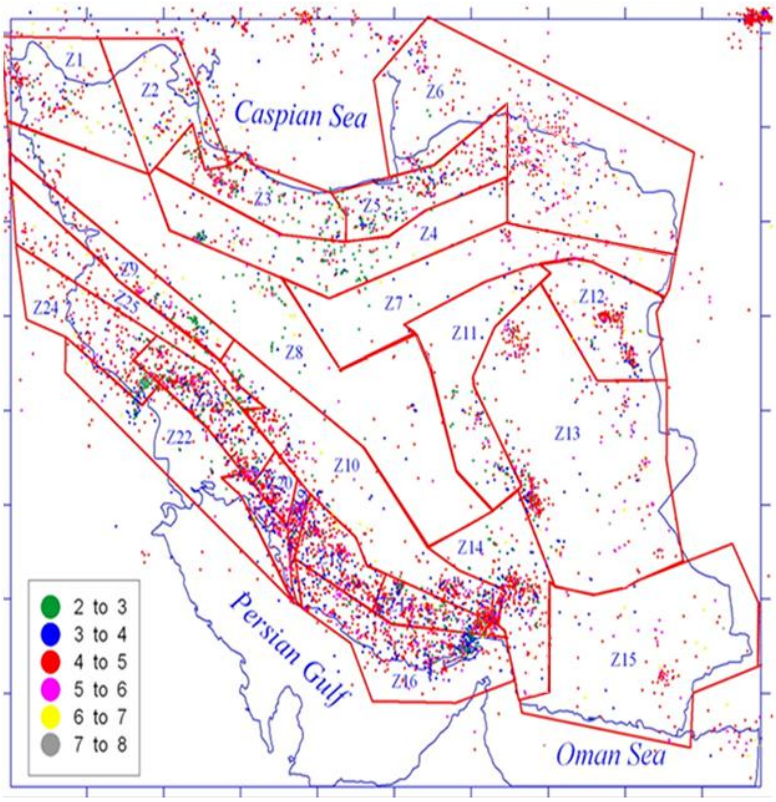

Figure 2. Major seismic source zones.

2. DATA

The basis for earthquake hazard analysis is the analysis of seismicity or the occurrence of the earthquake in space and time. The historic record may contain reports of earthquakes that occurred during the hundreds and, in some cases, thousands of years of recorded human history. The instrumental record yields information about those earthquakes for which actual instrumental evidence exists. Ambreseys and Melville (1982) have been studied the historical and instrumental earthquakes in Iran. For this study, the IIEES catalogue, which is based on the reports from International seismological institutes, and reports from Ambreseys and Melville (1982) have been used. The used catalogue includes historical and instrumental earthquakes. Historical seismicity around the study area is shown in Fig.2. Historical seismicity is seismicity for which evidence can be found in the written or historical records. There is always uncertainty in estimation of earthquake magnitude. The moment magnitude (M_W) is used in all calculations. The available earthquake catalogs usually contain two type of information: historical and instrumental data. Kijko (2000) introduced a method making it possible to combine the information contained in the historical part of catalog with the instrumental part of catalog. The method is based on assumption of the Poisson occurrence of earthquakes with the activity rate of λ and the doubly truncated Gutenberg- Richter distribution. We used Kijko (2000) method to estimate seismicity parameters and the return period for different earthquake magnitudes.

3. SEISMIC HAZARD ANALYSIS

In contrast to the typical deterministic approach, which makes use of discrete single value events or models to arrive at the required description of earthquake hazard, probabilistic analysis allows the use of multi- values or continuous events and models. The methodology, which is used in most probabilistic seismic hazard analysis, was first defined by Cornell (1968). The first step in probabilistic seismic hazard analysis is to define the sources of earthquakes that could affect the location at which the hazard is being evaluated. Step 1 is the definition of earthquake sources. The sources are explicitly defined as being of uniform earthquake potential, that is, the chance of an earthquake of a given size occurring is the same throughout the source. Sources may be range from small planer faults to large seismotectonic provinces. Step 2 is definition of seismicity parameters for each source zone. We used kijko (2000) to estimate seiscmicity parameters. Each source zone is characterized by an earthquake probability distribution. A maximum or upper bound earthquake is chosen for each source zone, which represents the maximum event to be considered. In contrast to the deterministic procedure, this maximum event does not represent the only earthquake to be considered, but rather the upper limit of earthquakes of all sizes that will enter into the analysis for each source. Earthquakes are assumed to occur anywhere within the earthquake source, therefore, distances from all possible locations within that source to the site must be considered. Thus in the probabilistic analysis a range of earthquake size-site distance pairs and their associated probability of occurrence are taken into account. Step3, estimation of the earthquake effect, is similar to the deterministic method except that in the probabilistic analysis, the range of earthquake sizes considered requires a family of earthquake attenuation or ground motion curves, each relating a ground motion parameter, such as peak acceleration, to distance for an earthquake of a given size. Finally, the effects of all the earthquakes of different sizes, occurring at different locations in different earthquake sources at different probabilities of occurrence are integrated into one curve that shows the probability of exceeding of different levels of ground motion levels at the site during a specified period of time.

On the basis of geological (Fig. 3) and seismological studies 25 source zones have been identified (Fig.2). For each source zone seismicity parameters have been estimated after omitting foreshocks and aftershocks from the catalogue.

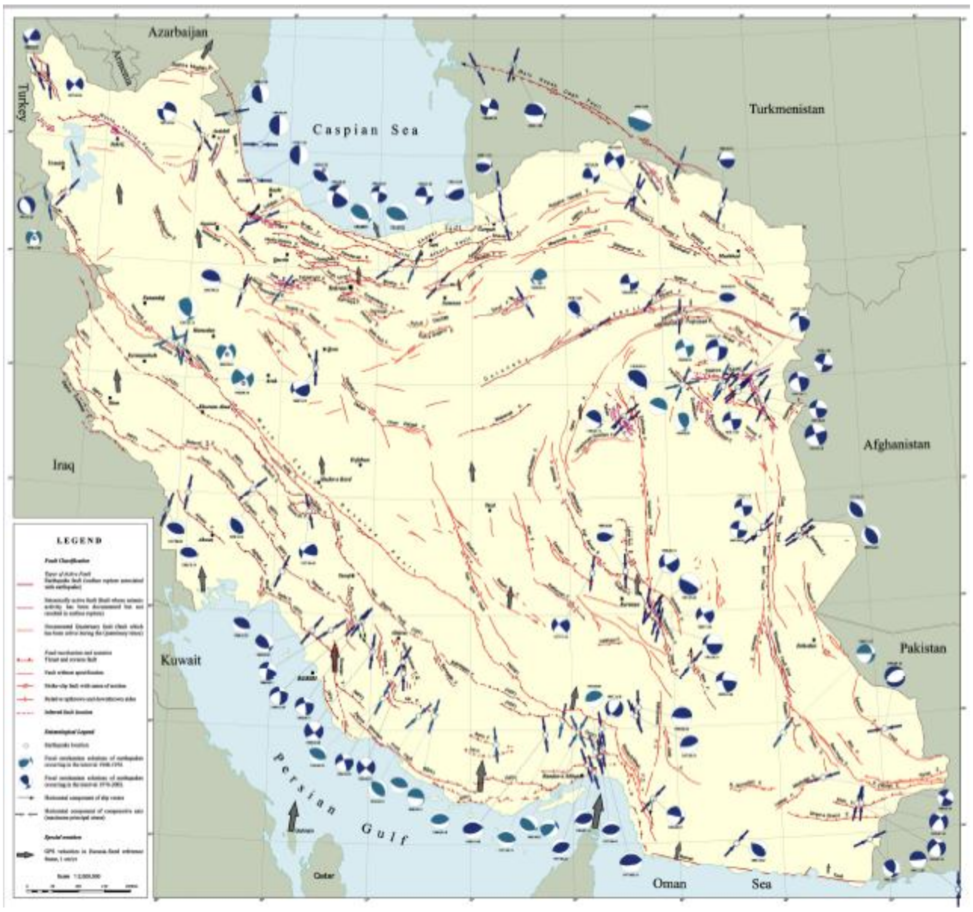

Figure 3. Major active faults of Iran (Hesami et al., 2003).

4. RESULTS

A reliable assessment of seismic risk in a region requires knowledge and understanding of both the seismicity and the attenuation of strong ground motion. It is well known that some of the larger uncertainties in earthquake hazard analysis are caused by uncertainties in seismic wave attenuation. The peak value of horizontal acceleration is one of the important parameters that is considered in the earthquake safe seismic design of engineered structures. Accordingly several studies have been carried out to obtain attenuation relations of peak ground accelerations for various regions of the world. Most of these studies are based on regression or multiple regression analysis of large data sets of strong motion acceleration records. Due to the use of various data bases, various published empirical attenuation relations for peak ground acceleration provide widely varying results. Thus it becomes difficult to select a relationship that can be considered appropriate for a specific application. Further, the use of a particular relationship for an area with different geological and tectonic features would lead to results that may differ significantly from the actual values.

Four attenuation relationships have been considered. These are Boore et al, (1997), Ghasemi et al., (2009), Campbell and Bozorgnia (2003) and Abrahamson and Silva (1997). Figure 4 to 7 show peak ground acceleration and spectral acceleration for period of 0.2 sec maps for return periods of 475 and 2475 years. We have also performed disaggregation of hazard for major cities of Iran. Disaggregating the hazard results, which shows the contributions of different magnitude-distance pairs to the exceedance of the probabilistic ground motion, is a useful approach to define design earthquake(s) for the dominant contributor(s). The total seismic hazard is expressed as the aggregation of the contributions from each possible combination of magnitude-distance on each of the sources. The mean values of magnitude and distance are considered to identify the seismic events (controlling earthquakes) dominating the hazard.

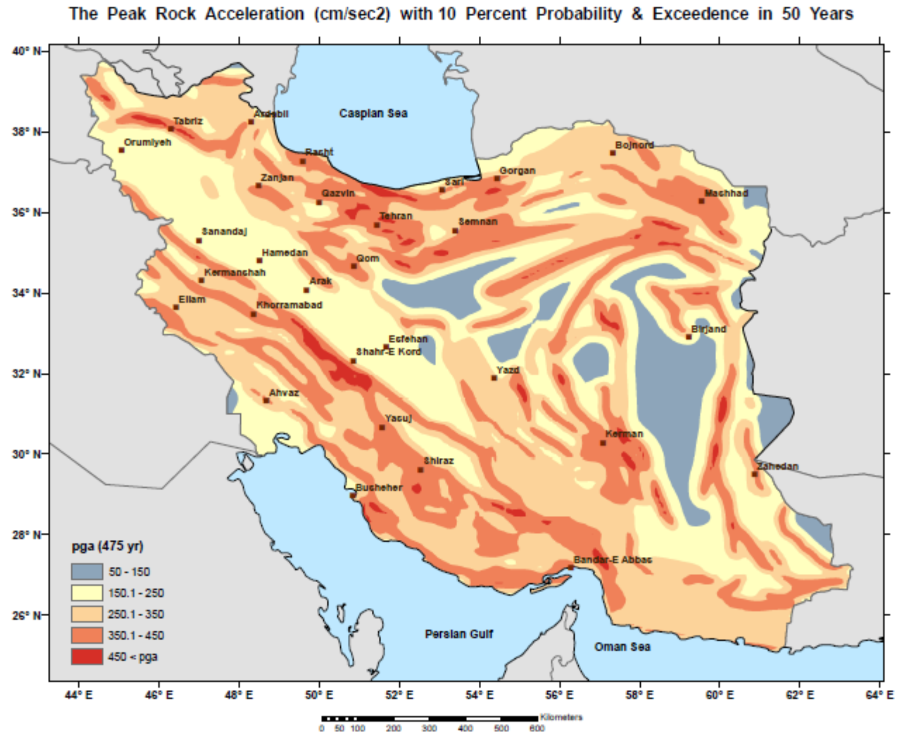

Figure 4. Peak ground acceleration map for return period of 475 years.

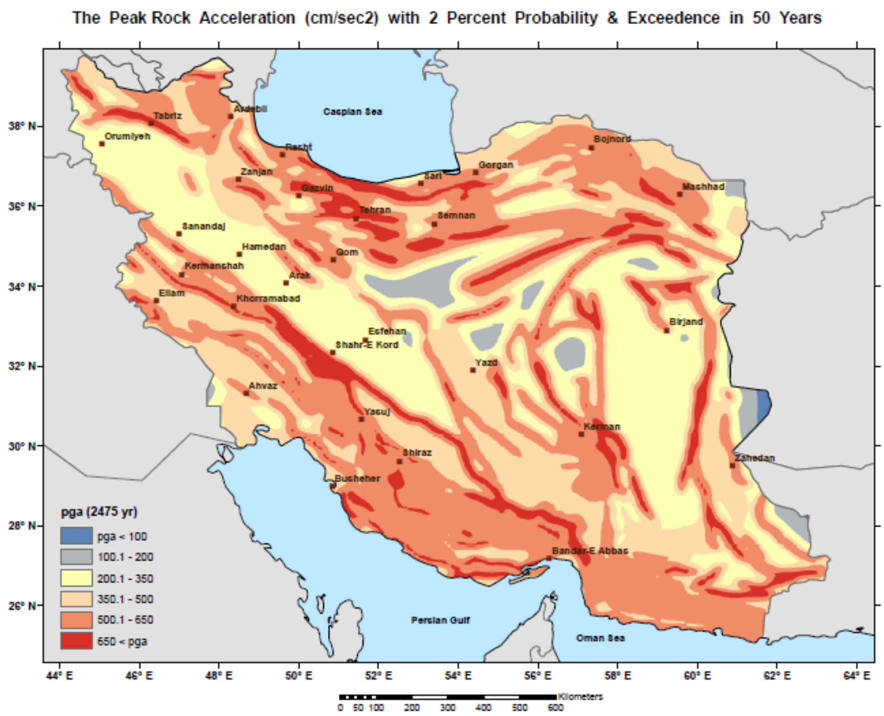

Figure 5. Peak ground acceleration map for return period of 2475 years.

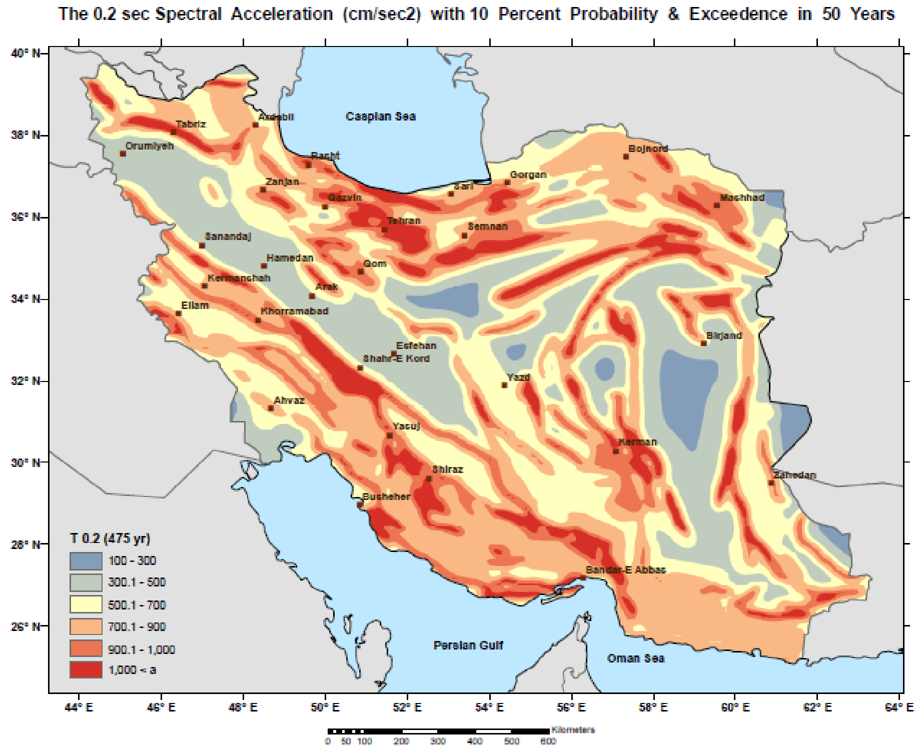

Figure 6. Spectral acceleration map for return period of 475 years for period of 0.2 sec.

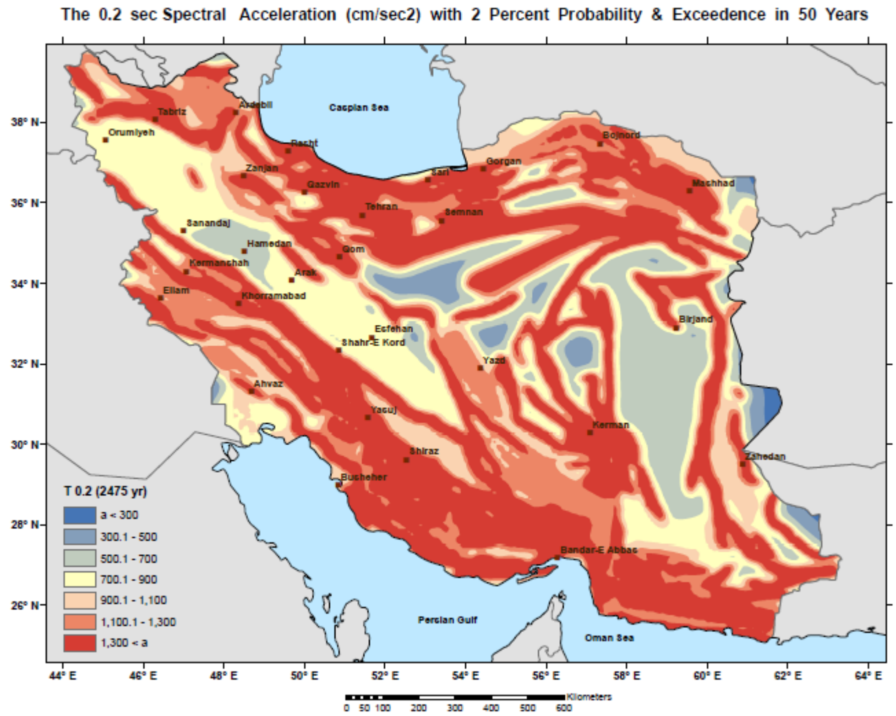

Figure 7. Spectral acceleration map for return period of 2475 years for period of 0.2 sec.

Disaggregation of the total hazard as a function of magnitude and distance for (return periods of 475) and 2475years at period of 0.2 sec and 1 sec for Arak city is shown in Figure 8. Figure 9 shows an example of uniform hazard spectra for different return period for Arak city in central Iran.

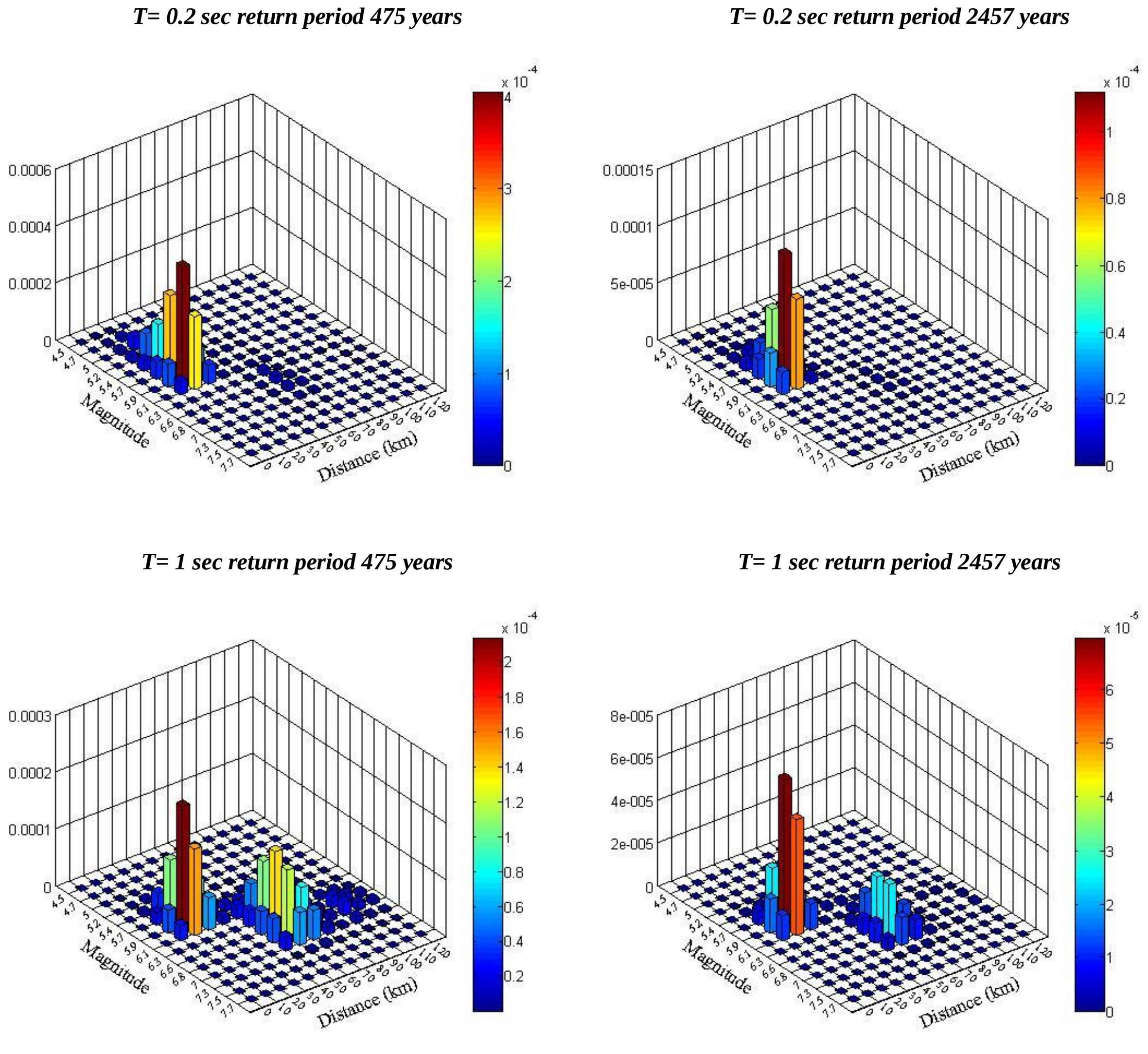

Figure 8. Disaggregation of the total hazard as a function of magnitude and distance for return periods of 475 and 2475years at period of 0.2 sec and 1 sec for Arak city.

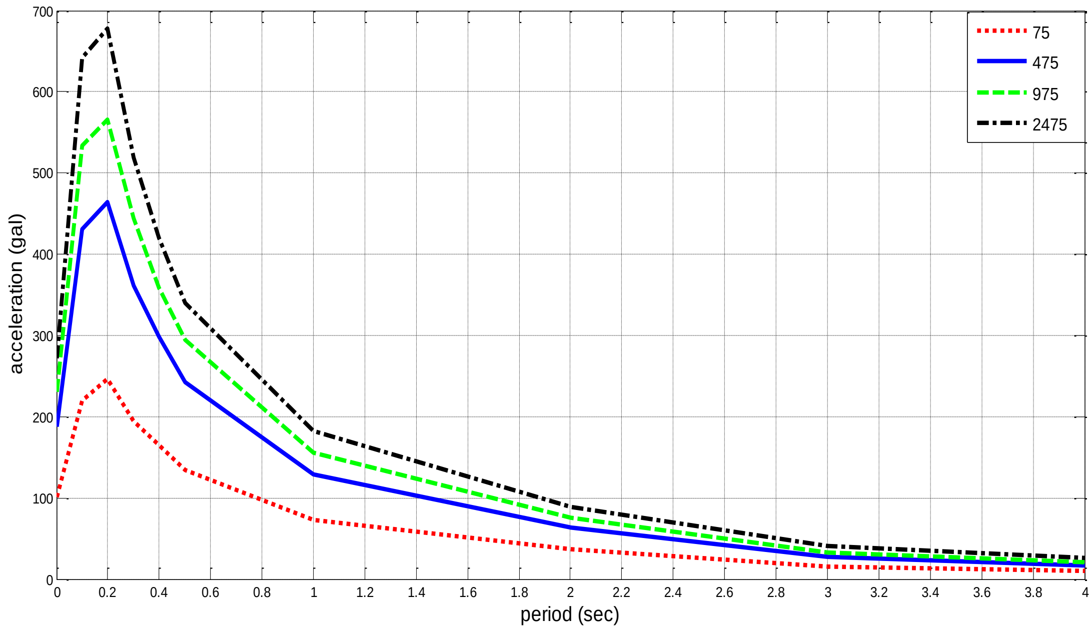

Figure 9. Uniform hazard spectra for Arak city for different return period.

5. CONCLUSIONS

We presented a set of peak ground and spectral acceleration maps for return period of 75, 475, 975 and 2475 for Iran based on probabilistic hazard analysis. We present disaggregation plots showing the contribution to hazard for major cities in Iran. The uniform hazard spectra has also been calculated.

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REFERENCES

Abrahamson, N. A., Silva, W. J. (1997). Empirical spectral attenuation relations for shallow crustal earthquakes. Seismological Research letter, 68, 94-127.

Ambraseys, N. N. and C. P. Melville (1982). A history of Persian earthquakes, Cambridge University Press, London, 219 p.

Berberian, M., (1976). Contribution to the seismotectonics of Iran (Part II), Geological Survey of Iran, Report No.39,141p.

Boore, D. M., Joyner, W.B., Fumal,T.E. (1997). Equations for estimating horizontal response spectra and peak acceleration from western north American earthquakes: A summary of rcent work. Seismological Research letter, 68, 128-153.

Campbell, K.W., Bozorgnia, Y. (2003). Updated near source ground motion (attenuation) relations for the horizontal and vertical components of peak ground acceleration and acceleration response spectra. B.S.S.A., 93, 314-331.

Cornell, C.A. (1968). Engineering seismic risk analysis, B.S.S.A, Vol. 58, pp. 1583-1606.

Ghasemi, H., Zare, M., Fukushima, Y., Koketsu, K. (2009). An empirical spectral ground motion model for Iran, Journal of Seismology, 13, 499-515.

Hessami, K., Jamali, F., and Tabassi, H., (2003). Active Fault Map of Iran. Proof print, International Institute of Earthquake Engineering and Seismology, Tehran, Iran.

Kijko, A. (2000). Statistical estimation of maximum regional earthquake magnitude M_{max}, Workshop : seisimicity modeling in seismic hazard mapping project Solvenia, May 22-24.

Shoja- Taheri, J. and M. Niazi (1981). Seismicity of the Iranian plateau and bordering regions, Bull. Seism. Soc. Am., Vol.71, pp. 477- 489.