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MODELING OF ACTIVE FAULTS FOR PREDICTION OF STRONG GROUND MOTION AROUND TEHRAN, IRAN

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SUMMARY

Tehran as the capital of Iran is located in a high seismic zone. The seismic study of the region shows that it is prone to moderate as well as large earthquakes. Occurrence of large destructive earthquakes in Tehran region and inadequate instrumental data makes the important of occurrence of large earthquakes in this region for seismologist. Simulation of strong ground motion based on a hybrid method of Ricker wavelet and envelope waveform has been used to estimate the ground motion due to a hypothetical earthquake in this region. The simulated records show high peak ground acceleration in Tehran region, which can cause widespread damage to Tehran city. The return period for high PGA closed to 1g may be around 2475 years.

INTRODUCTION

Among all natural disasters earthquakes cause maximum damage to life and property. With growing urbanization new centers of high population density are coming up in areas that are earthquake prone. Thus with the passage of time earthquake risks are increasing. At the time of an earthquake, damage is maximum in the epicenteral region, where the ground experiences intense shaking, i.e., strong motion is maximum. Ground motion records from the epicenteral region can be of great help in understanding the earthquake process as effects of transmission path are minimal and rupture on the causative fault can be modeled. 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, 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 [1] has divided Iran into four major seismotectonics zones, viz., Zagros active folded belt, Central Iran, Alborz, and Koppeh Dagh. Berberian [1] has studied the seismicity of Iran based on the epicenters of the instrumentally located earthquakes between 1900 and 1976. The distribution of epicenters indicates that seismicity of the Zagros Active Folded Belt 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

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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. The southern limit of this activity is not well defined and extends south to the Alborz and Central Iran.

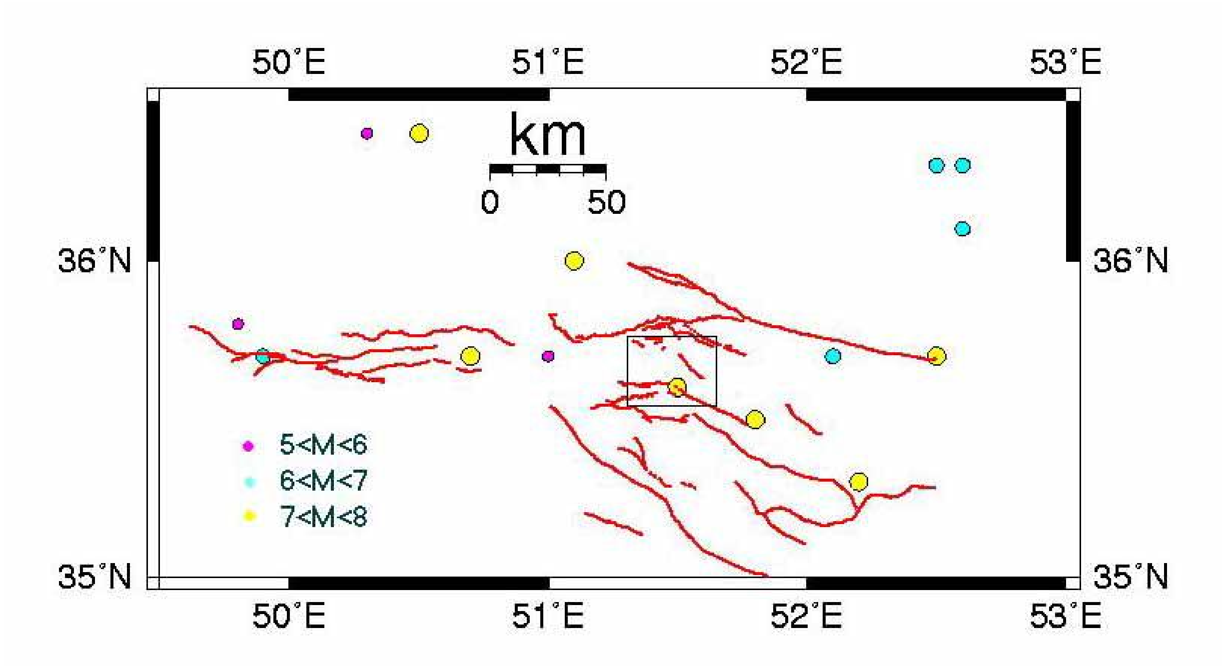

Fig.1 Historical earthquakes around Tehran. Tehran city is shown by rectangle.

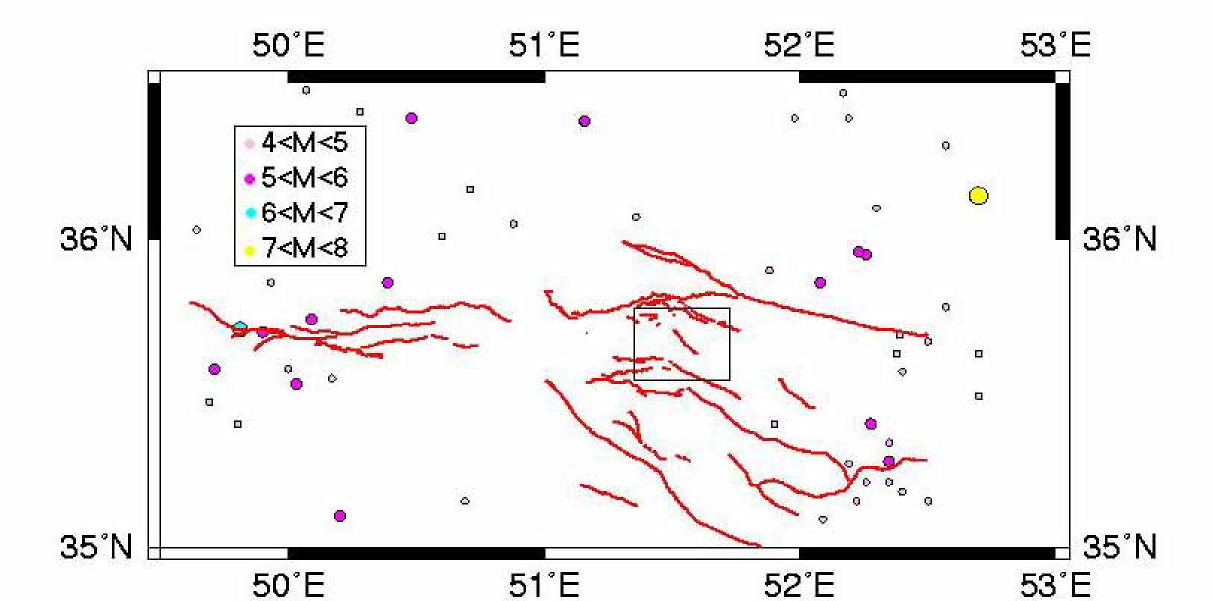

Fig.2 Instrumental earthquakes around Tehran. Tehran city is shown by rectangle.

A need of heuristic for identification of causative faults and modeling of rupture plane can not be over emphasized for earthquakes in the Iranian region. Studies concerned with evaluating seismic hazard related to ground shaking at the time of an earthquake event require prediction of strong ground motion from earthquakes that pose a potential treat. Modeling methods can be used to estimate strong ground motion for a given site due to a hypothetical earthquake where strong motion data does not exist. Such estimates can help in deciding the earthquake resistant design criteria for structures planned in an area such as Tehran where strong ground motion does not exist.

SIMULATION METHOD

In the present study, a method of Hamzehloo [2] and Hamzehloo et al [3], which is modified by using empirical relation for duration given by Atkinson and Boore [4] for simulation of strong ground motion, has been used. In this method estimation of peak acceleration from a preliminary simulated record is carried out on the basis of modeling parameters of rupture plane instead of empirical relations for peak acceleration.

The rectangular rupture plane is divided into square elements. Various modeling parameters are considered for simulation of strong ground motions at selected observation points. These parameters are length and downward extension of rupture plane, dip and strike of rupture plane, length of square element, velocity of S- waves in the medium, rupture velocity, nucleation point and energy released. Modeling parameters of rupture plane are given in Table 1.The fault plane is mapped into a three dimensional coordinate system. The nucleation point is a point on the fault at which rupture starts.

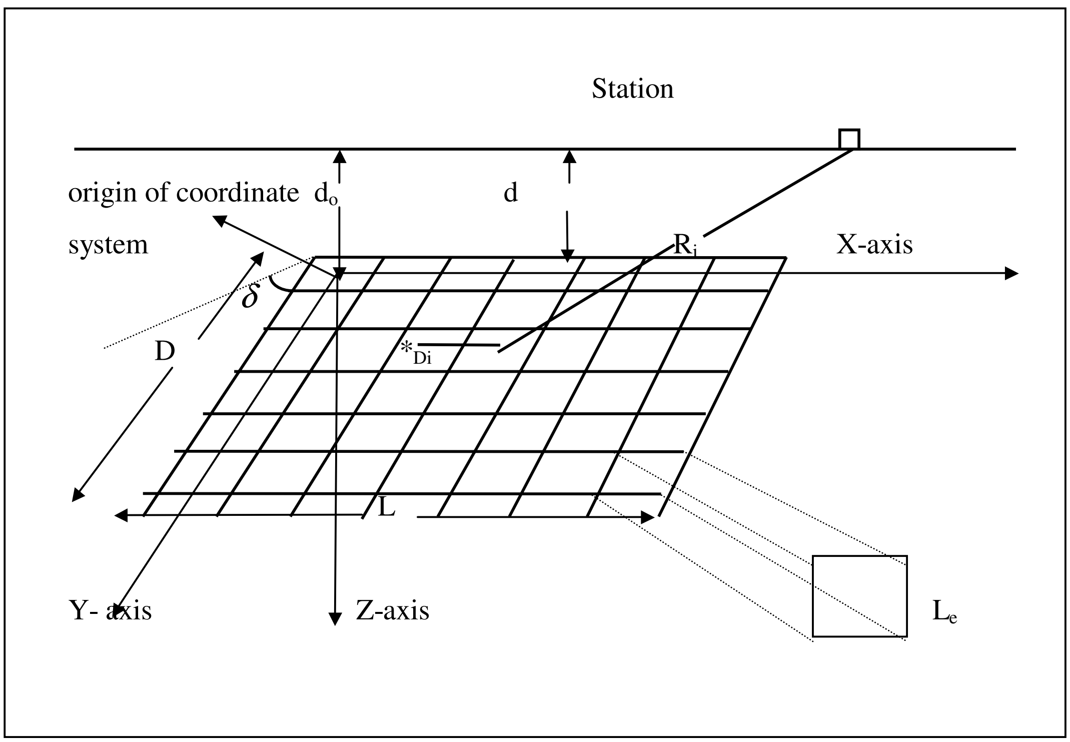

Fig.3 Model of rupture plane and coordinate system.

The energy is released at the center of each element when rupture approaches its center. This is expressed in the form of a source wavelet [5,6]. The source wavelet from each element reaches the observation point with different time lags. This depends on the time taken by rupture to reach a particular element from the nucleation point with rupture velocity and the time taken by the source wavelet to reach the observation point with the velocity of S-waves in the medium. The peak ground acceleration is estimated from this preliminary simulation at selected observation points. It is assumed that the acceleration record has the shape of the envelope waveform function given by Kameda and Sugito [7] as:

$$a(t) = (P_{ap}/t_d)\, t \exp(1 - t/t_d) \qquad (1)$$

where a(t) is the acceleration envelope waveform, P_{ap} is preliminary peak acceleration estimated from preliminary simulated acceleration record which is simulated by using modeling parameters of rupture plane and energy released, and t_d is the duration parameter of envelope waveform and estimated from relation given by Atkinson and Boore, [7] as:

$$t_d = 0.16\,(R-10) \qquad \text{for} \quad 10 \le R < 70 \text{ km}$$
$$t_d = 9.6 - 0.03\,(R-70) \qquad \text{for} \quad 70 \le R < 130 \text{ km}$$

where R is hypocentral distance. The envelope waveform function is derived using estimated peak acceleration from preliminary simulation and duration parameter from empirical relation for duration. White noise of desired length is then generated the same as sampling interval for observed records. Spectrum of generated white noise, F(f), is passed through a frequency- dependent function which takes into account material property, Q(f), Brune’s spectrum, S(f), and near site attenuation at high frequencies, P(f), and given as:

$$F(f)=S(f).P(f) \exp(-\pi f R / Q(f) V)/R \qquad (3)$$

where V is the velocity of S- waves in the medium. Time series of filtered white noise is obtained by Inverse Fourier transform. The acceleration envelope waveform multiplied by band limited normalized white noise to generate the final simulated record. Considering rupture length 50% of fault length, a magnitude of 7.0 and 6.9 are considered for North Tehran Fault and Eyvanaki Fault using Wells and Copersmith [8] relations, respectively.

Table 1. Modeling parameters of rupture plane.

Modeling Parameters	North Tehran Fault	Eyvanaki Fault
M_W	7.0	6.9
Rupture length	50	40
D	18	16
L_e	1	1
V_S	3.22	3.22
V_r	2.56	2.56
strike	110	140
dip	70	80

RESULTS

Using the method discussed above and considering various modeling parameters of the rupture plane strong ground motion have been simulated at epicenteral distances of 15, 20, 25, 30, 40 and 50 km from the hypothetical earthquake epicenter due to north Tehran fault and Eyvanaki fault. The simulated records at these distances are shown in Figures 4 and 5.

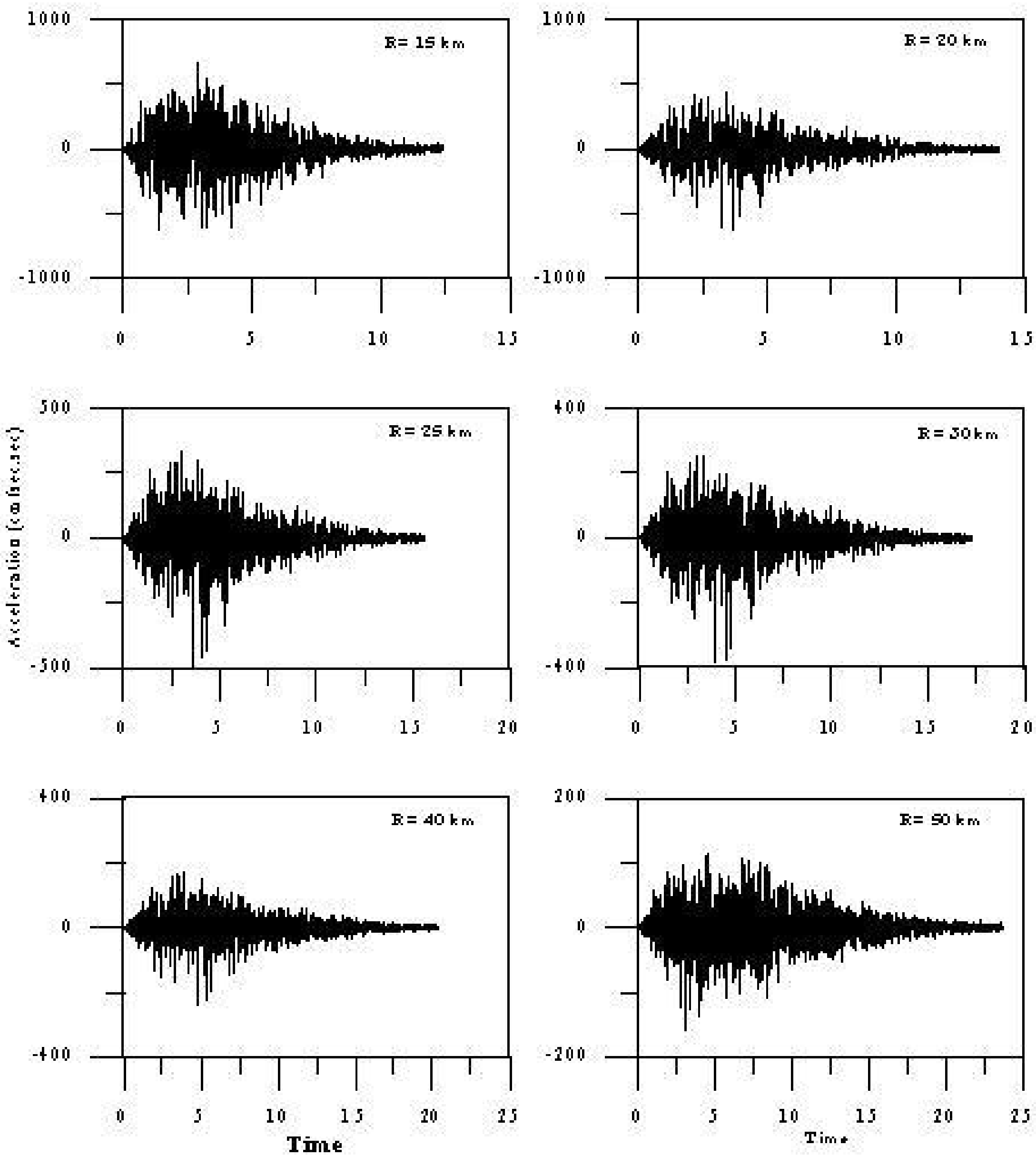

Fig.4 Simulated records at the epicenters of 15, 20, 25, 30, 40, and 50 for a hypothetical of magnitude M_W 7.0 due to north Tehran fault.

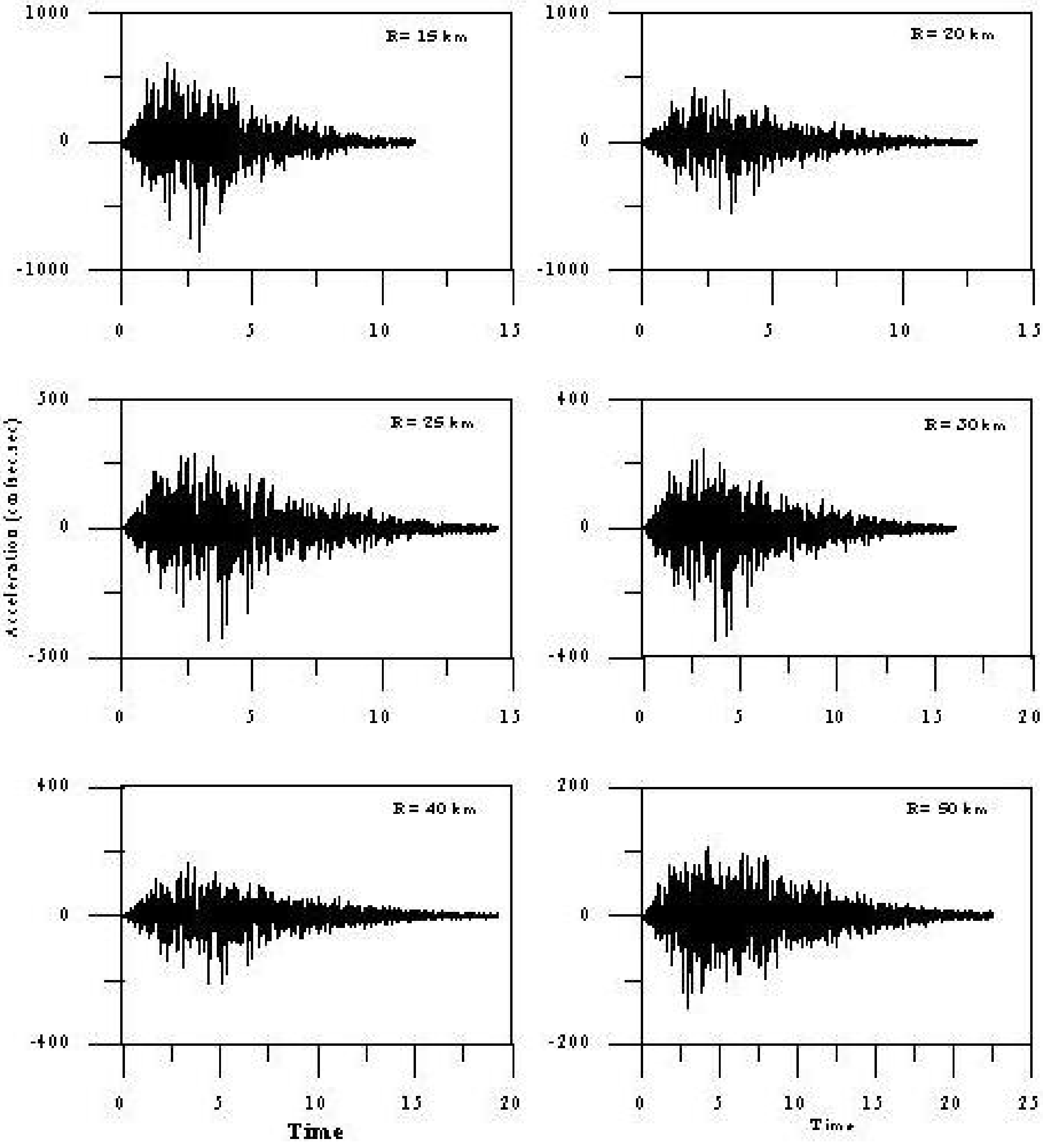

Fig.5 Simulated records at the epicenters of 15, 20, 25, 30, 40, and 50 for a hypothetical of magnitude M_W 7.0 due to Eyvanaki fault.

The simulated records are on the basis of occurrence of maximum earthquakes of 7.0 and 6.9 on the north Tehran fault and Eyvanaki fault, respectively. The estimated time histories show high peak ground acceleration close to north Tehran fault and Eyvanaki fault.
On the other hand, hazard has been estimated for return period of 475 and 2475 years by considering north Tehran fault and Eyvanaki fault separately. High hazard has been observed close to north Tehran fault and Eyvanaki fault (Fig.6 & 7).

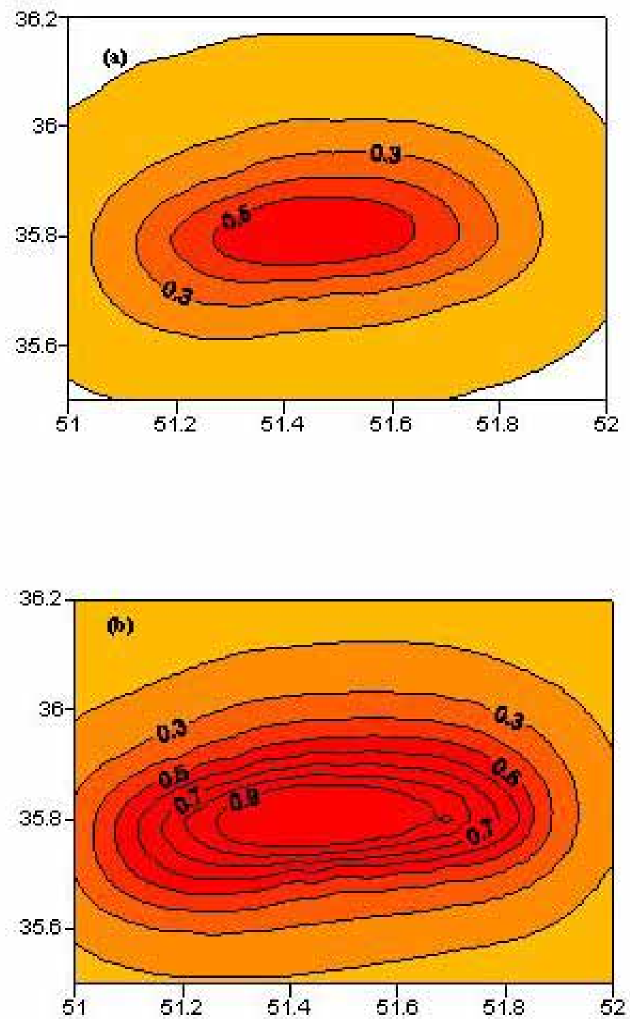

Fig.6 Earthquake hazard analysis for 10% probability of exceedence in 50 years (a) and 2% probability of exceedence in 50 years (b) for north Tehran fault.

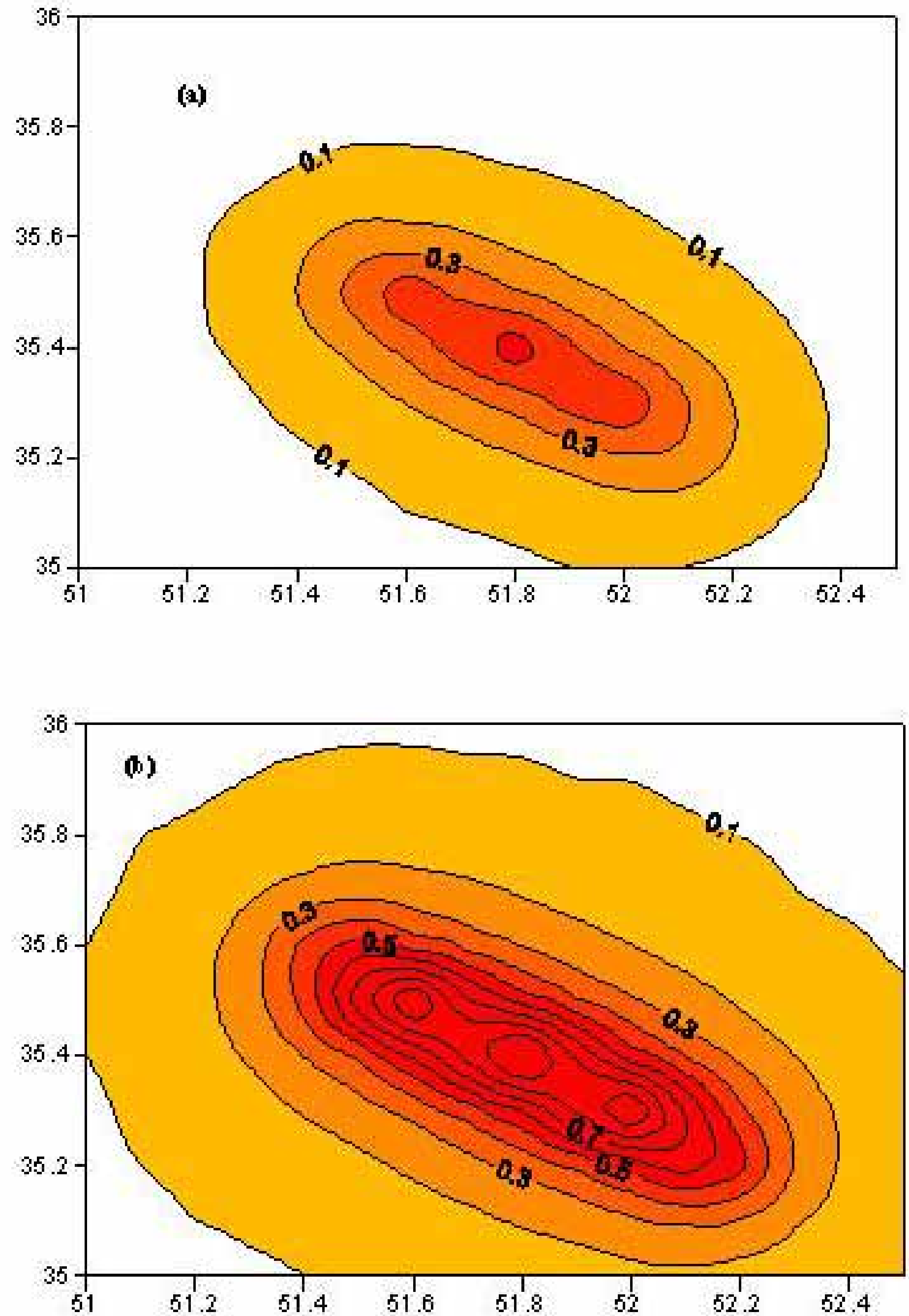

Fig.7 Earthquake hazard analysis for 10% probability of exceedence in 50 years (a) and 2% probability of exceedence in 50 years (b) for Eyvanaki fault.

DISCUSSIONS

Occurrence of large destructive earthquakes in Tehran region and inadequate instrumental data makes the important of occurrence of large earthquakes in this region for seismologist. On the other hand no strong ground motion data are available for this region to have a reliable estimation of ground motion. Therefore, simulation and hazard analysis can help us to estimate the ground motion due to a hypothetical earthquake in this region. Seimicity of Tehran region shows occurrence of three destructive historical earthquakes with magnitude greater than 7.0 in the southeast of Tehran close to Eyvanaki fault (Fig.1). The closest historical earthquakes with magnitude greater than 7.0 are located north and south of north Tehran fault (Fih.1). The location of the instrumental earthquakes from 1900 to 2003 shows that east and southeast of Tehran are more active than west of southwest. Based on the tectonic situation of this region the north Tehran fault and Eyvanaki fault are considered as two important sources, which can generate a destructive earthquake in future. A magnitude of 7.0 and 6.9 are considered for the north Tehran fault and Eyvanaki fault.

The simulated records which generated due to activation of north Tehran fault shows high peak acceleration close to 1g at location close to the north Tehran fault. Again high peak acceleration has been estimated for location close to Eyvanaki fault. The high peak acceleration has been observed close to causative fault for the 1978 Tabas earthquake, the 1990 Rudbar earthquake, and the 2003 Bam earthquake in Iran. The causative fault for these earthquakes caused widespread damage and killed more than 100,000 people in these three earthquakes. The simulated records also show high peak ground acceleration in Tehran region. The hazard analysis for the north Tehran fault and Eyvanaki fault show high hazard due to activation of these two faults. The hazard analysis shows that the high acceleration close to 1g may be occurred with long return period (2475 years).

CONCLUSIONS

On the basis of preliminary analysis of simulation of strong ground motion and hazard analysis for north Tehran fault and Eyvanaki fault in the Tehran region, it is concluded that the Tehran has the potential to experience high peak acceleration, which can cause widespread damage to Tehran city. The return period for high PGA close to 1g is around 2475 years.

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