ABSTRACT

Effect of Coulomb Stress Changes on Time-Dependent Model in East of Iran

Samira Sorkhvandi[1], Hamid Zafarani[2], and Abbas Ghalandarzadeh[3]

1. M.Sc. Student, School of Civil Engineering, College of Engineering, University of Tehran, Tehran, Iran
2. Associate Professor, International Institute of Earthquake Engineering and Seismology (IIEES), Tehran, Iran, Corresponding Author, e-mail: h.zafarani@iiees.ac.ir
3. Associate Professor, School of Civil Engineering, College of Engineering, University of Tehran, Tehran, Iran

In recent years, many models for earthquake recurrence were proposed. The methodology adopted in this study is based on the fusion of the statistical renewal model called Brownian passage time (BPT) with a physical model. The later taking into account the instantaneous change of the static Coulomb stress (ΔCFF) for the computation of both the permanent and the transient effects of earthquakes occurring on the surrounding sources. Renewal models are frequently used to estimate the long-term time-dependent probability of the next large earthquake on specific faults or fault segments where large shocks occur repeatedly at approximately regular intervals. In this approach, it is assumed that the times between consecutive large earthquakes (inter-event times or recurrence intervals) follow a certain statistical distribution.

East of Iran experienced more than ten destructive historical earthquakes and 14 instrumental earthquakes with magnitudes larger than 5.5 (Mw). Two of these events by Mw>7.1 occurred in east and west of the Dasht e Bayaz fault. This fault by east-west trend in west segment is perpendicular to the Abiz fault that experienced one of the most destructive earthquakes (Mw=6.2) in this region. Both mentioned faults have strike-slip mechanism, but the largest event (Mw=7.3) occurred on the Tabas fault that showed a reverse mechanism. Because of the high potential of a large earthquake occurrence, we decided to use the BPT model in this area and calculate the probability of future events on the Tabas, and Ferdows faults, and east and west segments of the Dasht e Bayaz fault.

The analysis has been carried out on East (Dasht e Bayaz-Ferdows region) of Iran (32–35◦ N; 56–61◦ E), containing four seismogenetic sources. In this study, we adopt the BPT distribution to represent the inter-event time probability distribution for earthquakes on individual sources. Unlike all the other renewal models, which are based only on an arbitrary choice of the probability density distribution, the BPT is associated to considerations on the fault physical properties [1]. For this model, in addition to the expected mean recurrence time, the coefficient of variation (also known as aperiodicity) α of the inter-event times is required. If $\alpha > 1$, the time series will exhibit clustering properties. Values below the unit indicate the possible presence of periodicity, with increasing regularity for decreasing α. In this study, we considered 0.5 and 0.75 for α.

By using the probability density function and the time of the last event, we will be able to compute the probability of an event that occurs between time t and $t+\Delta t$. This renewal process assumes that the occurrence of a characteristic event is independent of any external perturbation, but in real circumstances, earthquake sources may interact. Therefore, we consider fault interaction by the computation of the Coulomb stress change (ΔCFF) caused by Birjand-Qaen earthquake (May 10, 1997) on the investigated fault. For this purpose, we used the Coulomb stress Change function that used by King et al [2]. For calculation of imposed stress, we used an amount of 0.4 as an effective coefficient of friction because for faults in the continental region, it is the best choice [3].

The permanent effect of Coulomb stress changes on the probability of an impending characteristic event can be approached from two points of view [4]: (1) Modification of the elapsed time since the previous earthquake, and (2) Modification of the expected mean recurrence time. Both of these approaches have the same effect, and in this study, we used the first approach. We need to consider the transient effect, due to rheological properties of the slipping faults. The application of the Dieterich [4] constitutive friction law to an infinite population of faults leads to the expression of the seismicity rate as a function of time after a sudden stress change. The transient effect of the stress change is expressed as a change in expected rate of the segment events [4].

By considering East of Iran, as a study area that had been limited by the rectangle of coordinates 32–35◦ N and 56–61◦ E, and assuming an earth model such as a half space characterized by uniform elastic properties, we calculated the maximum amount of imposed Coulomb stress changes due to Birjand-Qaen on the East and west Dasht e Bayaz, Tabas and Ferdows faults and the obtained amounts are 5.076, - 0.0014, 0.0015 and 0.0051 Mpa, respectively.

The computation of the occurrence conditional probability of future earthquakes would require the knowledge of the mean recurrence time of characteristic earthquakes (T_r), aperiodicity, the time elapsed since the previous earthquake, and tectonic stressing rate. By using the relation given by Field et al [5], we computed T_r. In this study, $M_w \geq 6$ has been considered as the characteristic magnitude. Khodaverdian et al [6] calculated shear strain rate for the Iranian Plateau. The values of the average shear strain rate have been used for the computation of $\dot{\tau}$ multiplying it by μ. The computation of the probability connected to the transient effect, combined with the permanent effect would require the knowledge of the aftershock duration (t_a) and Aσ. The values of the aftershock duration has been obtained 11.32 year. By using the relation given by Dieterich [4] we computed Aσ.

Positive coulomb stress changes indicate loading on receiver fault and brings it to fracture and negative Coulomb stress changes unloads the receiver fault, and there will be a delay time on the future event on that fault. Obtained results showed that East Dasht e Bayaz, Tabas and Ferdows faults received positive coulomb stress changes, and West Dasht e Bayaz fault received negative amount of imposed Coulomb stress changes. For the Ferdows and Tabas faults, the received Coulomb stress changes are less because of the large distance from the epicenter of the Birjand-Qaen earthquake, and thus the obtained amount from probability model is less and near to zero. On the other hand, we obtained high-imposed Coulomb stress changes for the East Dasht e Bayaz fault because the occurred Birjand-Qaen earthquake had a little distance from this fault. Imposed negative Coulomb stress changes on the West Dasht e Bayaz fault caused delay on the future event on this fault and reduced the probability on this fault a little.

Keywords: Coulomb Stress; Time-Dependent Model; Seismic Hazard; East of Iran.

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