

Seismic Damage Analysis of Tehran Using Damage Spectra



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SUMMARY:

Predicting of damage in a region is interested issue in earthquake engineering. By using the attenuation relationships of earthquake parameters it is possible to predict the amount of those parameters using probabilistic methods. It is possible to predict the amount of damage using the attenuation relationships of damage spectra. By using these relationships the amount of damage can be calculated. The relationships have been made with consideration of variation in the nonlinear parameters of structures like the yield force and capacity ductility. Finally, probabilistic seismic damage analysis of Tehran has been performed using the proposed relationships. By using the results of this study, it is possible to predict the amount of damage in Tehran with any considered probable earthquake.

Keywords: Damage spectra, Damage index, PSHA

1. INTRODUCTION

Predicting the effect of earthquake on structures is an interesting field of study in earthquake engineering. The main parameter which is used by many codes to calculate the earthquake force is peak ground acceleration. This is because of the relationship between the amount of force and acceleration in the structures. But the more important parameter can be the parameter which is able to directly reflect the amount of loss in structures.

There are many damage indices to show the amount of damage in the structures and widely used in past researches. Some of them are based on structural parameters like period. This kind of damage index have been introduced by (DiPasquale & Cakmak 1987)

$$\delta_m = 1 - \frac{(T_0)_{initial}}{(T_0)_{max}} \quad (1.1)$$

In fact, the above equation is known as softening of the structure. The amount of damage in a structure can be related to the amount of maximum response of the structure under specified loading. This parameter also can be normalized using the threshold amount of the considered parameter. One of these equations have been introduced by (Powell & Allahabadi 1988)

$$DI = \frac{\delta_{max} - \delta_y}{\delta_u - \delta_y} \quad (1.2)$$

Where δ_{max} , δ_u and δ_y are maximum deformation under specific loading, maximum deformation capacity and the yield deformation respectively. This kind of damage index has the ability to show the percentage of the used strength and remaining strength in one cycle. This will become more useful if one use it in combination with amount of dissipated energy in the structure. One of the famous types

of damage indices is the following definition (Park & Ang 1985)

$$DI_{PA} = \frac{\delta_{max}}{\delta_u} + \frac{\beta}{F_y \delta_u} \int dE \quad (1.3)$$

Where F_y , β and dE are yield strength, nonnegative parameter and incremental absorbed hysteretic energy respectively.

In this research using the Park & Ang damage index, the attenuation relationships of damage spectra have been developed and the amount of damage in Tehran has been predicted. In the next section the brief definition of damage spectra has been prepared.

2. DAMAGE SPECTRA

For developing a damage spectrum for an earthquake record, a nonlinear dynamic analysis using series of single degree of freedom structures should be performed. The properties of the series of the SDOF structures should be defined. As the first step, the damage index should be selected from various damage indices. The Park and Ang damage index (Eqn 1.3) is used. By selecting a force-displacement diagram for a SDOF system, and capacity ductility and the yield force and also by performing a nonlinear dynamic analysis for calculating maximum displacement and dissipated energy, it is possible to calculate the damage index for the selected SDOF system with the specific period. If one applies this method to a series of SDOF systems, a damage spectrum can be obtained for the selected record with a specified capacity ductility and yield force. The example of damage spectrum for Tabas Earthquake has been shown in Fig. 2.1.

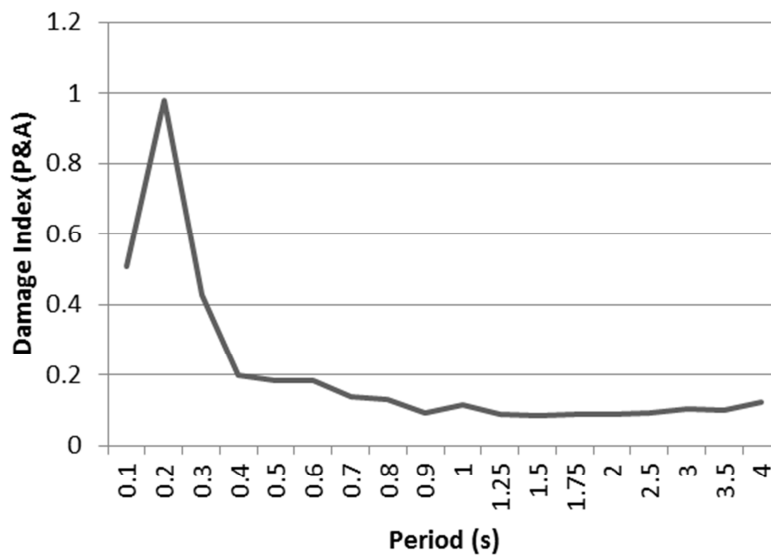


Figure 2.1. Damage spectrum for Tabas earthquake

The Fig. 2.1 predicts the amount of damage in any structure with specified period under Tabas earthquake. In the other hand if one has the period of the structure and its nonlinear parameters, using the above figure, is able to predict the amount of damage in the selected structure.

3. ATTENUATION RELATIONSHIPS AND PSDA

Once we have the damage spectra for many records, it is possible to develop the attenuation

relationship of the damage spectra like the other parameters of the ground motion. The example of the damage spectra attenuation relationships is illustrated in Fig. 3.1.

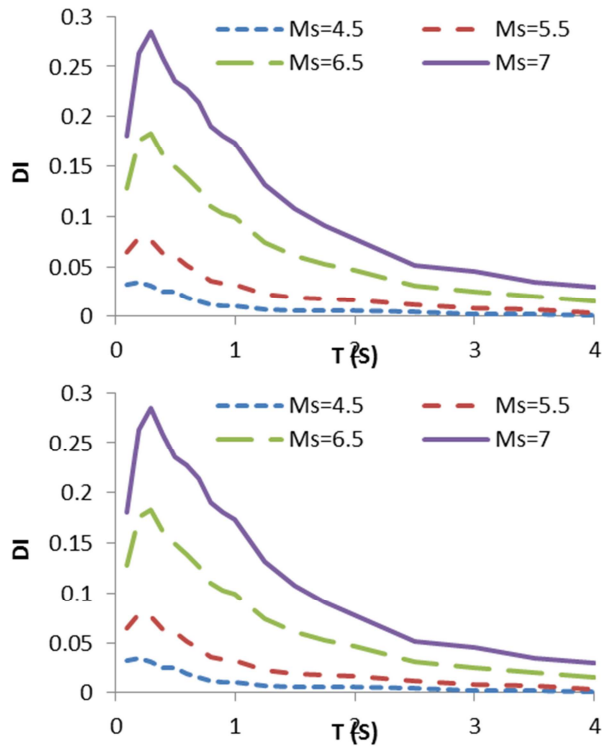


Figure 3.1. Damage spectra in different magnitude and distances of fault

By using the above relationships it is possible to perform the probabilistic seismic damage analysis for a region. The methodology is the same as the probabilistic seismic hazard analysis for spectral acceleration. The only difference is using damage spectra attenuation relationship instead of spectral acceleration attenuation relationship. The methodology is shown in Fig. 3.2.

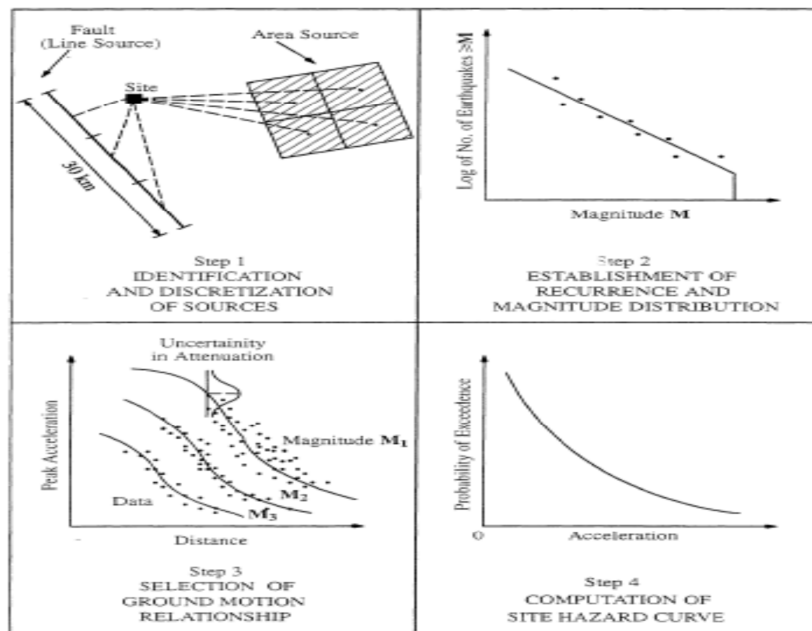


Figure 3.2. Methodology of PSHA (Reiter, 1990)

After performing these steps, the damage curve can be drawn. This curve shows the relationship between Damage and its probability of exceedence.

4. RESULTS

The explained methodology is used to draw the iso-damage curves for metropolitan Tehran. The curves are used to predict the amount of damage in any location for the earthquake with 475 years return period.

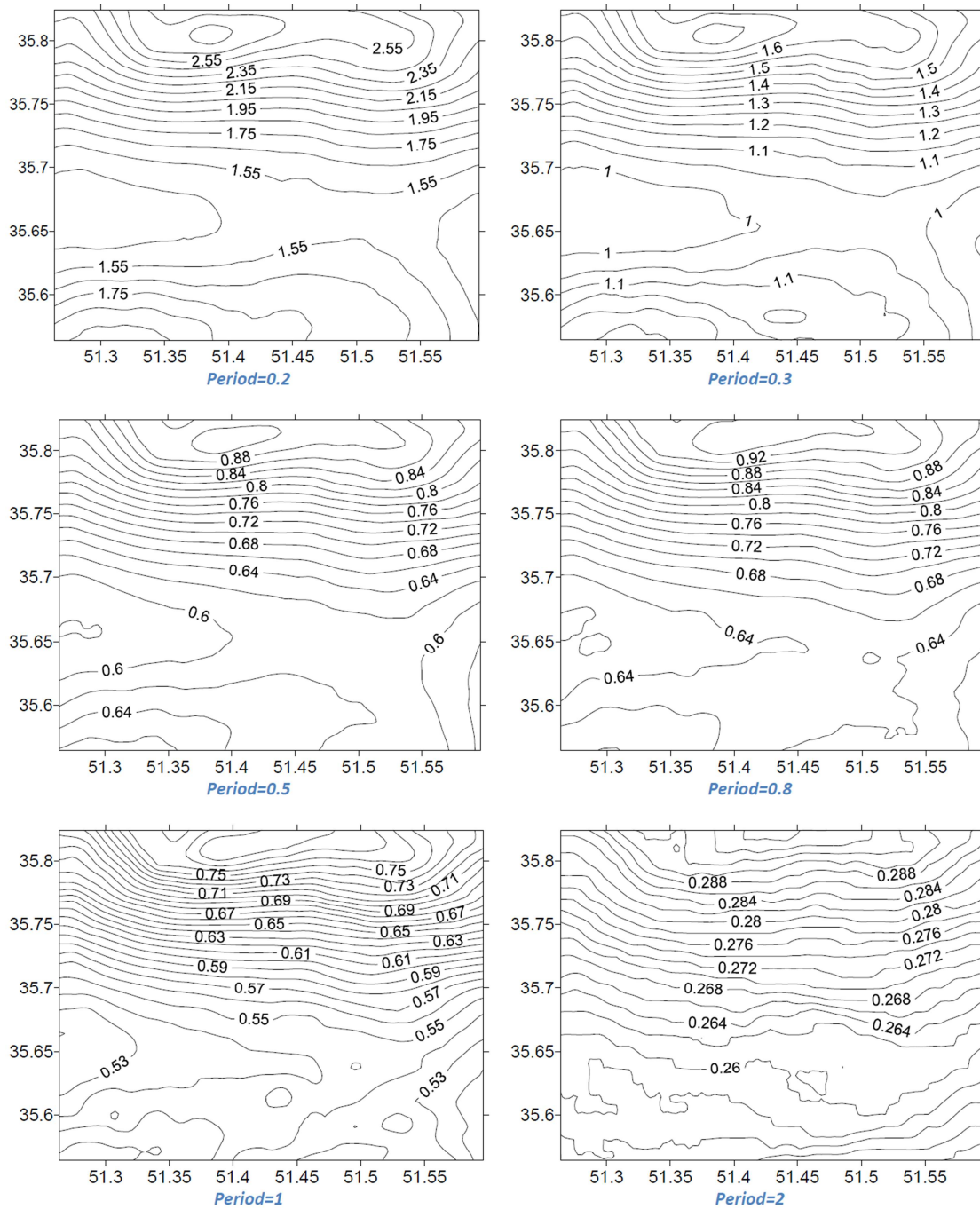


Figure 4.1. Predicted damage in Tehran

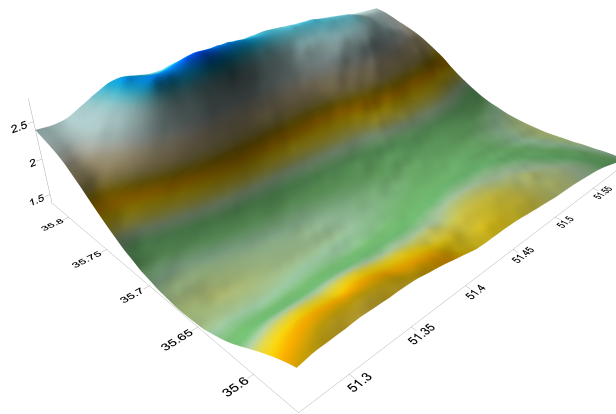


Figure 4.2. 3D visualization of Damage in T=0.2 in Tehran

5. CONCLUSION

In this paper the methodology for predicting damage in a region using the probabilistic seismic damage analysis is briefly explained and used the method to predict the amount of damage in RC structures in Tehran. By using the results of this research it is possible to provide more facilities for post-earthquake activities in the regions with more expected damages or make a retrofit priority plan for a city or a region.

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