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Simulating the earthquake of May 7, 2020 in Damavand, Tehran with magnitude 5 using the empirical Green's function method.

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Abstract

To simulate the strong movement of the Damavand earthquake, the empirical Green's function method has been used. One of the conventional methods of simulation to produce strong ground motion is the use of aftershocks and foreshocks of large earthquakes using the empirical Green's function method; As a result, we used the ground motion simulation algorithm based on the empirical Green's function to simulate the Damavand earthquake waveform. On 02/18/2019, an earthquake with a magnitude of 5 occurred in Damavand, located in Tehran province. In this study, with the aim of estimating the parameters of the spring and the mode of fracture in this earthquake, the empirical Green's function method has been used to simulate the powerful movement of the earth. To simulate the main earthquake, a foreshock with a magnitude of 2.9 near the center of the main earthquake, as well as aftershocks with a magnitude of 3.9 and 4.1 recorded at the Masha and Rodhen accelerometer stations, have been considered as experimental Green's function. The length and width of the fracture in this earthquake are 2 and 3 km, respectively, in the direction of extension and slope. Calculations show that the direction, slope and tilt of the fault that caused the earthquake were 196, 76 and 156.5 degrees, respectively. The focal mechanism of this earthquake is of reverse type with strike-slip component, which is consistent with the mechanism of earthquakes in this area.

Key words: *Damavand, simulation, strong ground motion, empirical Green's function.*

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Extended Abstract:

1. Introduction

On the 19th of May 2019, at 00:21:48 local time, an earthquake of magnitude 5 occurred in Damavand, located in Tehran province. This earthquake occurred in an area close to the Masha fault. The calculations show that the epicenter of this earthquake was located at 35.86 degrees north latitude and 52.11 degrees east longitude, 7 kilometers north of Damavand and near Masha village. The focal depth of the Damavand earthquake is reported to be 7 km (Seismological Center of Iran). For the studies of seismology, earthquake engineering and seismic hazard analysis, determining the parameters of the seismic source is useful (Huang and Cheng., 2011). In order to better understand and determine the necessary parameters of the Tehran area, it is possible to use the simulation of the strong earth movement for the Damavand earthquake and to know the area in terms of the occurrence of future earthquakes (Raghu, 2008). In this study, near-field accelerometer data were used, which were taken from the data of the Building and Housing Research Center. For this purpose, the empirical Green's function method has been used to simulate the powerful movement of the earth (Figure 1).To simulate the main event, aftershocks with magnitudes of 3.9 and 4.1 have been considered as small events. In this method, the focal mechanism of the small event and the main event should be similar (Irikura, 1986).

2. Materials and methods

In a specific structure, the sum of a series of movements is obtained, which are caused by individual failures of small pieces on the fault plane with a certain time delay. The important assumption of this method is the point source in small events. The construction steps of the artificial earth movement can be summarized as follows: First, the appropriate model of the source and magnitude of the target earthquake in the desired structure is selected. This model should be selected according to the geological documentation of the place. Then, the small earthquake recorded at the station where the main earthquake was recorded is selected for the desired source. This earthquake contains the main characteristics of the mechanisms of larger earthquakes and the effects of the geological structure between the source and the station are also included in it. In the next step, the size of the earthquake can be selected according to the seismic moment. Then, the fault surface is determined according to a preliminary grid of finite elements. The empirical Green's function mentioned above is applied to each of the network components in the desired order to obtain the appropriate rupture speed on the entire fault surface and at the same time to maintain the specific overall torque for a larger earthquake. The superimposition can be done in terms of the amplitude and phase spectra with the help of a prepared computer program and the synthetic acceleration map can be obtained at a surface point in the vicinity of the original recorded empirical Green's function. Then, by summing the results of all parts, the total movement of the earth at the desired station is calculated. Irikura method (Irikura, 1986) has been used for simulation. The relationship between the parameters of two large and small earthquakes is obtained based on Kanamori's laws (Kanamori, 1975).

3. Tests results

In this study, the data recorded by 12 near-field accelerometer stations have been used, and processing including baseline correction and frequency content has been performed on the data. In order to determine the stress drop in this event, the Fourier spectrum has been used in a logarithmic scale, by determining the corner frequency and the seismic moment, in this way, the stress drop is obtained from these two parameters. Using the maximum accelerations recorded in 12 nearby field stations, the PGA (maximum ground acceleration) map in this area has been drawn for this earthquake (Figure 2). In this study, the fracture spread from the center in one direction with a speed equal to 0.8 of the shear wave speed. In this method, the main event is considered to include a set of small events, the fault plane of the main event is divided into a number of sub-faults with the same dimensions, the dimensions of the main fault and sub-fault are respectively proportional to the rupture related to the main event and the small event. . In this study, the small event is considered the largest aftershock of this earthquake with magnitudes of 4.1 and 3.9; Using Wells and Coppersmith relations (Wells and Coppersmith, 1994), the length of the fault in the Damavand earthquake was about 2 km along the extension and the width of the fault was 3 km along the slope. To determine the dimensions of the element, Irikura's law of similarity of earthquakes (Irikura, 1986) and the relations related to Kanamori's law of similarity of earthquakes (Kanamori., 1975) have been used. In the mentioned earthquake, 4 elements were determined in the direction of extension and 6 elements in the direction of slope.

4. Conclusion

According to the simulated parameters, the maximum acceleration in the stations was estimated by the experimental Green's function method and compared with the observed maximum acceleration (Figures 4, 5 and 6). To select the best point as the epicenter of the earthquake, the fault surface using the law of similarity of earthquakes , is divided into a number of sub-faults. Using the data of strong earth movement obtained from accelerometers, the parameters of the spring of the 19th May 2019 Damavand earthquake in Tehran, as well as its rupture characteristics, were determined using this method. Using this method, the number of elements in the direction of the extension and the starting point of the rupture and the depth of the earthquake center were obtained on the fault plane using the empirical Green's function method (Table 2). Calculations show that the direction, slope and tilt of the fault that caused the earthquake were 196, 76 and 156.5 degrees, respectively. The focal mechanism of this earthquake is of reverse type with strike-slip component, which is consistent with the mechanism of earthquakes in this area.

Table 2. Rupture plate specifications

fault length	2 Km
fault width	3 Km
The number of elements along the length	4
The number of elements along the width	6
The starting point of rupture	(1,1)
depth	27 Km

References:

Aki, K., 1968. Seismic Displacements near a Fault, Geophys.Rer, 73, pp 5359-5376

Boore, DM.,1983. Stochastic Simulation of High-Frequency Ground Motion Based on Seismological Mod of the Radiated Spectra, Bull .Seis. Soc. Of Am , Vol. 73, No. 6: 1865-1894

Cheng, F., Huang, H.,2011. Strong ground motion simulation of the October 22, 1999 Chiay earthquake using Hybrid Green function method: 4th IASPEI international symposium, University of California Santa Barbara.

Hanks, TC., and McGuire, RK.,1981. The character of high frequency Strong ground motion , Bull Seism. Soc. Am., 71: 2071-2095

Hartzell, SH., 1978. Earthquake aftershocks as Green's functions, Geophys. Res. Lett.5: 1-4

Haskell, NA., 1969. Elastic Displacements in the Near-Field of a Propagating Fault", Bull. Seism. Soc. Am., 59:865-908

Hutchings, L., 1991. Prediction of strong ground motion for the 1989 Loma Prieta earthquake using Empirical Green's functions, Bull. Seism. Soc. Am., 81: 88-121

Hutchings, L and Ioannidou, E, Foxall W and Voulgaris N., 2007. A physically based strong ground motion prediction methodology; application to PSHA and the 1999 Mw = 6.0 Athens earthquake, Geophys. J. Int,168: 659–680

Irikura, K., 1986. Prediction of strong acceleration motion using empirical Green's function. Proc.7th Japan Earthquake Engineering Symposium, Tokyo, 151-156

Irikura, K and Muramatu, I., 1982. Synthesis of strong ground motion from large earthquakes using observed seismograms as small events, Paper presented at 3rd International Earthquake Microzonation Conference, National Science Foundation

Kanamori, HK and Anderson, DL.,1975. Theoretical basis of some empirical relations in seismology, Bull. Seism. Soc. Am. 65: 1073-1095

Raghu, STG.,2008. Modeling and synthesis of strong ground motion: Department of civil engineering,Indian institute of technology, Madras, India.

Wells, DL and Coppersmith, KJ.,1994. New empirical relationships among Magnitude, rupture length, rupture width, rupture area, and surface displacement, Bull. Seismol. Soc. Am., 84: 974-1002