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Ground motion duration and earthquake magnitude

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Stochastic Green's function method is one of the useful tools to calculate ground motions. To account for the effects of asperities and rupture propagation, the entire fault of dimension L is sub-divided into small sub-faults of dimension R, and ground motions from all sub-faults are integrated instead of evaluating from a point source. Though the size of element is arbitral, the final synthesized ground motion must not depend on the sub-fault size. Stochastic Green's function is based on the product of Gaussian time series and envelope shape function e(t). In many cases, duration Tr of the envelope shape function is set as inversely proportional to the corner frequency fc of sub-fault, or in other words, as proportional to the dimension of sub-fault R.

Tr=d/fc=(d/Cc)(R/Vs)...(1)

When a point source is assumed, total duration of ground motion T is coincide with the envelope function duration,

T=Tr=(d/Cc)(L/Vs)...(2)

The total duration of synthesized ground motion T is the sum of time for the rupture Tp to propagate the entire fault and the duration of sub-fault ground motion Tr.

Tp=Cp(L/Vs)...(3)

T=Tp+Tr...(4)

Generally, equation (2) for a point source and equation (4) for finite source give different values of ground motion duration. As the sub-fault size gets small, the sum also gets small, and the synthesized ground motion does depend on the sub-fault size. Ground motion duration is dependent not only on terms related to the seismic source, such as rupture propagation time Tp and sub-fault duration Tr, but also on terms Tm attributed to the medium, such as reflections and scattering. Therefore, the ground motion duration is expressed as,

T=Tm+Tp+Tr...(5)

As the entire fault size L increases as the earthquake magnitude increases, the total duration of ground motion also increases as the magnitude increases. Equation (5) gives a different relationship between ground motion duration and magnitude from equation (5).

In order to clarify which is more acceptable, I investigated the dependency of ground motion duration on earthquake magnitude. I analyzed big earthquakes and their aftershocks which recently occurred in and around Japan. They include shallow crustal earthquakes, inter-plate earthquakes, and intra-plate earthquakes. The magnitude ranges from 3.6 to 8.0. The observed records from K-NET and KiK-net of NIED and JMA are used. There is variety of definition of ground motion duration. In this paper, I adopted the Tw defined in Boore's envelope shape function, accounting for stochastic Green's function method for strong ground motion prediction.

e(t)=a t^b exp(-ct), t>Ts...(6)

Tw=b/c/0.2...(7)

where t is time, the parameters a, b, and c determines the envelope shape, Ts is the arrival time of S wave. Equation (6) is fit to the envelope of observed records of each observation and from each earthquake, the unknown parameters a, b, c, and Ts being determined by the least squares method. The duration of ground motion is calculated by using equation (7).

The following results are obtained.

1. Ground motion duration strongly depends on epicentral distance.
2. Ground motion duration depends on earthquake magnitude.
3. Ground motion duration also depends on velocity structure near the observation station. Longer duration is observed for longer characteristic period of ground..
4. For earthquakes with small magnitude, ground motion duration is not so short as expected from equation (4).
5. Equation (5) better explains the observed ground motion duration.

Keywords: ground motion duration, earthquake magnitude, rupture propagation, rise time, strong ground motion prediction, stochastic Green's function