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Strong Ground Motion Evaluation for an Active Fault System by the Empirical Green Function Method

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1. Introduction

In an area with a high seismic activity, a design earthquake ground motion is generally determined empirically by investigating the historical records concerning damaging events. But it is difficult in Korea to obtain such seismic records that reflect the local characteristics because of the low seismic activity.

A geological survey on the active faults near the sites of nuclear power plants has been carried out recently, and the segmentation, slip rate and the latest activity of the fault system are partly revealed. It will be significant for the advanced seismic design of nuclear facilities to utilize the information derived from these geological investigations and evaluate the strong ground motions.

In this study, the empirical Green's function method (EFGM) was used to simulate strong ground motions from an active fault system in Korea. The source models are assumed by using the information obtained from the geological survey and the trench investigation on the fault system. Finally, the applicability of this approach to Korea was estimated.

2. Empirical Green's Function Method

The schematic illustration of the empirical Green's function method is shown in Fig. 1.

The EGFM uses the observed records of a small event which occurred near the source region as an empirical Green's function (EGF) that represents the wave-propagating path effect from the source to the earth's surface [1].

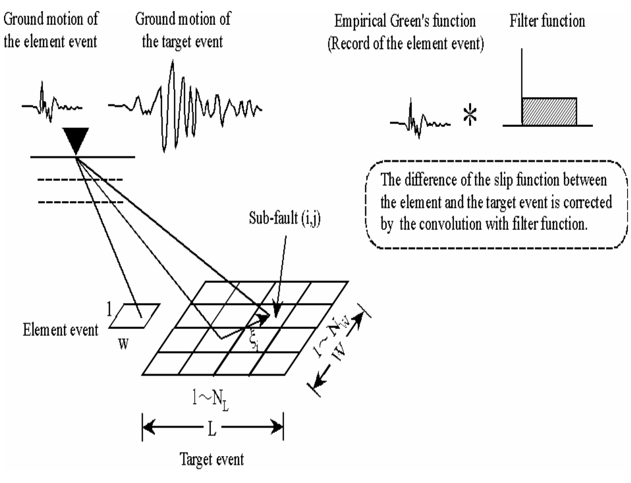

Fig.1 Empirical Green's Function Method

The ground motions from the small event are superimposed assuming that they are radiated from different points on the target fault with a delay of time according to the rupture propagation and the geometrical relation between the fault plane and the observation station, after being corrected for the difference in the slip velocity time function between the target and the small event. The EGFM provides a high-precision estimation of broadband-frequency ground motions even if sufficient knowledge about the velocity structure along the propagation path is not available, though it requires appropriate strong-motion records from small events. As for the representation of the seismic source process, we can model it with the spatial grid interval corresponding to the source size of a small (element) event. Even in the higher frequency range roughly determined by the fault length l of the element event and the rupture velocity V_r as $f > l/V_r$, the EGFM estimates the wave radiation correctly in the sense of statistics by superimposing the employed EGF, because an EGF itself holds an appropriate high-frequency energy.

When suitable element events cannot be obtained, an artificial ground motion synthesized by assuming a point source and a rather simple layered medium for the observed motions from an actual earthquake can be used [2]. This is called the stochastic Green's function method (SGFM). The SGFM requires information about the subsurface velocity structure in order to estimate the local site effect, which is not needed for the EGFM.

3. Example Evaluation

3.1 Data

In this study, the Ulsan fault system, located near the Wolsung nuclear power plant, is assumed as a hypothetical active fault system and estimated by using the empirical Green's function method

In 29 May, 2004 strong-motion data from a moderate event of Mw5.1 was obtained at several stations installed in Korea. The epicenter is about 80 km from the east coast of the Korean Peninsula and it is one of the largest events observed by the Korean Meteorological Administration (KMA) since they developed a seismic database in 1978. The focal mechanism of the 29th May event is a thrust type with east-west compression stress, which corresponds to the stress field in and around the Ulsan fault system. The fault size is rather small and the stress drop is high for this event when compared with the general scaling relations for the seismic moment [3].

Though the epicenter of the event is about 150 km away from the Ulsan fault system, we use the observed records from this event as empirical Green's functions for the target event by assuming a common local site effect. WSA is the nearest observation station from the Wolsung nuclear power plant. The strong motions from the Ulsan fault system at eight stations located within about 60 km from WSA were evaluated.

The Ulsan fault system is located near the east coast of southern Korea, and there is another clear lineament called the Yangsan fault on the west. The Yangsan fault system shows a NNE-SSW direction for the strike angle and mainly a right lateral slip, while the Ulsan fault exhibits a NNW-SSE lineament and is considered as an east-dipping reverse fault [4].

Inoue[5] indicated that the Ulsan fault system is divided into at least two segments based on the difference of the long-term slip rate, and both segments show a dip angle of 60 degrees. Following his comments, it was assumed that the length of the north fault is 22 km and that of the south fault is 24 km

As for the location of the asperities on the fault plane, there is no obvious criterion, but some researchers reported asperities tend to be located at a deeper area of the fault. And the fault rupture often starts from a rather deep position and from a non-asperity area. Considering these empirical relations we finally constructed the source models for the northern and southern segment of the Ulsan fault system as shown in Fig. 2. The projection on the distribution of the strong-motion stations is shown in Fig.3.

Fig. 4 shows the synthetic strong ground motions

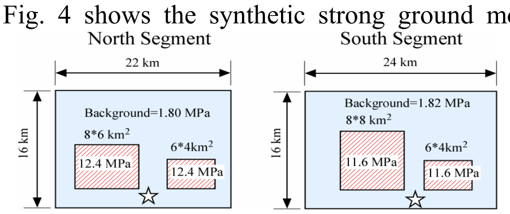

Fig. 2 Assumed Source Models for the Ulsan Fault

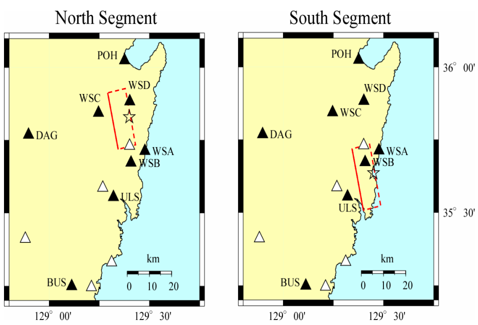

Fig.3 Locations of Assumed Seismic Faults

from the north and the south segments at WSA, which are compare with the observed motions, used as the element event for the empirical Green's functions. The S-wave motions for the two horizontal components were estimated. Circular rupture propagation with a velocity of 0.72 Vs is assumed, where Vs is the S-wave velocity in the source region defined as 3.5 km/s. The attenuation factor, Qs value, is corrected during the analysis by assuming $Q_S(f) = 254 f^{0.53}$, which is estimated from an observation in Korea by Yun et al. [6].

4. Conclusion

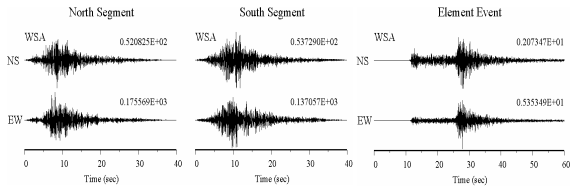

Fig. 4 Synthetic Ground Motions (left, center) and the Observed Records (right) at WSA.

The evaluated peak ground accelerations for the WSA site were within the standard deviations of the attenuation relation. For an accurate evaluation of the peak ground acceleration, an evaluation of the local site effect for the observation station is needed. The Fourier amplitude of the synthetic ground motion shows a small fall-off in the frequency range between 0.2 to 1 Hz due to an artificial phenomenon which arises when the moment ratio between the target event and the element event is too large.

A small events occurring near the source region of the target event are essential for an effective application of the EGFM.

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