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SIMULATION OF STRONG GROUND MOTION FROM THE 1994 NORTHRIDGE EARTHQUAKE USING HYBRID GREEN'S FUNCTION

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ABSTRACT

A hybrid simulation method for strong ground motion in broad-frequency band has been proposed in this study. Firstly, we estimate the ground motion from the small-events, combining the 2.5-D finite difference computation for a point source in the heterogeneous structures in the low frequency range (<1 Hz) and stochastic simulation technique in the high frequency range (>1 Hz). Finally, strong ground motion from the large events is computed by superposition of such a hybrid Green's function following the empirical Green's function method. We examine the applicability of this method in simulation for the 1994 Northridge earthquake (M_w=6.7). As a result, using this method it is possible to make strong ground motion simulation including the effects of complicated geological structures, and in broad frequency band for engineering interest.

KEYWORDS

Strong ground motion simulation; hybrid Green's function; heterogeneous structure; stochasic simulation; finite difference computation; empirical Green's function technique.

INTRODUCTION

Complete modeling of the wave-field in realistic media is extremely difficult for estimating strong ground motion in broad-frequency band for interest of engineering seismology. One technique which is used often because of advantage not necessary to compute propagation path effects is the empirical Green's function method (E.G.F. method). Disadvantage is that the records of small events occurring in the source area of the target events are needed. It is very rare to have good records of such small events, especially for future earthquakes. In this paper, we propose a hybrid method for estimating ground motions in the whole frequency range. Firstly, we estimate the ground motion from the small events, combining the 2.5-D finite difference computation for a point source in the heterogeneous structures in the low frequency range (<1 Hz) and stochastic simulation technique (Boore, 1983) in the high frequency range (>1 Hz). Finally, strong ground motion from the target events is computed by superposition of the hybrid Green's function mentioned above following the E.G.F. method by Irikura (1986). We examine the applicability of this method comparing simulation and observation from the 1994 Northridge earthquake (M_w=6.7). From the simulation using the E.G.F. method the the useful source model, which is composed of two subevents, is determined for the mainshock.

METHOD

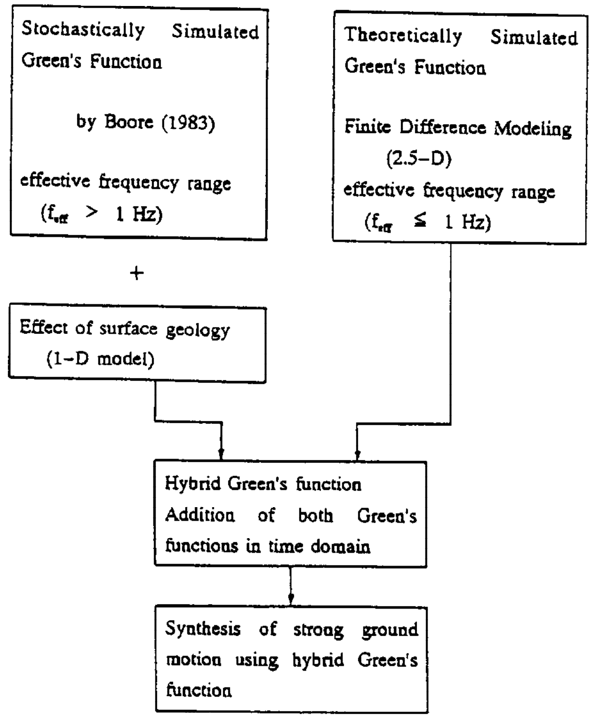

Fig.1.Flow chart of simulation methodology of strong ground motions using a hybrid Green's function.

It is very difficult to estimate theoretically strong ground motions including the effects of complicated geological structure in broad-frequency band for engineering interest. The E.G.F. method simulate successfully broad-band ground motions in cases where suitable records of actual small-events are available. From engineering point of view, we have already proposed the method in case of having no appropriate records in the objective site (Kamae et al., 1992). In this method, we used the stochastically simulated motions as semi-empirical Green's functions. Then, we could consider the local site effects by 1-D modeling. It is also necessary to estimate strong ground motion including the effects of 2-D or 3-D geological structure. In this study, we propose a new method for estimating strong ground motion in broad-frequency band. The procedure of this method is presented in Fig.1. Firstly, we simulate ground motion from a small event in high frequency range (>1 Hz) using stochastic simulation technique proposed by Boore (1983). Then, we consider the effects of local surface geology by 1-D modeling. Next, we theoretically simulate ground motion from a small event using the 2.5-D finite difference computation technique for a point source in the heterogeneous structure in the low frequency range (<1 Hz). After that, we estimate a hybrid Green's function by combining two Green's functions in time domain. Finally, we simulate strong ground motion from a large earthquake by superposition of the hybrid Green's function following the E.G.F. method proposed by Irikura (1986).

A PRELIMINARY EXAMPLE FOR APPLICATION

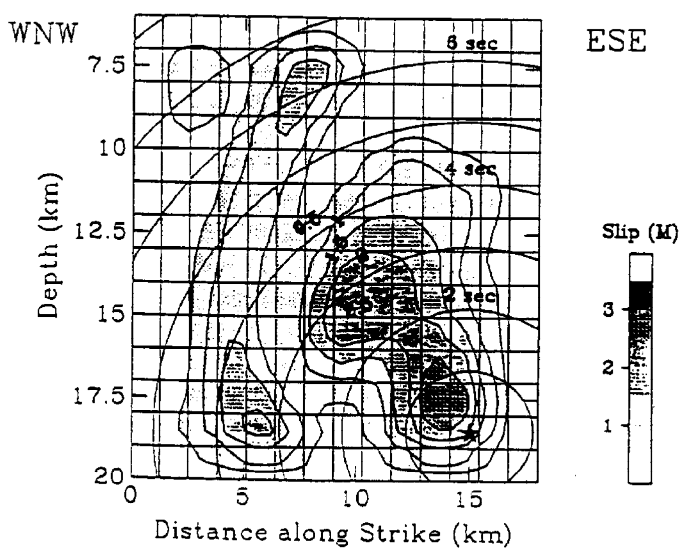

Fig.2.Cross-section of the slip distribution for the 1994 Northridge earthquake (M_w=6.7) obtained by Wald and Heaton (1994).

We examine the applicability of this method comparing simulation and observation from the 1994 Northridge earthquake (M_w=6.7). Pitalka and Irikura (1996) simulated ground motions during the aftershock and the mainshock of the 1994 Northridge earthquake using the 2.5-D finite difference technique proposed by Vidale et al. (1985) in order to investigate basin structure effects in the San Fernando valley and in the Los Angels basin. They obtained a good fitting between the synthetics and the recorded waveforms at southern sites in the mainshock simulation, while the large difference between the peak amplitudes of the recordings and the synthetics at sites north of the epicenter. They concluded that this discrepacies come from not including the rupture propagation effect because of using only two double couple point sources. In our simulation, we use their simulation result for an aftershock with magnitude 4.1 as Green's function in the low frequency range

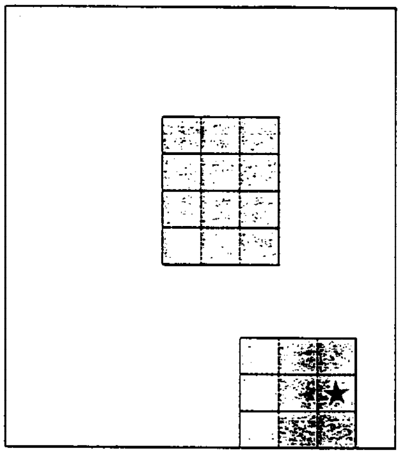

Fig.3.Source model used in this study.

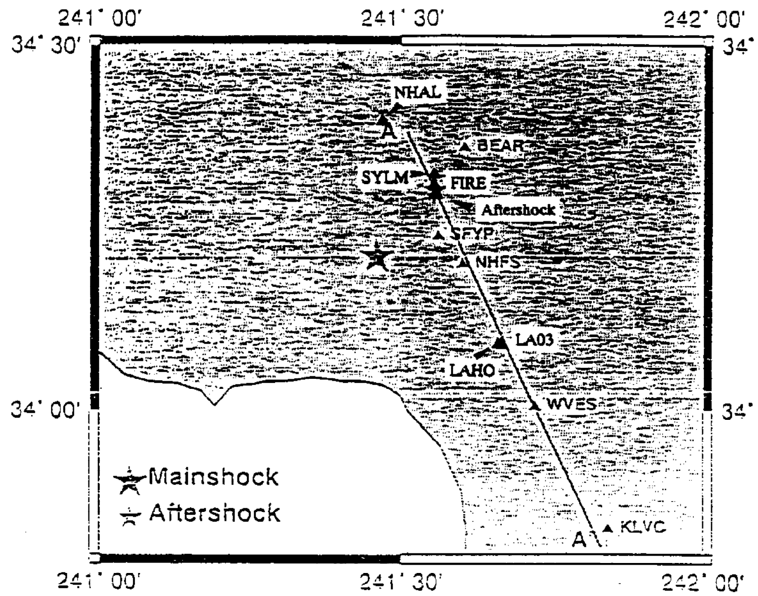

Fig.4.Locations of observation stations and epicenters of mainshock and aftershock of the 1994 Northridge earthquake.

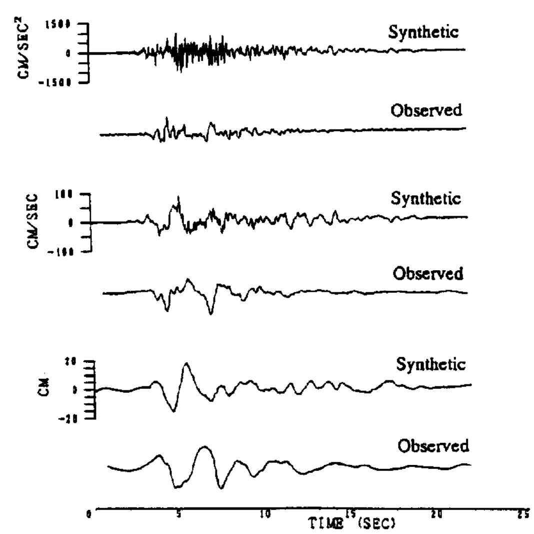

Fig.5.Comparison between observed and synthetic seismograms at SYLM station using the E.G.F. method.

(<1 Hz). On the other hand, Green's function in the high frequency range (>1 Hz) are estimated according to the Boore's method (Boore, 1983) based on the source parameters for that aftershock. We assumed a simple source model for the main–shock which is composed of two subevents based on the preliminary waveform inversion by Wald and Heaton (1994). Fig.2 shows the slip distribution obtained by Wald and Heaton (1994), and the simple source model used here is shown in Fig.3. Star mark in this figure represents the rupture starting point, and rupture extends radially from this point. The size of each element consistents with that of the aftershock used here. Strong ground motions of the 1994 Northridge earthquake and its aftershocks were recorded in a wide area from the San Fernando valley to the Los Angels basin. Firstly, we examine the validity of the source model using the E.G.F. method. We simulate strong ground motion at SYLMAR (SYLM) station using the record of the aftershock with magnitude 4.1 at FIRE station where was temporarily installed near SYLM station shown in Fig.4. Because we could not obtained any records for aftershocks at SYLM station. Fig. 5 shows the comparison of the synthetics and the recordings. It appears that we can roughly simulate the strong ground motion by means of the simple source model used here. The reason for discrepacies of the high frequency components may be attributed to taking no account of the difference in the local site effects between SYLM and FIRE stations. Next, we tried to simulate the strong ground motion during the main–shock at NEWHALL (NHAL) station located in northern part of the epicenter using a hybrid Green's function. In order to estimate the effects of local surface geology in the high frequency range at NHAL station, we assumed 1–D structure model by referring the microtremore observation results. Fig 6 shows the 1–D model assumed here and its amplification function. Fig.7 shows the fourier spectra for stochastically simulated motion including the effect of surface geology in higher frequencies than 1 Hz and for numerically simulated motion based on the 2.5–D modeling in lower frequencies than 1 Hz. After combining these motions in time domain, we can obtain the

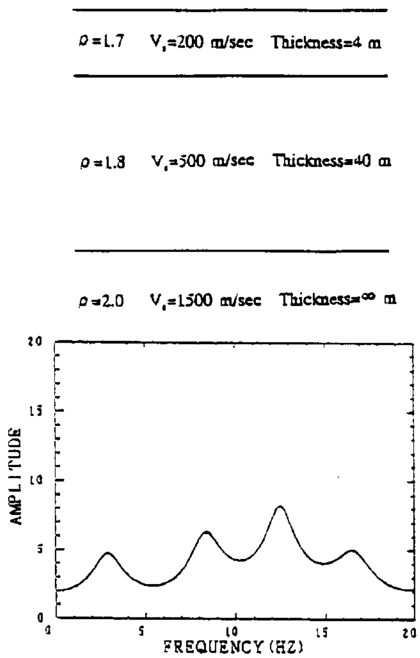

Fig.6.1–D modeling and its amplification function at NHAL station.

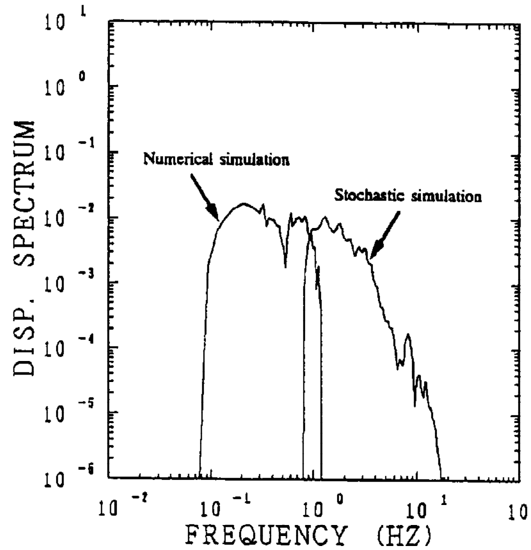

Fig.7.Fourier displacement spectra for hybrid Green's function.

hybrid Green's function as shown in Fig.8. We synthesized the strong ground motion during the main–shock at NHAL station using this hybrid Green's function. Fig.9 shows the comparison of the synthetics and the recordings. We can see that the synthetics are agreement with the recordings in the duration time and the peak amplitudes, althogh the waveforms are not in detailed agreement with each other.

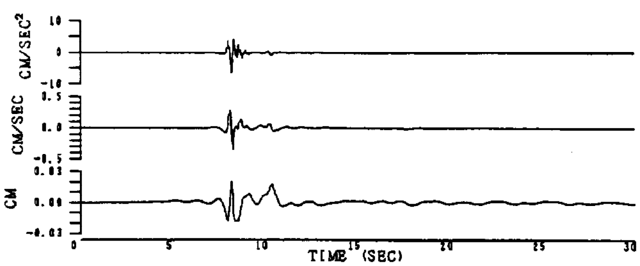

Fig.8.Hybrid Green's function

CONCLUSIONS

It is extremely difficult to estimate strong ground motion in broad frequency band based on the complete modeling of the wave–field in realistic media. In this paper, we proposed a hybrid simulation method for estimating ground motions from small events, combining the 2.5–D finite difference computation for a point source in the heterogeneous structures in the low frequency range (<1 Hz) and stochastic simulation technique including the effects of local surface geology in the high frequency range (>1 Hz). The strong ground motion from the large event is computed by superposition of the hybrid simulation result for the small event following the E.G.F. method. We examined the applicability of this method comparing synthetics and recordings from the 1994 Northridge earthquake (M_w=6.7). As a result, the

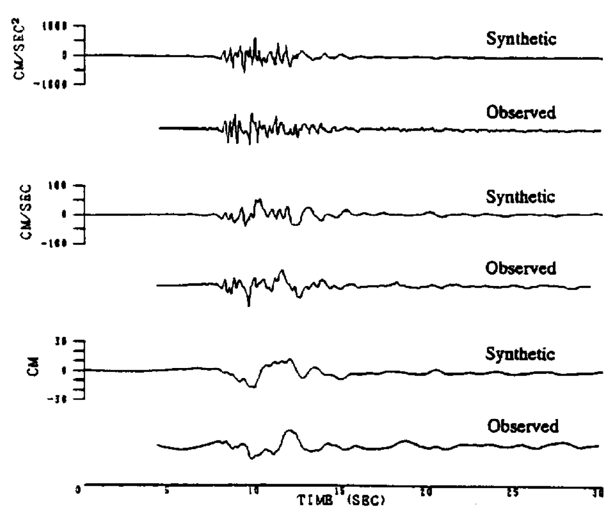

Fig.9.Comparison between observed and synthetic seismograms at NHAL station using hybrid Green's function.

simulation using this method gives better agreement with observation in broad frequency range. Simulations will be performed using this method for different sites, using the revised fault model in order to verify the validity of this method.

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