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SIMULATION OF STRONG GROUND MOTION FROM THE 1993 NOTO-HANTO-OKI EARTHQUAKE COMBINED EMPIRICAL GREEN'S FUNCTION METHOD WITH STOCHASTIC SIMULATION METHOD

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ABSTRACT

We applied the empirical Green's function method to simulate strong ground motion during a large earthquake. The purpose of this study is to examine the applicability of the method for evaluating input motion for the earthquake resistant design of structures. There are two ploblems to improve for its practical application. One is a case where observed records from small events are significantly affected by the directivity effect different from the target event. We propose a method to correct the directivity effect contained in the empirical Green's function and comfirm its effectiveness. The other is a case where we have no appropriate records from small events occurring near the target source area. We develope an extended method that combined the empirical Green's function method with the stochastic simulation method. This extended method is effective to estimate PGA, PGV and response spectrum.

KEYWORDS

Strong ground motion, The empirical Green's function method, The stochastic simulation method, 1993 Noto-Hanto-Oki Earthquake, Directivity effect

INTRODUCTION

The empirical Green's function method has a great advantage to take the complex path and site effects into account for synthesizing strong ground motions from large earthquakes. But there are some problems to apply it practically to evaluate input motion for the earthquake resistant design of structures. There are two problems to improve for its practical application. One is that, if the seismograms from the small event are significantly affected by the directivity effect different from the target event, simulated motions would be either overestimated or underestimated. We propose a method to correct the specific directivity effect with respect to the small event. The other is that we often have no appropriate records from small events occurring near the target source area. Then the stochastic simulation method is used for estimating the small event records. We examine the applicability of the extended method that combined the empirical Green's function method with the stochastic simulation method by applying it to simulate strong ground motion during the target earthquake.

METHOD AND DATA

Case1:Apply the Empirical Green's Function Method to the Noto-Hanto-Oki Earthquake

On February 7 in 1993, an earthquake with JMA(Japan Meteorological Agency) magnitude 6.6 broke out off the coast of Noto peninsula. Wajima was shaken with the JMA Intensity V, Kanazawa and Toyama, with the intensity IV, and Takada,with the intensity III. This earthquake was named "Noto-Hanto-Oki earthquake". Fig.1 shows locations of four JMA stations and the mainshock epicenter. The empirical Green's function method (Irikura,1986) is applied to simulate ground motions from the mainshock at four sites (Wajima, Kanazawa, Toyama, Takada). The empirical Green's functions are the records from an aftershock with JMA magnitude 5.0 occurring near the mainshock. The applicability of the method is examined by comparing simulated ground motions with observed records from the mainshock.

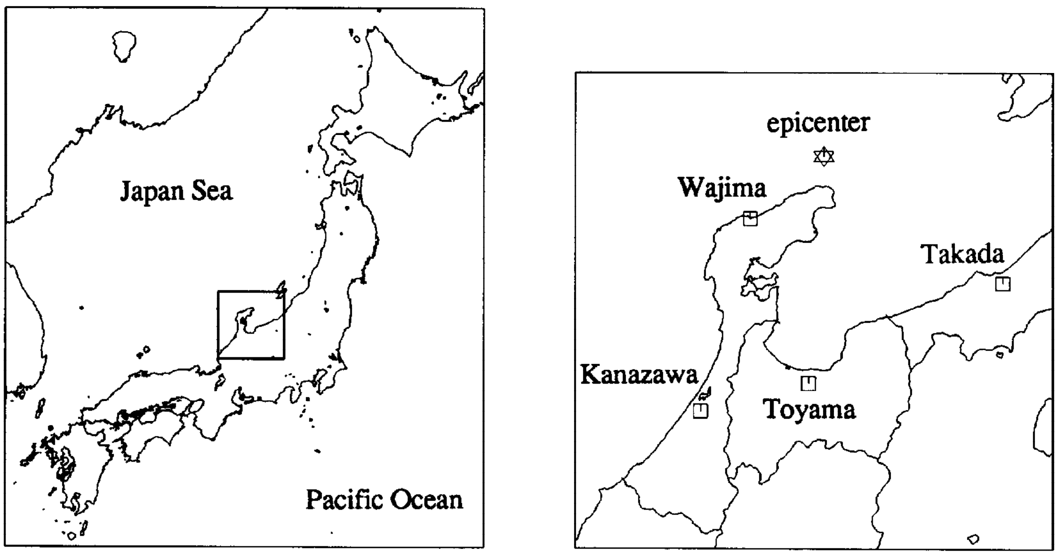

Fig.1. Locations of four JMA stations and mainshock epicenter

Case2:Correct the Directivity Effect Contained in the Aftershock Records

Some aftershocks have directivity effect different from the target earthquake. It is desirable that the empirical Green's function in this method is approximated to be a ground motion from a point source without being influenced by the source process of the small event. Therefore, we examine a method to correct the specific directivity effect contained in the aftershock records. An extended method to correct the directivity effect contained in the aftershock records is here tesed. The directivity effect for a finite line-segment fault is givin by Ben-Menahem (1961) as follows (Fig. 2).

$$Zc=(\sin Xc / Xc)\, e^{-iXc} \tag{1}$$

$$Xc=(\omega L / 2c)\ \{(c / Vr)-\cos\theta\} \tag{2}$$

where, ω : Angular frequency, L : Fault length (km), c : Velocity of shear wave (km/sec), Vr : Velocity of rupture propagatation (km/sec), θ : Azimuthal angle to object site from direction of rupture propagatation (degree)

It is considered that θ =0(degree) in case of the aftershock and θ =90 (degree) in the case of mainshock at Takada.

$$F'(\omega)=F(\omega)\ \{Zc(\theta=0) / Zc(\theta=90)\} \tag{3}$$

where, $F'(\omega)$: Fourier spectrum of the empirical Green's function after the directivity effect is corrected, $F(\omega)$: Fourier spectrum of observed record, $Zc(\theta=0)$: Zc when $\theta=0$, $Zc(\theta=90)$: Zc when $\theta=90$
The waveform in time domain is obtained by inverse Fourier transform $F'(\omega)$.

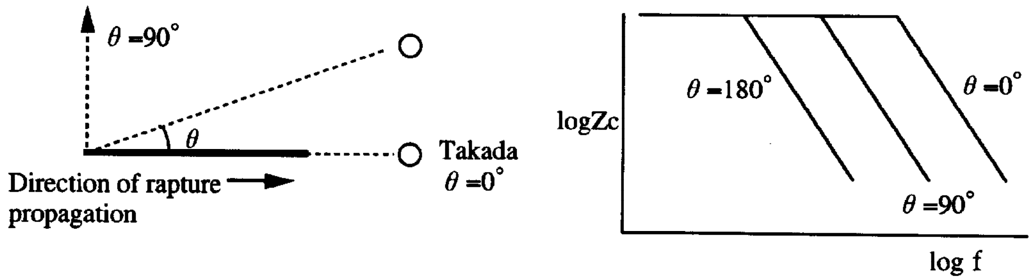

Fig.2. Image of correcting directivity effect

Case3:Combine the Empirical Green's Function Method with the Stochastic Simulation Method

Synthetic motions from magnitude 5.0 event at rock sites are calculated by the stochastic simulation method (Boore,1983) likewise Kamae *et al.*(1991). Site effects for soft-sediment sites are evaluated by spectral ratios between the sediment and rock sites. Then the magnitude 5.0 ground motions at sediment sites convolving the rock motions with the site effects is obtained. The ground motions from the target large event are estimated using the synthetic motions instead of observed records from small events.

RESULT

Case1:Apply the Empirical Green's Function Method

Figure 3 shows comparison of the observed velocity records from the mainshock with synthetic motion using the records from the aftershock as the empirical Green's function. The velocity waveform from the mainshock is obtained integrating observed acceleration records. The simulated ground motions agree well with the observed ones at Wajima, Kanazawa and Toyama in maximum velocity value and envelope of velocity waveform. However, it is overestimated at Takada, probably because of the directivity effect of the aftershock records.

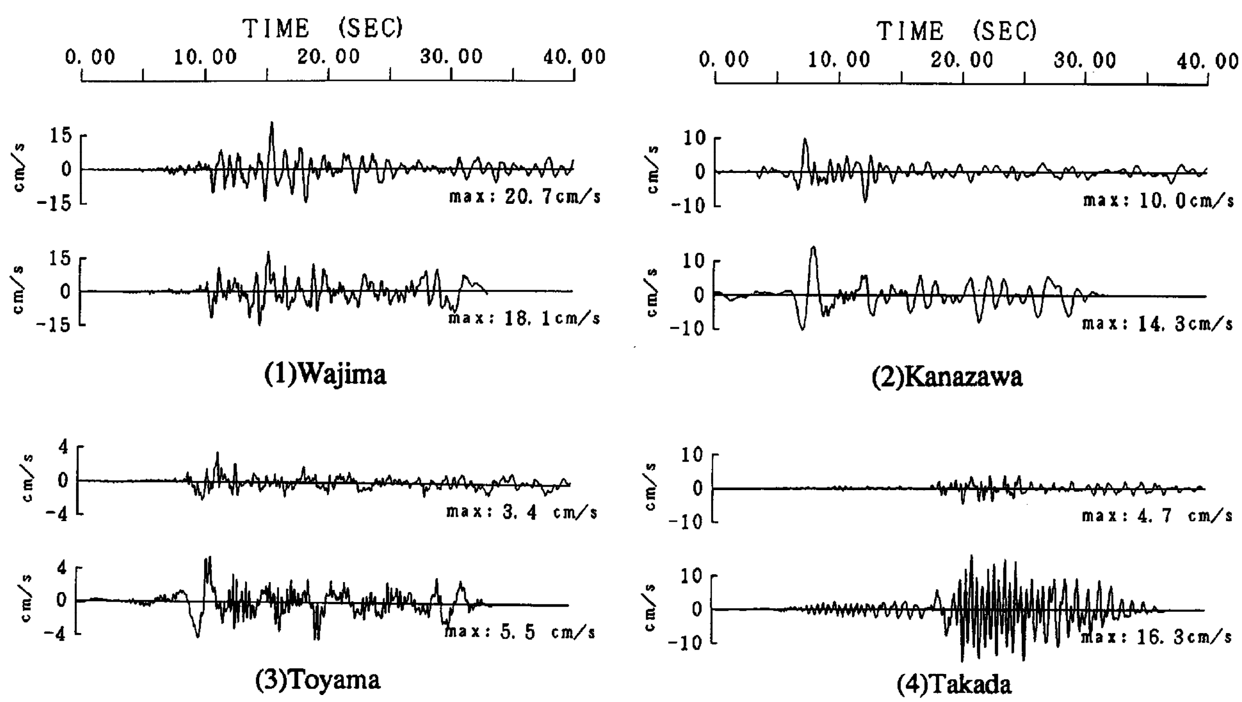

Fig.3. Comparison velocity waveform (Upper : Observed, Lower : Synthesized)

Case2:Correct the Directivity Effect Contained in the Aftershock Records

Figure 4 and 5 show comparison between velocity waveform and pseudo velocity response spectrum of the observed records from the mainshock and those of synthetic motion using the corrected record givin by (3) to correct the directivity effect as empirical Green's function at Takada. The damping coefficient in response spectrum is 0.05. We find that the agreement between the simulated motion and the observed record from the mainshock become better by correcting the directivity effect contained aftershock record.

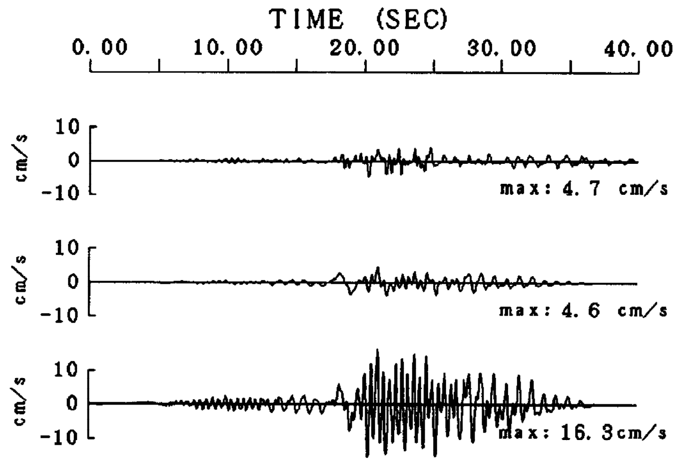

Fig.4. Comparison velocity waveform at Takada
Upper : Observed
Center : Synthesized(Using Corrected aftershock record)
Lower : Synthesized(Using Non-corrected aftershock record)

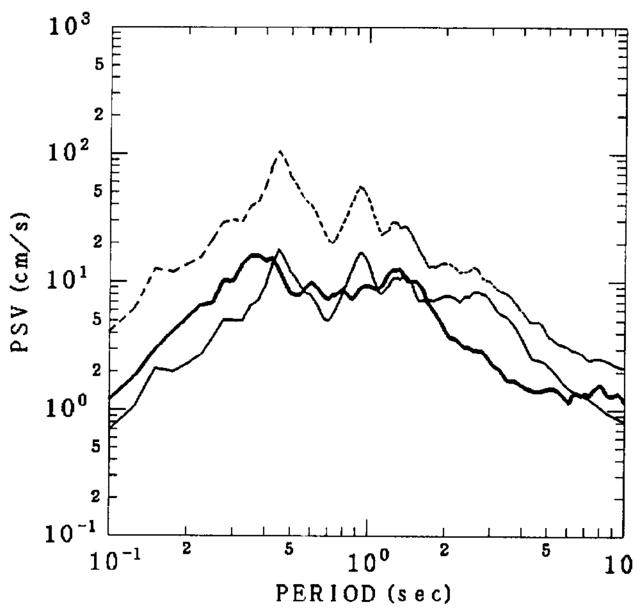

Fig.5. Comparison pseudo velocity response spectrum at Takada
—— : Observed
—— : Synthesized(Using Corrected aftershock record)
----- : Synthesized(Using Non-corrected aftershock record)

Case3:Combine the Empirical Green's Function Method with the Stochastic Simulation Method

Figure 6 and 7 show comparison between velocity waveform and pseudo velocity response spectrum of the observed records from the mainshock and those of the synthetic motion using stocahatically simulated small event motion at wajima. The simulated ground motions match well the observed one not only in maximum velocity value but also in pseudo velocity response spectrum. However, good agreement in envelope of velocity waveform and duration time cannot be obtained. Same results are obtained at Kanazawa, Toyama, Takada.

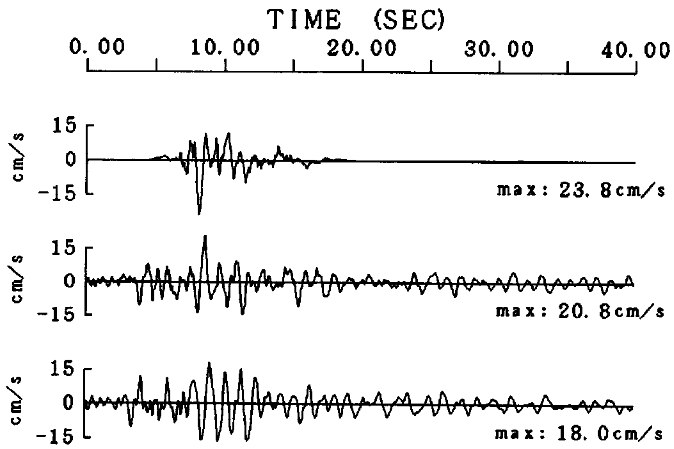

Fig.6. Comparison velocity waveform at Wajima
Upper : Synthesized(Using the simulated small event record)
Center : Observed (East-West Direction)
Lower : Observed (North-South Direction)

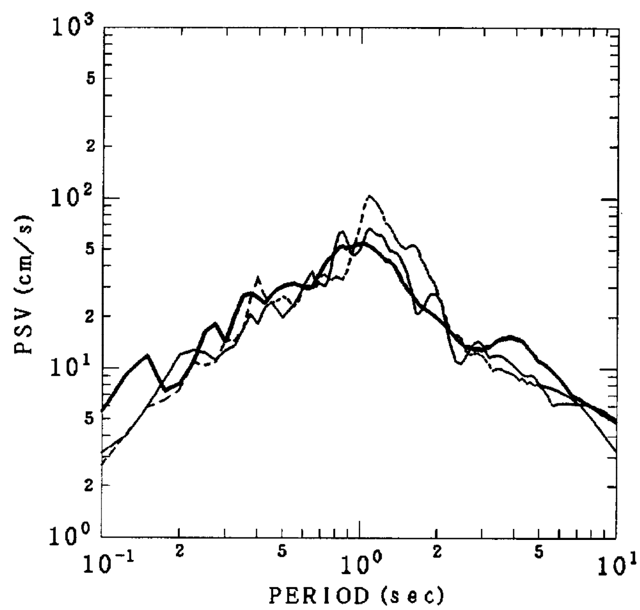

Fig.7. Comparison pseudo velocity response spectrum at Wajima
—— : Synthesized(Using the simulated small event record)
—— : Observed (East-West Direction)
----- : Observed (North-South Direction)

CONCLUSIONS

We applied the empirical Green's function method to simulate strong ground motion during a large earthquake. The purpose of this study is to examine the applicability of the method to evaluate input motion for the earthquake resistant design of structures. We find the following results.

1)It is reconfirmed that the empirical Green's function method has a great advantage to simulate strong ground motions from large earthquakes.

2)There are some problems to apply the method practically to evaluate input motion for the earthquake resistant design of structures. One is that, if the seismograms from the small event are significantly affected by the directivity effect different from the target event, simulated motion would be either overestimated or underestimated. We propose a method to correct the directivity effect contained in the empirical Green's function and comfirm its effectiveness.

3)The other is that we often have no appropriate records from small events occurring near the target source area. We propose an extended method that combine the empirical Green's function method with the stochastic simulation method. The method was applied to evaluate the storong motion from the Noto-Hanto-Oki earthquake, we find that it is effective to estimate maximum value of ground motion and response spectrum. However, some problems remain in the future such as envelope of waveform and duration time.

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