Study on the near-field ground motion of Fukuoka earthquake by the method of computing Green's functions for a layered half-space

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Abstract

The slip distributions on the fault, the source rupture process and the other seismic parameters of Fukuoka earthquake determined by Japan researchers are accepted in this paper. The station Genkai is chosen as a site to analyze the Fukuoka Earthquake wave in near field by using the Green's function method for a layered half-space. A comparative study of the acceleration time history of the calculated results and records are carried out. The waveforms of the calculated results are in good agreement with those of the observed records at the station Genkai, and the peak values in the calculated results are close to that of the records. The Fourier spectra of the calculated acceleration time history are basically identical with those of the records while the frequency is below 5. Some useful conclusions are drawn that the near-field ground motion of Fukuoka earthquake can be effectively estimated by the method of computing Green's functions for a layered half-space in the condition of the uniform geologic site. The seismic parameters of Fukuoka earthquake are helpful to study the near-field and far-field ground motions and the influence on eastern China including Shanghai.

Key words: Fukuoka earthquake, Green's function, near-field, ground motions

Introduction

Based on the strict theoretical derivation and calculation seismology, the method of computing Green's functions for a layered half-space is used for the synthesis and prediction of the earthquake ground motion. The propagation of seismic wave is represented by Green's function, and the calculation model is established by the structure of the earth crust of the site in the method. The calculation model is established by the method of computing Green's functions for a layered half-space. And the seismic source is expressed by shear dislocation dipole source. It is more strict then the stochastic method by considering the fault and the upper crustal structure. Without considering the discontinuity of the stress and body force, the elastic displacement of the both sides of fault interface caused by displacement discontinuity can be summarized in the following equation (Aki and Richards, 1980):

$$u_k(x,t) = \int_{-\infty}^{+\infty} d\tau \iint_{\Sigma} [u_j(\zeta,\tau)] c_{jkpq} \upsilon_k G_{ip,q}(x,t,\zeta,\tau) d\Sigma(\zeta) \tag{1}$$

in which c_{jkpq} is elastic modulus of the fault, and υ_k is the cosine of normal direction of the fault plane, and $G_{ip}(x,t,\zeta,\tau)$ is the path effect between a point ζ on the fault and the observation point x, and $G_{ip,q}(x,t,\zeta,\tau)$ is the G_{ip}'s partial derivative to ζ_q.

It is difficult to compute Green's functions for layered half-spaces with sources and receivers at nearly equidistant depths, because their integrands oscillate with slowly decreasing and increasing amplitudes for displacements and stresses, respectively. To remedy this problem, Luco and Apsel (1983) proposed an asymptotic technique, in which we subtract asymptotic solutions from the integrands and integrate them analytically, and numerically integrate the remaining integrands. These procedures can be summarized in the following equation:

$$G = \int_0^{+\infty} \{(V - \tilde{V})b_1 + (H - \tilde{H})b_2\} dk S + \Delta\tilde{V} + \Delta\tilde{H} \tag{2}$$

where G is a displacement or stress Green's function, b_j is a Bessel function, S is a sinusoidal function, k is the horizontal wavenumber, and V and H are displacement-stress vectors for P-SV and SH waves, respectively. $\tilde{V}$ is the asymptotic solution to V as k goes to infinity, $\Delta\tilde{V}$ is the analytical integration corresponding to V. $\tilde{H}$ and $\Delta\tilde{H}$ are those for *SH* waves.

However, Hisada (1994) found that the convergences of the asymptotic solutions are rather slow, when sources and/or receivers are very close to layer boundaries, because the reflected waves from the boundaries are not included in the solutions. Hisada (1995) derived the analytic asymptotic solutions of the direct, reflected, and transmitted waves from layer boundaries and showed the procedure for computing Green's functions due to point and dipole sources.

An earthquake with magnitude M_S 7.0 occurred in the West Off Fukuoka Prefecture earthquake, which is occurred in Kyushu, Japan, at 10:53 (JST) on March 20, 2005 (Xinhua news Agency, 2005). The epicenter is about 930-kilometer apart from Shanghai. The dwellers in high-rise buildings in the Southeast of Shanghai can feel the earthquake (Sheng Yueming and Dong C., 2005). This earthquake has received high attention from seismologists in Japan. A complete research is make on the source rupture process, attenuation relationship, site condition and the effect on KYUSHU, JAPAN. Source rupture process was estimated by the linear waveform inversion using multi time-windows. Total seismic moment is $1.15\text{x}10^{19}$Nm (M_W6.6). Maximum slip and average slip are 3.2m and 0.8m, respectively (Asano and Iwata, 2006).

The slip distributions on the fault, the source rupture process and the other seismic parameters of the Fukuoka earthquake determined by Japan researchers are accepted in the paper. The station GENKAI is chosen as a site to analyze the Fukuoka Earthquake wave in near field by using the Green's function method, and this research will contribute to the evaluation of the effect of Fukuoka earthquake in eastern China.

Synthesis of Fukuoka Earthquake wave in near field by using the Green's function method

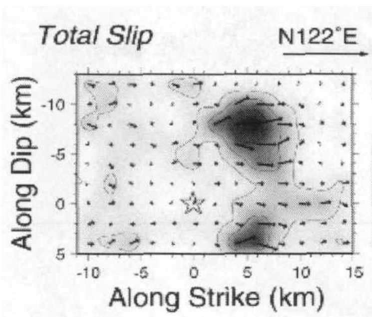
Observed digital acceleration data are integrated into the ground velocities in the time domain and bandpass filtered with a Chebyshev filter between 0.05 and 1.0 Hz. Asano and Iwata (2006) inverted 16 s of the S-wave portion from 1 s before the direct S-wave arrival. Theoretical Green's functions are also bandpass filtered in the same manner (Asano and Iwata, 2006).

Table 1 Seismic parameters of Fukuoka Earthquake (Asano and Iwata, 2006)

Strike φ/(°)	Dip λ/(°)	M_w /dyne cm	L×W /km	Δσ/bar	Depth /km	$\bar{D}$ /m
122	87	1.15×10^{26}	26×18	8.7	14	0.8

The rupture front propagation velocity, which triggers the rupture of the first time window, was selected to be 2.1 km/s. This is approximately equal to 60% of the shear-wave velocity at the depth of the rupture, that is a little slower than the average rupture velocity (72%) of shallow crustal earthquakes empirically obtained by Geller (1976).

Data at nine stations of the K-NET and seven stations of the KiK-net are used for the waveform inversion (see Fig.1). Fig.2 shows the final slip distribution on the fault surface estimated by the inversion.



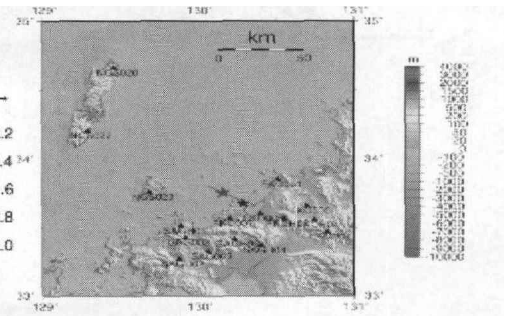


Fig. 1 Map showing stations and the epicenter (Asano and Iwata, 2006)

Fig. 2 Final slip distribution of the mainshock estimated from the inversion. The open star indicates the rupture starting point. The arrows show the slip vectors of the hanging wall relative to the foot wall. The interval of contours is 0.8 m (Asano and Iwata, 2006).

According to Fig.1, the parameters of seismological station GENKAI in near field are listed in Table 2.

Table2 Parameters of station FKOH09 (NIED,2005)

Station name	Latitude	Longitude	Altitude (m)	Depth (m)
GENKAI	33.85	130.55	25	200

We divided the fault plane into subfault of 2km × 2km. The slip at each subfault is represented by the 6 time windows, and basis function of each time window is smoothed ramp function. The risetime of one time window is 1.0 s, and time window interval is 0.5 s. The final slip distribution of the mainshock in Figure 2 is used to synthesize the ground motion in the paper.

The site condition parameters of GENKAI are listed in Table 3.

Table 3 Site condition at station GENKAI (NIED*, 2005)

Soil layer	Thickness (m)	Density(t/m^3)	P-wave Velocity Section (m/s)	S-wave Velocity Section (m/s)
Rock	Infinite	2.65	5500	3000

The S wave quality factor is obtained as Q_S=300.

We obtain the source parameter and site condition at station GENKAI, which can be directly applied to the method of computing Green's functions to synthesize the ground motion in the near-field (Wudi, 2008). Figure 3 and Figure 4 shows the observed acceleration (solid line) and synthesized (broken line) of main shock in NS direction at station GENKAI.

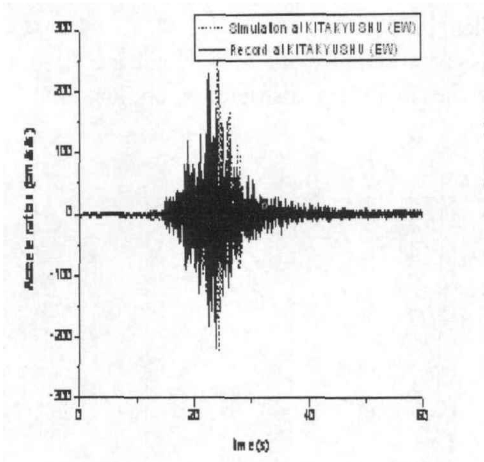


Fig. 3 Observed acceleration and synthesized acceleration of main shock in NS direction at station GENKAI

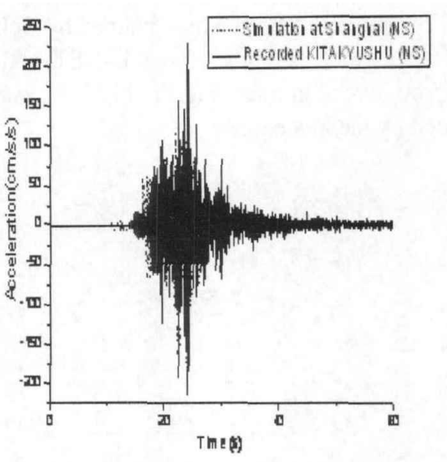


Fig. 4 Observed acceleration and synthesized acceleration of main shock in EW direction at station GENKAI

Fig.3 and Fig.4 show that the result obtained from the synthesized results are consistent with the observed acceleration. Table 4 shows the observed and synthesized peak accelerations at the station GENKAI.

Table 4 Observed and synthesized peak accelerations at the station GENKAI (Gal)

	NS	EW
Observed	228.31	228.34
Synthesized	179.73	244.00

Fig.5 and Fig.6 shows the Fourier amplitude spectrum of the observed (solid line) and synthesized (broken line) accelerations of the main shock at station GENKAI.

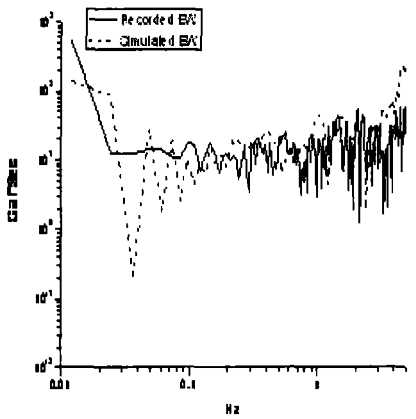


Fig. 5 Fourier amplitude spectrum of the observed (solid line) and synthesized (broken line) accelerations of the main shock in NS direction at station GENKAI

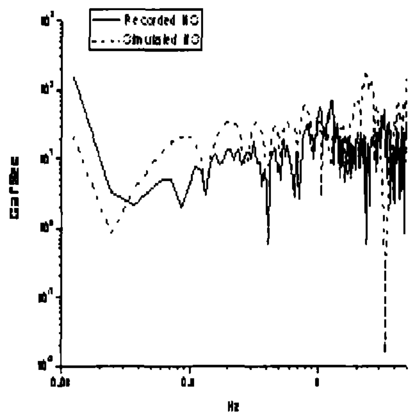


Fig. 6 Fourier amplitude spectrum of the observed (solid line) and synthesized (broken line) accelerations of the main shock in EW direction at station GENKAI

Fig.3 and Fig.4 show that when the frequency is lower than 5 Hz, the Fourier amplitude spectra of synthesized accelerations at station GENKAI are consistent with those of the observed accelerations of the main shock.

Conclusions

The slip distributions on the fault, the source rupture process, the site conditions in near field and the other seismic parameters of Fukuoka earthquake determined by Japan researchers are researched in the paper. The Green's function method for a layered half-space is used to synthesize the near field ground motion of Fukuoka Earthquake at the station Genkai. Some conclusions could be inferred from the synthesized accelerations of Fukuoka earthquake.

1. The waveforms of the calculated results are in good agreement with those of the observed records at the station Genkai, and the Peak Values in the calculated results are close to that of the records.

2. The Fourier spectra of the calculated acceleration time history are basically identical with those of the records while the frequency is below 5. A conclusion is draw that the near-field ground motion of Fukuoka earthquake can be effectively estimated by the method of computing Green's functions for a layered half-space in the condition of the uniform geologic site.

3. The source parameters, the site conditions in near field and the other seismic parameters of Fukuoka earthquake accepted in the paper are accord with the fact. Consequently, the near-field ground motion of Fukuoka earthquake can be effectively estimated by the method of computing Green's functions for a layered half-space. The seismic parameters of Fukuoka earthquake are helpful to study the near-field and far-field ground motions and the influence on eastern China including Shanghai.

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