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Prediction of strong ground motions due to earthquake faulting in Japan

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ABSTRACT; The objective of this paper is to present an improved method for synthesized ground motion by taking the actual focal process into consideration. As an example, this improved method is applied to the ground motion that was due to the Izu–Oshima–Kinkai Earthquake of 1987, and also the Tokachi–Oki Earthquake of 1968. The results are then compared with the actual observed record. Moreover, in the case of the Tokachi–Oki Earthquake, a simple five–division model is proposed, pointing out the advantages of this improved model. Finally, using the proposed five–division model, ground motion is predicted for the Tokai, Kwanto, and Edo Earthquake at the center of Tokyo, where actual observed data dose not exist.

1 INTRODUCTION

Japan is characteristically subjected to seismic activity; therefore, it is a matter of concern how building structures behave under earthquake conditions. Currently, the research focus for a seismic design method has been changed from static analysis to dynamic analysis. In actuality, however, there are no standardized earthquake waveforms used as fundamental data. Therefore, thorough investigation should be conducted during the design phase of the structure to determine what type of earthquake waveforms are to be used for the design of building structures constructed on various ground types.

Recently, many trials have been conducted using realistic earthquake input to the structures, including, among others, pseudo–ground motions and superposition of many seismic waves from aftershocks, etc (Hartzell S. 1978, Irikura K. 1983).

In this study, we propose an improved method for synthesized ground motions, by taking the focal process into consideration. In addition, this method was used to predict the ground motion of the Tokai, Kwanto, and Edo Earthquake, where actual data does not exist.

2 CALCULATION METHOD

In order to obtain more realistic ground motions, the calculation is performed using the following assumptions:

1)earthquake occurrence is due tofault formation within the earth,

2)sources which radiate strong seismic waves are localized on the fault plane,

3)the fault plane is located in the multiple layers,

4)the main components of earthquake ground motion are S–waves, their reflected phases, and the surface waves.

The synthesis of body and surface waves are conducted separately, and then combined. The body wave is calculated exactly using the expression given by Kawasaki and Suzuki (1973), and the surface wave using the method developed by Takeuchi and Saito (1972). Figure 1 shows the seismic wave path from each strong radiation source to the observation site.

Displacement, $U_A^{k,m}$, at point A due to this source can be calculated exactly with the expression given by Sato (1975). The transfer function, h_A, of the mid-point between A and the ground surface is computed by the Haskell Method (1960). Convolution of $U_A^{k,m}$ with h_A, gives the ground motion, $U_k(t)$, due to the k–th source and m–th layer as follows;

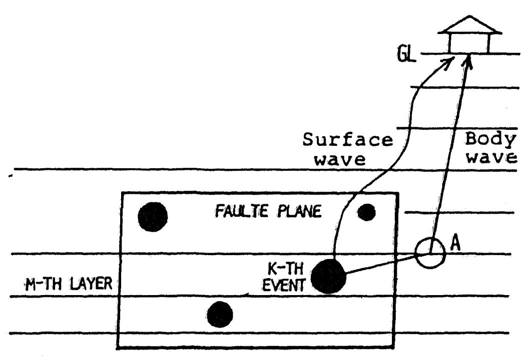

Figure 1. Seismic wave path from source to observation point.

$$U_k(t)=U_A^{k,m}(t)*h_A \qquad (1)$$

Thus, the predicted ground motion, U(t), is obtained by a summation of the contributions from all sources:

$$U(t)=\sum_{k=1}^{N} U_k(t) \qquad (2)$$

where N is the total number of sources.

Also, synthesis of the surface wave is performed using the method developed by Saito (1972).

3 COMPARISON OF CALCULATED AND OBSERVED RECORD

This proposed analytical method is applied to the ground motion that was due to the Izu-Oshima-Kinkai Earthquake of 1978 (M=6.8), and Tokachi-Oki Earthquake of 1968 (M=7.9). The results were then compared with the observed record. Table 1 shows each earthquake parameter. Figure 2 shows each fault pla- location and observation point in Japan.

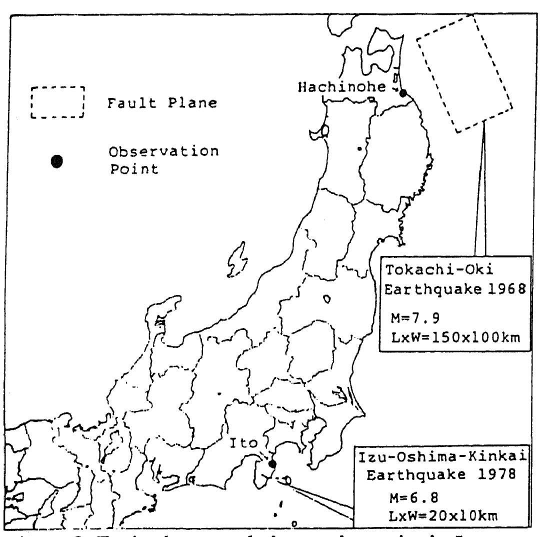

Figure 2. Fault planes and observation point in Japan (Izu-Oshima-Kinkai and Tokach-Oki Earthquake).

<u>Izu-Oshima-Kinkai Earthquake</u>

Figure 3 shows fault plane location and the observation point in Ito. The Izu-Oshima-Kinkai Earthquake of 1978 involved right lateral strike slip motion together with a small dip component on a steeply northward dipping fault. The observation point (Ito) is located at the northern part about 24 km from this fault plane (Shimazaki K. 1978). This earthquake consisted of two parts, one in an E-W direction and the other in a NW-SE direction. But the NW-SE direction fault is omitted for purposes of simplification in this study. The ground structure model used the Izu-Peninsula region model proposed by Kudo (1978).

Figure 4 shows the EW component of both the synthesized acceleration wave , obtained by the method and procedures mentioned above, and the observed accelerogram in the Ito region. The synthesized accelerogram agrees qualitatively and quantitatively with the observed one.

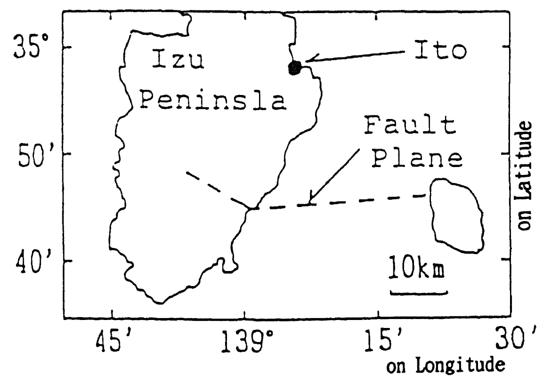

Figure 3. fault plane and observation point (Izu-Oshima-Kinkai Earthquake of 1978).

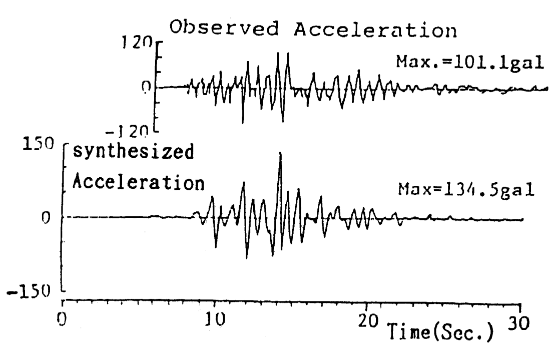

Figure 4. Synthesized and observed acceleration in Ito region(EW component).

Figure 5 shows the response velocity spectrum calculated from the above acceleration waves. The peak period and the value of each spectrum is identical.

<u>Tokachi-Oki Earthquake</u>

Figure 6 shows the fault plane (dotted line, Kanamori H. 1971) and the observation point in Hachinohe. Kikuchi (1984) pointed out that this earthquake focal process constituted four main point sources, as seen in Fig. 6. In this study two models are used:

Table 1. Earthquake source paramenters.

	Dimension	Izu-Oshima Kinkai	Tokachi Oki	Kwant	Tokaio	Edo
Fault length	km	20	150	95	115	40
Fault width	km	10	100	54	70	30
Dip-angle	deg.	85	20	25	34	20
Slip-angle	deg.	188	38	140	71	-20
Strike direction	deg.	N 90W	N 156W	N 66W	N 162W	N 45W
Dislocation	cm	-----	410	480	400	200
Seismic moment	dune·cm	$8.8X10^{26}$	$2.8X10^{28}$	$8.4X10^{27}$	$1.6X10^{28}$	$2.24X10^{26}$
Magnitude		6.8	7.9	8.0	8.0	6.9±1
Rupture velocity	km/sec.	2.8	3.5	2.0	2.1	2.5
Rise time	sec.	2.0	-----	5.0	5.0	5.0
Depth	km	8.0	7.1	23.0	20.5	20.0
Stress drop	bars	----	150	45	----	----
Model proposer		Shimazaki (1978)	Kanamori (1971)	Matsuura (1980)	Ishibashi (1981)	Kawasaki Matsuda(1987)

one that is proposed by Kikuchi (Kikuchi models 1985), and the second model that is divided into five equal seismic moments(five-division model). The five-division model is simpler than the Kikuchi model, because in the Kikuchi model contains is a distribution of twenty points sources on the fault plane. The ground structure model proposed by Tanaka has been used (1976).

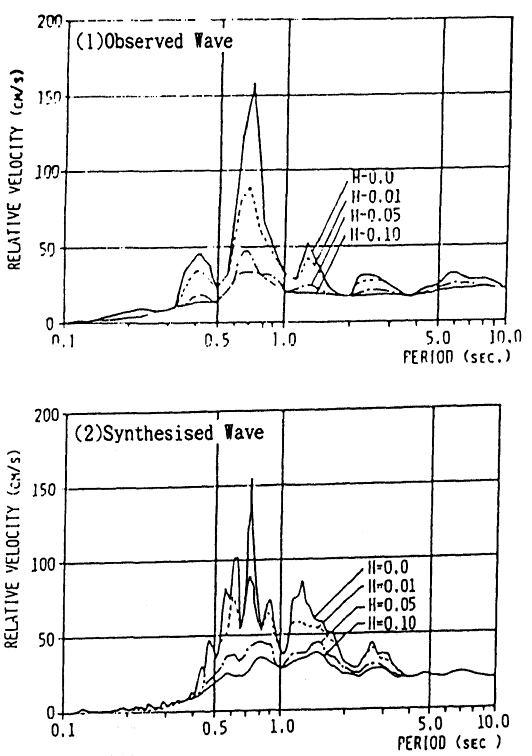

Figure 5. Response spectrum of synthesized and observed wave(EW component).

Figures 7(a),(b),(c) show observed acceleration, velocity, and displacement wave in the Hachinohe region EW component (Fig.7 a), synthesized ground motion calculated by the Kikuchi model (Fig.7 b), and the five-division model (Fig.7 c). In the synthesized ground motion calculated by the Kikuchi model there are two large wave groups in the acceleration and velocity results. The first wave group can explain the observed data, but the second wave group cannot. The second wave group occurred at position 2 in Fig. 6, and Ishida (1976) pointed out that the main parts of earthquake ground motion from the position 2 are SV-waves.

Figure 8 shows the response spectrum calculated from the above acceleration waves. As seen in Figs.7(c) and 8, synthesized ground motion determined from the five-division model explains the observed data very well, even though it is a very simple model.

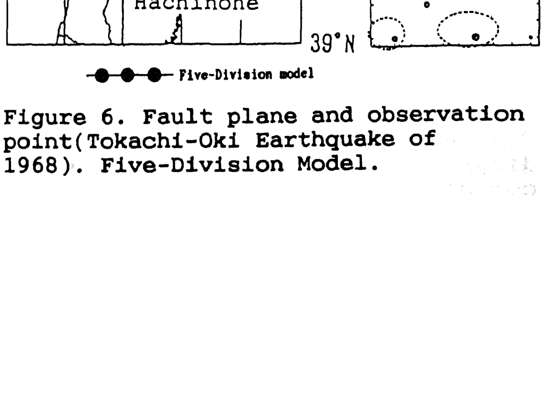

Figure 6. Fault plane and observation point(Tokachi-Oki Earthquake of 1968). Five-Division Model.

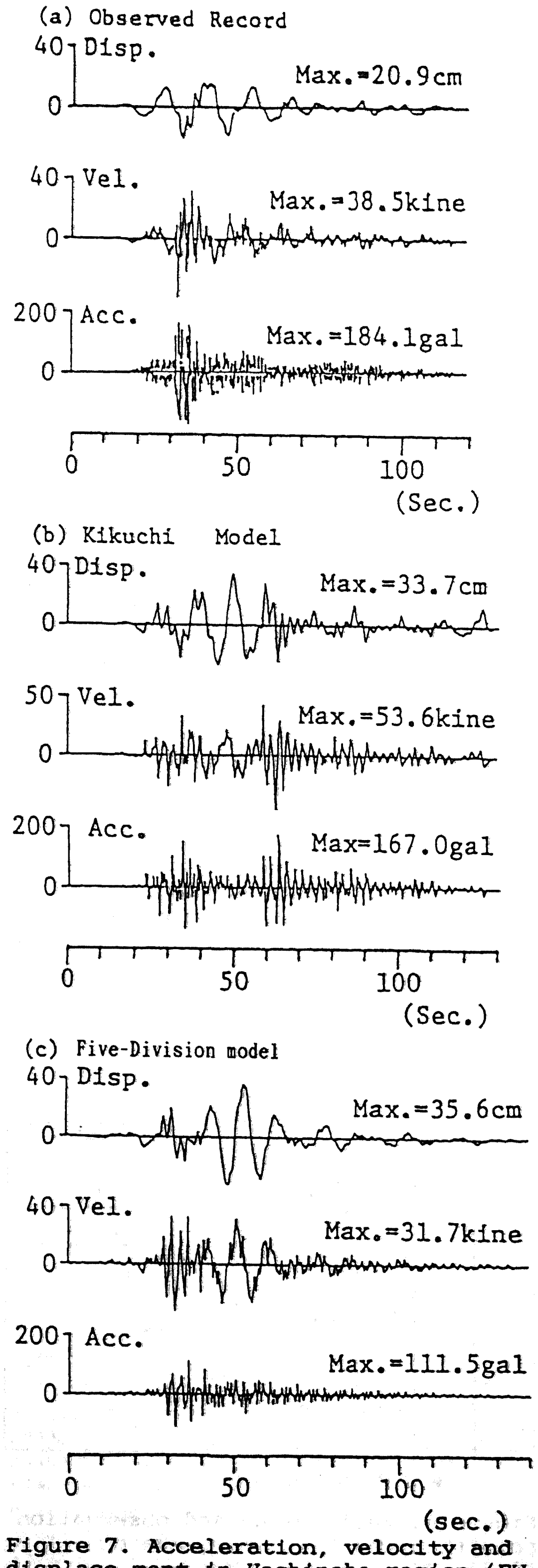

Figure 7. Acceleration, velocity and displace ment in Hachinohe region (EW component).

4 PREDICTION OF STRONG GROUND MOTIONS

By utilizing this five-division model, and the Kwanto region ground structure proposed by Mikumo (1966), the ground motion on the Kwanto area bedrock with shear wave velocity of 0.7 km/s can be predicted for the Tokai Earthquake (M=8.0, Ishibashi 1977), the Kwanto Earthquake (M=8.0, Matsuura 1980), and the Edo Earthquake (M=7.0, Kawasaki I. and Matsuda K. 1987). Each earthquake source parameter is shown in Table 1. Figure 9 shows the fault planes (dotted line) and prediction points for the Tokai, Kwanto, and Edo Earthquakes.

Figure 10 shows the predicted acceleration, velocity, and displacement wave forms, and Table 2 lists the predicated maximum amplitude of acceleration, veloci-

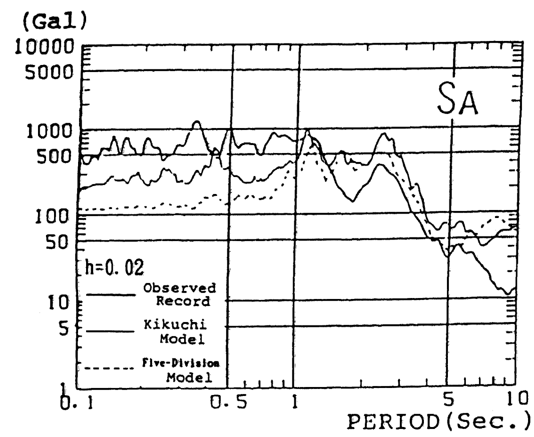

Figure 8. Response spectrum of synthesized and observed wave in Hachinohe region(EW component).

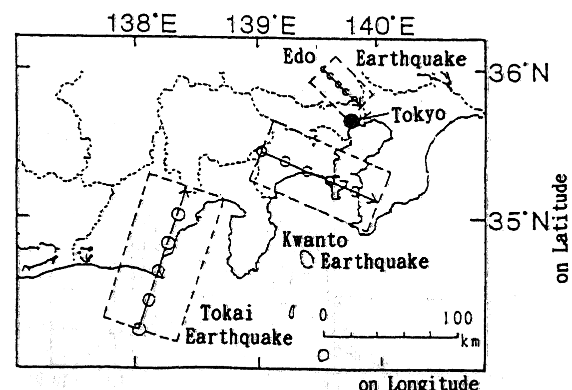

Figure 9. Fault planes and predication point(Tokai, Kwanto< and Edo Earthquake).

ty, and displacement for the Tokyo region under the above given conditions.Figure 11 shows the response spectrum calculated from the predicted acceleration waves.

In the case of the Kwanto Earthquake (M=8.0), the ground motion (NS component), predicted for a layer with shear wave velocity of =0.7km/s, had a maximum displacement=20cm, maximum velocity=50kine, and maximum acceleration=210 gal. This acceleration value nearly equals that estimated from earthquake expectancy calculated from earthquake data accumulated over a 300-year time span (Kitagawa 1991,see Fig.12).

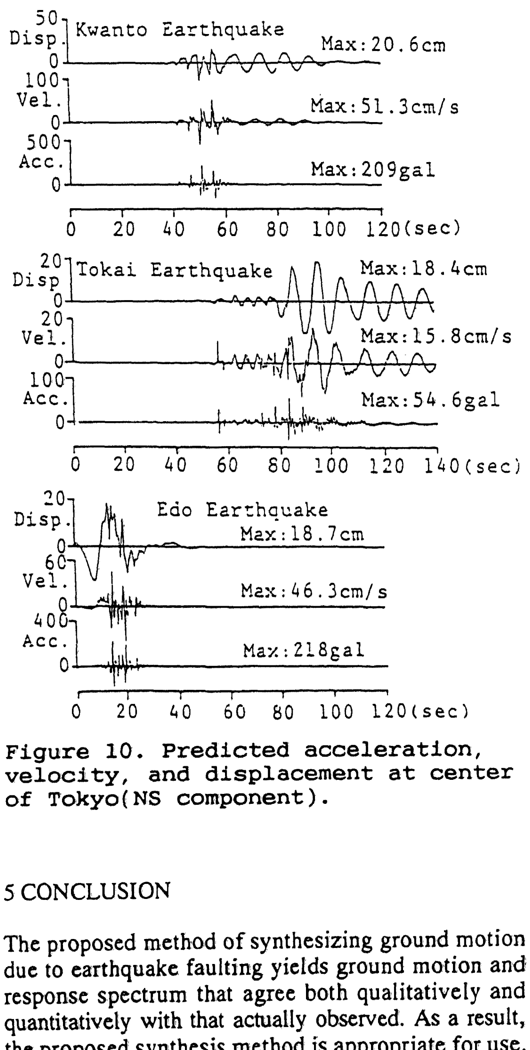

Figure 10. Predicted acceleration, velocity, and displacement at center of Tokyo(NS component).

5 CONCLUSION

The proposed method of synthesizing ground motion due to earthquake faulting yields ground motion and response spectrum that agree both qualitatively and quantitatively with that actually observed. As a result, the proposed synthesis method is appropriate for use, during the structure design phase, as realistic earthquake input motion to structures. It needs to be pointed out that international cooperative data exchange, as well as free use of actual observed data, would greatly enhance progress in this research field.

Table 2. Predicted maximum amplitude of acceleration, velocity, and displacement for Tokai, Kwanto, and Edo Earthquake using the five-division model.

	Tokai	Kwanto	Edo
Disp. (cm)	18.4	20.6	18.7
Vel. (cm/s)	15.8	51.3	46.3
Acc. (gal)	54.6	209	218

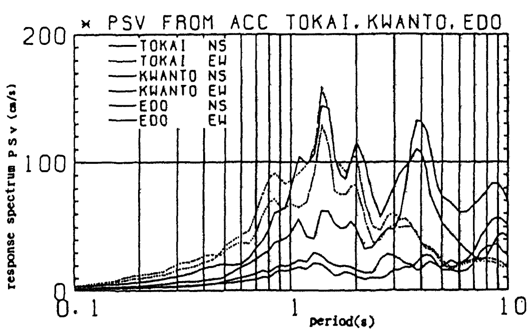

Figure 11. Response spectrum of predicted wave(h=0.05).

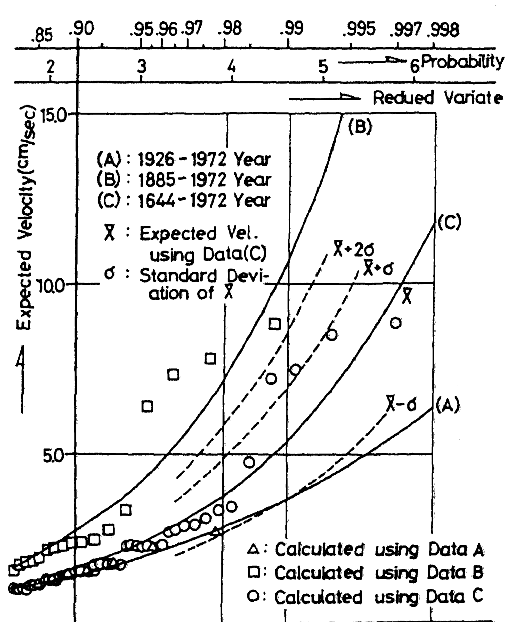

Figure 12. Expected maximum velocity with standard deviation VS. return period, at base rock with shear wave velocity of 2-3 km/s in Tokyo region.

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REFERENCES

Hartzell, S. 1978. Earthquake aftershocks as Green's function, Geophys. Res. Letters, vol.5:1–4.

Haskell, N. A.1960. Crystal reflection of plan SH waves, J.G.R., vol.65, No.12:4147–4150.

Irikura,K.1983. Semi-empirical estimation of strong ground motions during large earthquakes, Bull. Disaster prevention Res. Inst. Kyoto Univ., vol.33:63–104.

Ishibashi, K. 1981. Specification of a soon-to-occur seismic faulting in the Tokai district, central Japan, based upon seimotectonics, Earthquake Predication-An International Review, Series 4:297–332.

Ishida, K.1976. Tokachi-Oki Earthquake, few considerations to compare with synthesize ground motion, 4-th Symposium of ground oscillation, A.I.J.

Kanamori, H.1971. Focal mechanism of the Tokachi-Oki Earthquake of may 16, 1968: contortion of the lithosphere at a junction of two trenches, Tectonophysics, 12:1–13.

Kawasaki, I., Y.Suzuki, R. Sato. 1973. Seismic waves due to a shear fault in a semi-infinite medium, part 1:point source, J. Phys. Earth, vol.21:251–284.

Kawasaki,I. and K. Matsuda. 1987.Interpolate seismic coupling in the South Want district, central Japan, and the hypothetical Tokyo Earthquake, BERI, vol.40:7–18.

Kikuchi, M. and K. Sudo. 1984. Inversion of teleseismic P-waves of January 14, 1978, J. Phys. Earth, vol.32:161–171.

Kikuchi, M. and Fukao, Y. 1985. Iterative deconvolution of complex body waves from great earthquake-the Tokachi-Oki Earthquake of 1968, Phys. of the Earth and Planetary Interiors, 37:235–248.

Kitagawa, Y. 1991. Study on expectancy Value in Tokyo district in Japanese, Summaries of Technical Paper of A.I.J.:2178–2179.

Kudo, K. et al.1978. On the Shear wave underground structure of Izu Peninsula, Bull. Earthq. Res. Inst., vol.53:779–792.

Matsuura, M. 1980. Statical and dynamical study on faulting mechanism of the 1923 Kanto Earthquake, J. Phys. Earth, 28:119–143.

Mikumo, T.1966. A Study crystal structure in Japan by use of seismic and gravity data, B.E.R.I., vol.44:965.

Saito, M.1972. Excitation of free oscillations and surface waves by a point source in a vertically heterogeneous earth., J.G.R.

Sato, R. et al. 1975. Seismic waves due to a shear fault in a semi-infinite medium, Part 2, J. Phys. Earth. 23:43–61.

Shimazaki, K. and Somerville, P.1978. Summary of the static and dynamic parameters of the Izu-Oshima-Kinaki Earthquake of January 14, 1978., B.E.R.I., vol.53:613–628.

Takeuchi, H. and M. Saito. 1972. Sesmic surface waves, methods in computational physics, vol.11: 217–295.

Tanaka, T. 1976. Tokachi-Oki Earthquake, Study on quasi-long period of strong motion in Hachinohe harbor, 4-th Symposium of ground oscillation, A.I.J.