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ESTIMATION AND PREDICTION OF STRONG MOTION DUE TO A REALISTIC EARTHQUAKE FAULTING

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SUMMARY

The objective of this paper is to present an improved method for synthetic ground motion by taking the actual focal process into consideration. As an example, this method is applied to the ground motion due to the Izu-Oshima-Kinkai Earthquake of 1978 and Tokachi-Oki Earthquake of 1968, and compared with the observed record. Moreover, in the case of the Tokachi-Oki Earthquake, the simple five divided model is proposed, pointing out the advantages of this model. In addition, as data of Kwanto Earthquake's ground motion do not exist, we tried to estimate it using this model.

INTRODUCTION

The ground motion due to earthquake occurrence is strongly affected by the earthquake process itself, the propagating path of seismic waves, the topography of the ground surface and the properties of ground surface layers. These factors cause damage to buildings and other structures in different ways. That is, buildings behave differently for each earthquake. In order to have more reasonable aseismic standards, it is necessary to examine how each factor mentioned above contributes to the actual motion.

Recently, many trials to have realistic "earthquake input to structures" have been conducted. They are pseudo-ground motion, superposition of many seismic waves from aftershocks, etc. (Refs.1,2). In this study we propose an improved method for synthetic ground motions, by taking the actual focal process into consideration.

CALCULATION METHOD

In order to have more realistic ground motions, the calculation is performed with the following assumptions:

1) Earthquake occurrence is due to fault 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 layer
4) the main parts of earthquake ground motion are in S-waves, its reflected phases and the surface wave.

Synthesis of body and surface waves are conducted separately. They are added after completion. In the first process in making a body wave, it is supposed that the k-th point source is in the m-th elastic layer, as seen in Figure 1.

Displacement $U_A^{k,m}$, at point A due to this source can be calculated exactly with the expression given by Sato (Ref.3). The transfer function h_A, of the mid-point between A and the ground surface is computed by Haskell's Method (Ref.4). Convolution of $U_A^{k,m}$ with h_A, gives the ground motion $U_k(t)$ due to the k-th source as follows;

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

Thus, the expected ground motion, U(t), is obtained by a summation of contribution from all sources as follows;

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

where N means number of sources.
Also, synthesis of the surface wave is done by using the method developed by Saito (Ref.5).

RESULTS

As an example, this analytical method is applied to the ground motion due to the Izu-Oshima-Kinkai Earthquake of 1978 (M= 6.8), and Tokachi-Oki Earthquake of 1968 (M= 7.9), and compared with the observed record. In addition, the ground motion on the Kwanto area bedrock with shear wave velocity of 0.7 km/s is predicted for the Kwanto Earthquake of 1923 (M= 8.0) by using this method. Table 1 shows each earthquake source parameter.

Izu-Oshima-Kinkai Earthquake Figure 2 shows fault place and observation point (Ito). The Izu-Oshima-Kinkai Earthquake of 1978 involved right lateral strike slip motion together with a small dip slip component on a steeply northward dipping fault. The observation point (Ito) is located at the northern part about 24 km from this fault plane. As seen in Figure 2, 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 (Ref.6), and Figure 3 shows the characteristics of ground structure and transfer function.

Figure 4 shows the EW component of synthetic acceleration wave in the Ito region, obtained by the method and procedures mentioned above, and observed accelerogram. The synthetic accelerogram agrees qualitatively and quantitatively with the observed one as seen in Figure 4. Figure 5 shows the response spectrums calculated by the above waves, peak period and the value of each spectrum is symmetrical.

Tokachi-Oki Earthquake Figure 6 shows the fault plane (doted line) and observation point (Hachinohe). Kikuchi (et al) pointed out that this earthquake focal process constituted four main point sources, as seen in Figure 6. In this paper two models are used. One is proposed by Kikuchi et al.(Ref.7, Kikuchi's model) and the second model is divided into five equal seismic moments (five divided model). The five divided model is simpler than Kikuchi's model, because in Kikuchi's model there is a distribution of twenty point sources on the fault plane. The ground structure model proposed by Tanaka has been used (Ref.8) and Figure 7 shows the characteristics of ground structure and transfer function.

Figure 8(a),(b),(c) shows observed acceleration, velocity and displacement waves in the Hachinohe region(EW component), synthetic ground motion calculated by Kikuchi's model (b) and the five divided model (c). In the synthesized ground motion calculated by Kikuchi's model there are two large wave groups on acceleration and velocity. 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 (Ref.9) pointed out that the main parts of earthquake ground motion from the position ② are SV-waves. As seen in Fig.8(c), synthetic ground motion by the five divided model can explain the observed data very well, though it is a very simple model.

Kwanto Earthquake Figure 9 shows the fault plane (doted line) and observation point (Tokyo). The seismic moment distribution used the five divided model mentioned above and the ground structure model used the Kwanto region structure proposed by Mikumo (Ref.10). Figure 10 shows the characteristic of ground structure and transfer function.

The ground motion (NS component) on a layer of Vs=0.7 km/s, max. displacement 20 cm, max. velocity 50 kine and max. acceleration 251 gal, was estimated, as seen in Figure 11. This acceleration value almost corresponds to the value which is estimated from earthquake expectancy calculated by using earthquake data over a 300-year period.

CONCLUSIONS

A method of synthesizing the ground motion due to earthquake faulting was proposed. The ground motion was synthesized and compared with the observed records. The case of Izu-Oshima-Kinkai Earthquake, synthetic ground motion and response spectrum agree qualitatively and quantitatively with the observed one. The case of the Tokachi-Oki Earthquake, synthetic ground motion by the five divided model, can explain the observed data, though it is a very simple model. As a result, it is pointed out that the proposed method is appropriate for the realistic earthquake input motion to structures.

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Table 1 Source Parameter

	Dimension	Izu-Oshima Kinkai	Tokachi Oki	Kanto
fault length	(km)	20	150	95
fault width	(km)	10	100	54
dip-angle	(deg.)	85	20	25
slip-angle	(deg.)	188	38	140
strike direction	(deg.)	N 90W	N156W	N66W
dislocation	(cm)	---	410	480
seismic moment	(dyne·cm)	8.8×10^{26}	2.8×10^{28}	8.4×10^{27}
magnitude		6.8	7.9	8.0
rupture velocity	(km/sec.)	2.8	3.5	2.0
rise time	(sec.)	2.0	---	5.0
depth	(km)	8.0	7.1	23.0
stress drop	(bars)	---	150	45
Model proposer		Shimazaki[11]	Kanamori[12]	Matsu'ura[13]

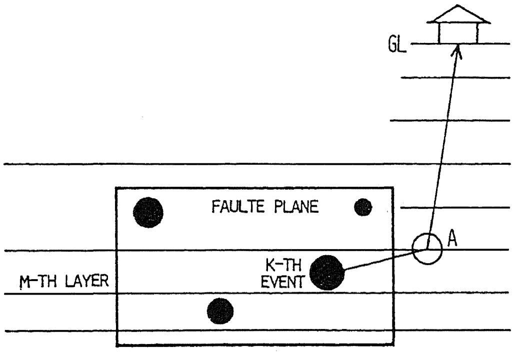


Figure 1 Seismic Wave Path from Each Strong Radiation Source to Ovservation Site

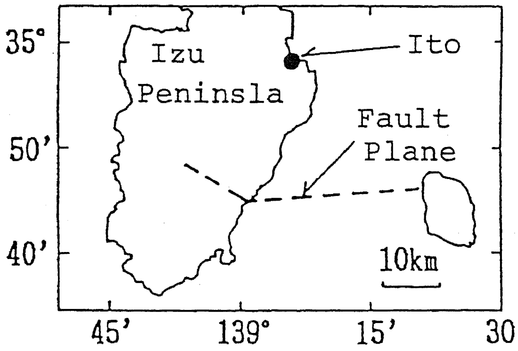
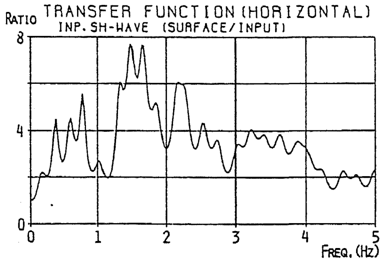


Figure 2 Fault Place and Observation Point (Izu-Oshima-Kinkai Earthquake of 1978)



Ground Property

NO.	Thickness (km)	Density (ton/m³)	Vs (km/s)	Q Value
1	0.02	1.50	0.20	5
2	0.03	1.80	0.35	15
3	0.25	2.00	0.70	60
4	0.70	2.20	1.46	125
5	1.00	2.50	2.30	175
6	2.00	2.50	2.50	200
7		2.80	3.70	250

Figure 3 Characteristic of Ground Structure and Transfer Function(Izu Peninsula Region)

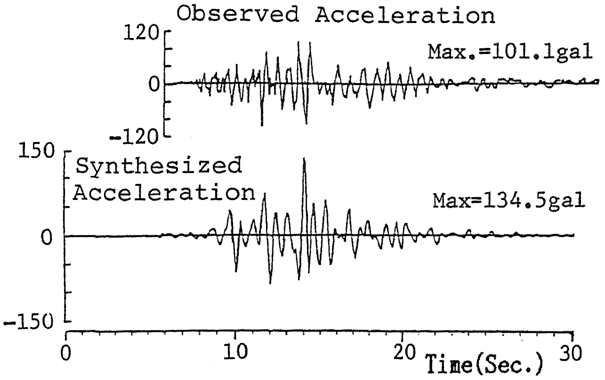


Figure 4 Synthetic Acceleration and Observed Record
(Ito Region EW Component)

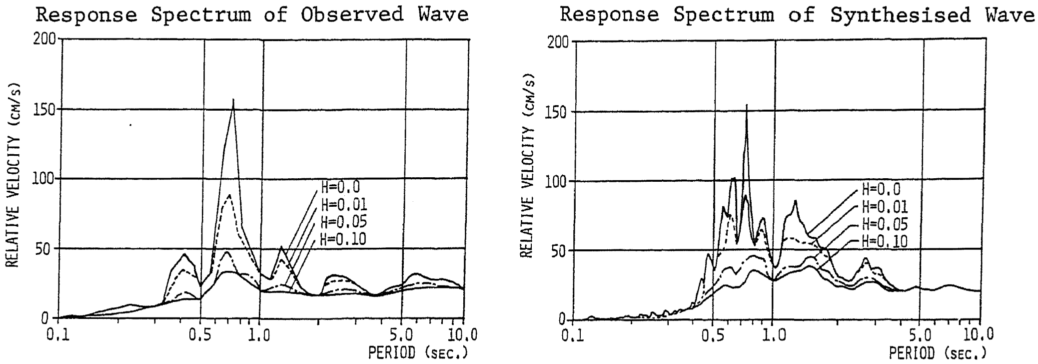


Figure 5 Response Spectrum
(Izu-Oshima-Kinkai Earthquake)

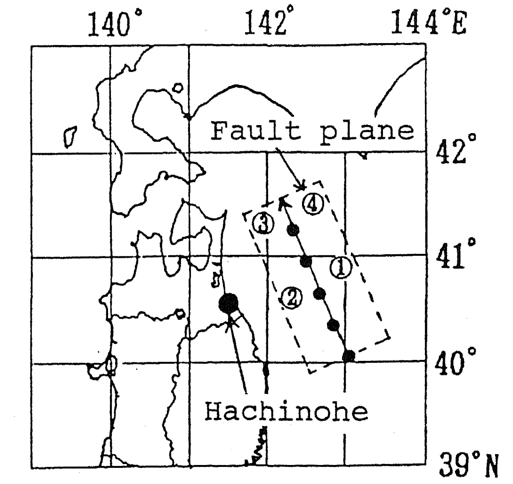
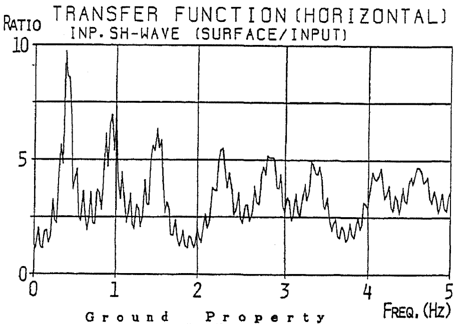


Figure 6 Fault Plane and Observation Point
(Tokachi-Oki Earthquake of 1968)
●●● Five Divided Model

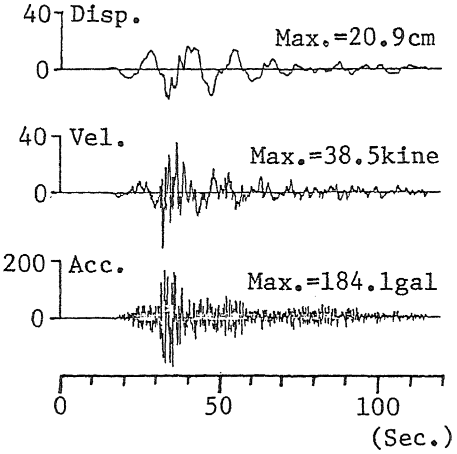


Ground Property

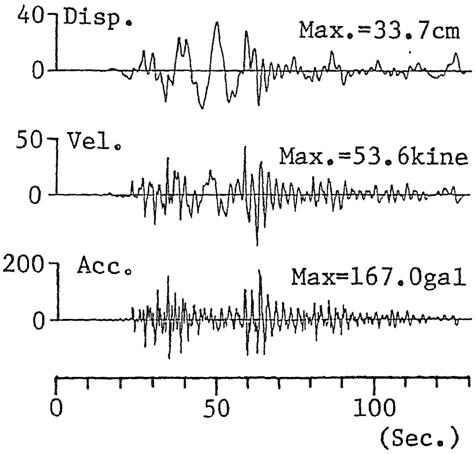
NO.	Thicknes (km)	Density (ton/m³)	Vs (km/s)	Q Value
1	0.009	1.80	0.17	20
2	0.086	1.80	0.31	20
3	0.105	1.90	0.38	20
4	0.180	2.00	0.69	80
5	0.020	2.10	1.10	100
6	15.00	2.50	2.80	300
7		3.32	4.36	500

Figure 7 Characteristic of Ground Structure and Transfer Function (Hachinohe Region)

(a) Observed Record



(b) Kikuchi's Model



(c) Five Divided Model

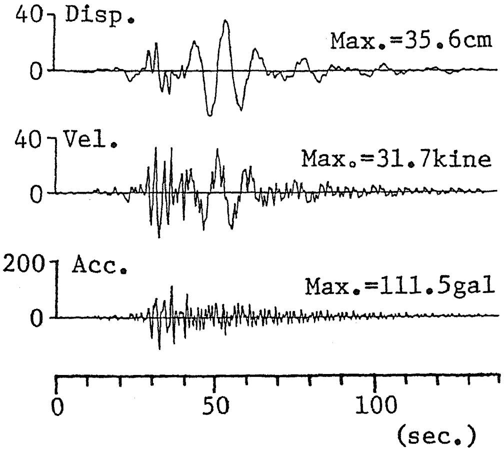


Figure 8 Acceleration,Velocity and Displacement in Hachinohe Region (EW Component)

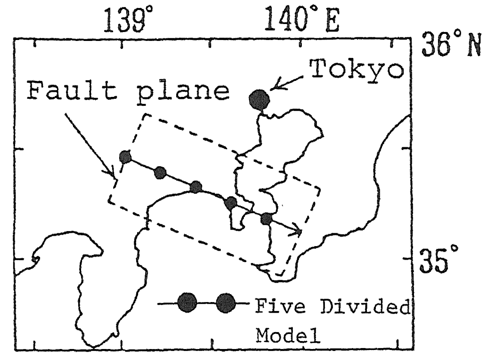
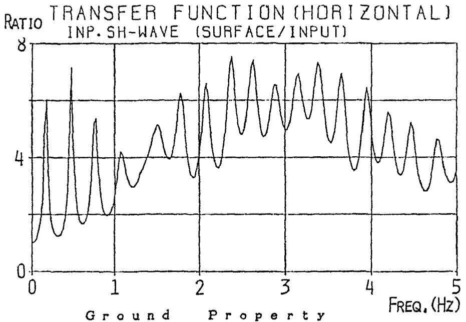


Figure 9 Fault Plane and Observation Point (Kwanto Earthquake of 1923)



Ground Property

NO.	Thicknes (km)	Density (ton/m³)	Vs (km/s)	Q Value
1	0.012	1.50	0.17	10
2	0.030	2.00	0.38	15
3	0.208	2.00	0.55	50
4	0.750	2.00	0.70	170
5	0.120	2.10	1.30	300
6	0.280	2.40	2.00	400
7		2.80	3.54	500

Figure 10 Characteristic of Ground Structure and Transfer Function(Kwanto Region)

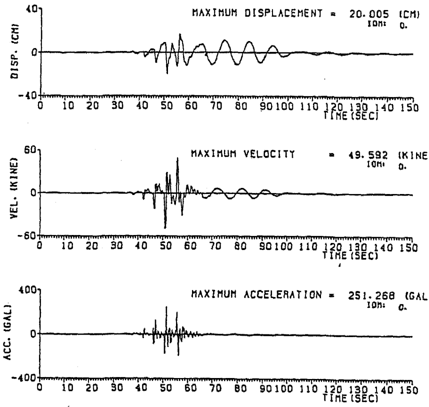


Figure 11 Estimated Ground Motion (Tokyo NS Component)