ON GROUND MOTIONS OF LONGER PERIODS IN STRONG EARTHQUAKES

Yoshimasa KOBAYASHI[I] and Toshiro FUJIWARA[II]

SUMMARY Seismograms in the Niigata earthquake 1964, the Tokachioki earthquake 1968 and its largest aftershock registered by strong-motion seismographs with particular period about 5 seconds are analysed. Undamped response spectra of the seismograms are computed for periods from 2 to 50 seconds. The relative velocity spectra revealed to be almost flat over the period range computed. Levels of the spectra at several sites suggest a strong effect of site conditions, and by reducing for the factor of each site a formula for the mean velocity level as a function of the earthquake magnitude and hypocentral distance is presented.

INTRODUCTION

Our knowledge of ground motions of longer periods up to several tens of seconds in strong earthquakes is yet unsatisfactory, since most strong-motion records available have been registered by accelerographs with low S/N ratios in these periods. But, today the interest in the longer-period ground motions steadily increases as the dimension of structures becomes greater, and it would be useful to draw information from existing strong-motion records registered by such instruments with longer periods as those of Japan-Meteorological-Agency type with particular periods about 5 seconds.

In the present Paper strong-motion seismograms registered by the JMA-type seismographs are analysed. It is unfortunately impracticable to reproduce all the sequence of a trace of seismogram at a sufficiently short time interval because of a too low paper speed of only about 30 mm/min. A procedure for reading a record only at maxima and minima aswell as at stationary points as Skoko et al.(1965)did was followed. After various reductions, the time series are interpolated at every 0.25 sec. by assuming a cosine curve between these read off points, and numerical differenciation is carried out to give accelerations for spectral analysis. For more details see Kobayashi and Fujiwara(1978).

COMPARISON OF RESPONSE SPECTRA IN LONGER PERIODS WITH THOSE IN CONVENTIONAL PERIOD RANGES

Response spectra for a series of accelerograms prepared as above (Table I)are computed up to 50 sec. period under undamped or slightly damped conditions and compared with those for ordinary Strong-Motion-Accelerograph records registered at almost the same sites as those for the longer-period instruments(Fig.I). The both spectra are overlapping at the periods of 2.0, 3.0 and 4.0 sec. and a substantial coincidence is found for relative-displacement, relative-velocity as well as absolute acceleration. The former spectra, therefore, may be regarded as an extension in the longer-period range of the latter.

TREND OF RESPONSE SPECTRA IN LONGER-PERIOD RANGE

From general trends of the response spectra for zero-damping factor as illustrated in Fig.2 it may be recognized that the relative-displace-

I. Assoc.Prof., Disaster Prevention Research Institute. Kyoto University
II. Associate Director, Oki Electric Industry Co., Ltd.

ment, relative-velocity and absolute acceleration increases, stays constant and decreases with the period, respectively. The relative-velocity response spectrum for zero damping factor is proportional to the Fourier Transform of input acceleration record, and therefore it may be concluded that the Fourier Spectrum of ground acceleration is approximately constant over the analysed period range suggesting ω-square law by Aki(I967).

INTENSITY OF VELOCITY RESPONSE SPECTRA

Velocity response spectra at about I0 sec. as well as 20 sec., more specifically the mean values of 8, I0 and I2 sec. as well as I8, 20 and 23 sec., are given in Table 2. The data exhibit so great scattering that it is difficult to derive an empirical formula for velocity spectra versus distance with earthquake magnitude as a parameter. The scattering is very likely due to observation-site conditions on which Okada and Kagami(I978) and Katsumata(I965 a,b)have discussed. Accordingly, the amplitudes at each station exhibit a consistent deviation from the mean expected values at the corresponding distances and for the magnitudes. One can, therefore, determine an amplification factor or a site constant C for every station by comparing observed amplitudes with the standard ones given e.g. by the relation by Tsuboi; $\log_{I0}A(\text{microns})=M-I.73\log_{I0}D(\text{km})+0.83$. The site constants taken from Okada and Kagami or determined from data in Seismological Bulletins JMA are given in Fig.3.

Taking the observed values, i.e. the computed response spectra in the present study, at Morioka as a base and supposing the site constant 0.63 determined by Okada and Kagami for the station being valid, and further employing the distance-decay coefficient I.73 by Tsuboi, the velocity response spectrum is given by

$$\log_{I0}V(\text{cm/s})=M-I.73\ \log_{I0}D(\text{km})-2.52$$

Values for each station can be calculated by multiplying the standard value given by the above formula by a corresponding site constant C. Observed values and calculated ones are compared in Fig.3. The coincidence is not very satisfactory but tolerable. All the observed points are bounded by a straight line 2.5 times as high as the standard line.

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Table I. Distance and Direction of Stations from Hypocenter.

Event	M	Station	Akita	Miyako	Mori	Morioka	Muroran	Suttsu
Tokachi	7.9	D		I9I km	298 km	24I km	282 km	366 km
Main S.		φ		S49°W	N58°W	S62°W	N50°W	N46°W
Tokachi	7.5	D			208	244		269
After S.		φ			N68°W	N38°W		N53°W
Niigata	7.5	D	I68		434			503
		φ	N29°E		NI5°E			N 9°E

Table 2. Velocity-Response Spectra at about I0 sec. and 20 sec. (cm/sec.)

Event	Station	Akita	Miyako	Mori	Morioka	Muroran	Suttsu
Tokachi	NS		8.82/I3.8	26.4/I6.3	II.3/II.4	9.70/9.50	9.30/8.77
Main S.	EW		6.27/7.50	22.2/23.7	II.5/II.9	8.25/II.8	8.I8(I6.4)
	UD				I3.2(20.5)		
Tokachi	NS			6.26/5.06	3.I8/3.42		2.50/I.58
After S.	EW			9.4I/3.52	4.39/3.25		3.I0/2.29
	UD				3.44/3.79		
Niigata	NS	33.4/I0.4		4.I7/2.I7			4.29/I.45
	EW	26.8/9.45		2.I5/I.05			4.69/I.64

xx/xx; Spectrum at about I0 sec./Spectrum at about 20 sec., ( ); unreliable

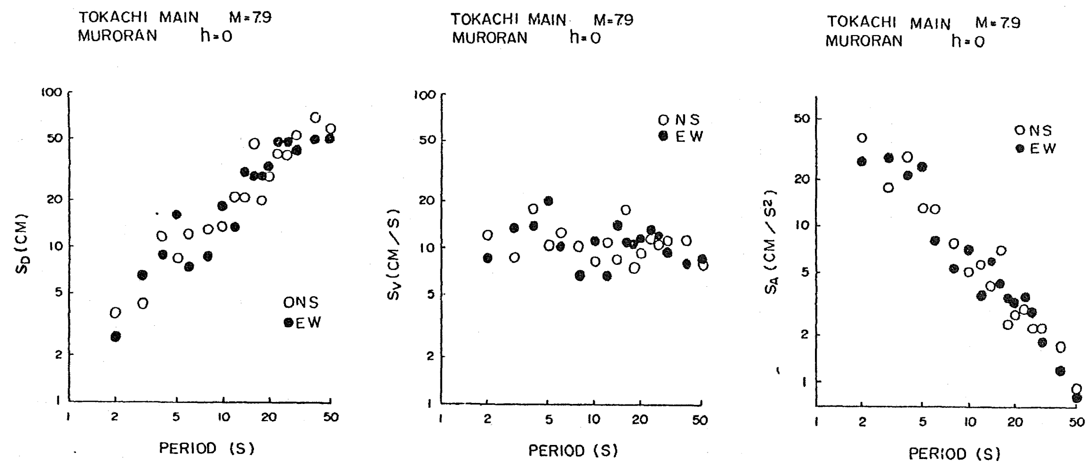

Fig.2. Trend of undamped response spectra from 2 to 50 sec. Relative-displacement, relative velocity and absolute acceleration increases, stays constant and decreases with the period, respectively. An undamped velocity response spectrum corresponds to Fourier Spectrum of input acceleration.

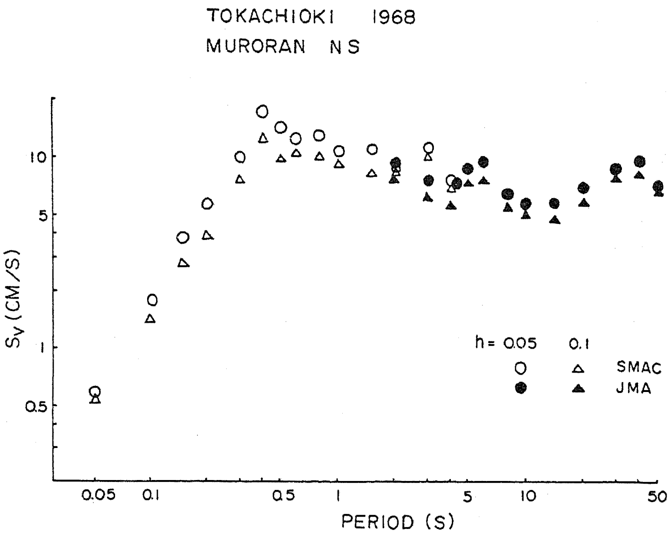

Fig.I. Comparison of Velocity-Response Spectrum computed for record by JMA-type Strong-Motion Seismograph(To=5 sec) with that for ordinary SMAC(To=0.I sec) record. A substantial coincidence at overlapping periods is recognized.

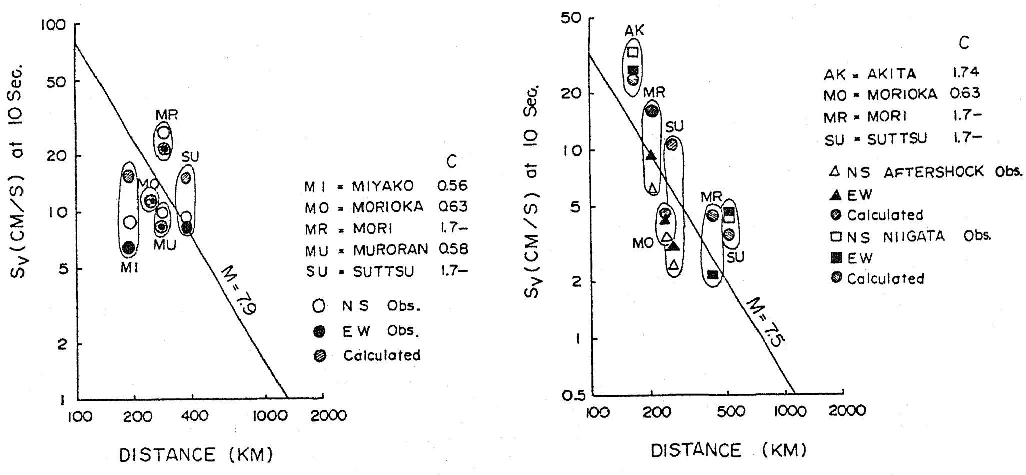

Fig.3. Intensity of Velocity-Response Spectrum as a function of distance and earthquake magnitude. Left; Tokachioki I968, M=7.9: Right; Tokachi-oki aftershock and Niigata earthquake I964, both of M=7.5. Amplitudes for each station is calculated by multiplying the standard value given by $\log_{10}V(cm/s)=M-1.73\log_{10}D(km)-2.52$, by the site constant C.