ON THE CHARACTERISTICS OF ACCELEROGRAMS RECORDED ON BEDROCK NEAR ORIGINS

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SYNOPSIS

Peak amplitude, duration of main phase and frequency characteristics of acceleration are investigated by using the records observed on the bedrock near origins in Japan. These factors can be expressed as a function of magnitude. However, analyses of the source parameters estimated from the spectral analysis indicate that the stress drop plays an important role in evaluating the peak acceleration. And the synthetic waves derived from the dislocation model comparatively agree with the observational ones in the phase of low frequency range.

INTRODUCTION

Evaluating the potential of seismic shaking has been studied by many researchers. Since most of these studies, however, are based on the accelerograms recorded on the soft ground besides the location far from the earthquake origin, the difinite method to estimate the seismic shaking on the bedrock near focal area is not still established. Therefore, to make advance in this problem, it is essential to investigate the characteristics of seismic waves on the bedrock near origins. Recently, in two events happened in Japan, these important ploblems are investigated by acceleration recorded near the origins.

This reports the characteristics of seismic shaking on the bedrock, e.g. the peak amplitude-magnitude relations, frequency properties and source parameters, and refers to usefulness of dislocation model in the engineering seismology.

OBSERVATION

During the Izu-Ōshima-Kinkai Earthquake(M=7.0) of January, 1978, numerous acceleration data of pre and post earthquakes including the saturated records of the main shock are observed at two stations settled on the rock ground in the Izu Peninsula. These data cover the range of magnitude from 1.2 to 5.8 and hypocentral distance from 5Km to 37Km. In case of Iwasaki Earthquake Swarm records with magnitude of 2-4 and hypocentral distance of 5Km - 15Km are also obtained at two temporary stations.

The recording system, as shown in Figure 1, consists of Servo-type accelerograph and the long term data recorder by means of direct recording form. Figure 2 shows the overall frequency response curve of the system from recording to reproducing. The dynamic range of the system is about 33dB in the observations.

The observation points in the Izu Peninsula, NST and YAS, are established on the hard andecites. NST is located at about 8Km from the end of estimated fault of the main shock and YAS is situated at about 20Km in rectanguler

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direction to the fault, while the epicentral distances of both stations are almost same. In case of the Iwasaki Earthquake Swarm, FRF and MGM have been founded on andesite lava and rtyolite respectively.

A number of selected data for the analysis are 74 in NST, 18 in YAS for the Izu and 56 in FRF, 18 in MGM for the Iwasaki.

The epicentral distributions of these earthquakes and the observation sites are shown in Figure 3(a),(b).

RESULTS

Main Shock of the Izu-Ōshima-Kinkai Earthquake

Figure 4 shows the accelerograms (horizontal component) of the main shock observed at NST and YAS. These records are saturated because of high gain amplification system, and the amplitude are strained remarkably. Therefore it is impossible to discuss about the amplitude characteristics of the waves. But, it should be assumed that the some of the general aspect of the seismic waves still remain to some degree.

The duration time with the relatively large amplitude in the records is about 7-8 sec, which approximately coincides with the propagation time of rupture along the fault estimated from the dislocation model by Shimazaki and Somerville(1978). The accelerograms of NST located near the fault are fairly characterized with the predominant high frequency components, on the other hand, in YAS located somewhat far from the fault, the longer period($T > 1$ sec) is comparatively predominant. This results shows that these frequency characteristics must be considered in evaluating the seismic motion near the fault.

Peak Amplitude - Magnitude Relation

The peak acceleration(AHmax) and velocity(VHmax) of horizontal components at hypocentral distance 22 Km $< r <$ 37 Km (almost data are r=30 Km) and the magnitude (M) are plotted in Figure 5. The following empirical formulas between AHmax or VHmax and M are obtained from the data.

$$\log AHmax = 0.452M - 1.42$$
$$\log VHmax = 0.595M - 3.59 \qquad \text{---------} \quad (1)$$

The curves from the existing formulas are also shown in Fig.5. As shown in this figure, it may be evident that AHmax and VHmax are proportional to the magnitude. The coefficients of M in Eq.(1) almost coincide with the several existing results by other researchers in Japan, but the absolute values of peak amplitude appear somewhat smaller than them.

The relations between AHmax and M at more closed hypocentral distance are shown in Figure 6(a),(b) for example. Fig.6(a) displaying the data at r = 10 Km in the Izu, shows a considerably scattering situation. On the other hand , at FRF in the Iwasaki, comparatively obvious relationship between AHmax and M can be founded as shown in Fig.6(b), though the coefficient of M in this case is about two times larger than that obtained above. This may be caused by the reason that the seismic waves in the Iwasaki are less affected by the propagation paths than those in the Izu because of the very small swarm area in the former.

Duration Time and Frequency Characteristics

The relationships between the duration time of accelerograms and magnitude have also been studied by many researchers, and the empirical formulas have been proposed. Since a few data observed on the rock ground near origin have been used in these studies, the study using the present data is interesting. The duration time from the shear wave arrival to 1/2 and 1/10 of peak amplitude is measured from the records in the Izu. As shown in Figure 7, the relations between M and the duration time for each definition(Td1/2 and Td1/10) are expressed as follows.

$$\log Td1/2 = 0.288M - 0.45$$
$$\log Td1/10 = 0.232M - 0.89 \qquad \text{---------} \ (2)$$

The coefficients of M are agree with the results of the others in Japan as well as the peak amplitude. Therefore, it may be concidered that the duration time is also related to the magnitude.

In order to investigate the dependency of acceleration spectra to the magnitude, the average Fourier's spectra for each magnitude range are calculated from the representive records in the Izu and the Iwasaki. The results are shown in Figure 8(a),(b). From these figures, it may be pointed out that the amplitude of spectra smoothly decreases as a magnitude goes down. The spectra of M = 5.4, 5.8 draw relatively flat shape in the frequency range of about 0.5Hz - 10Hz, while the peak of spectra turns to the high frequency as a magnitude decreases. It should be believed that these results well express the frequency characteristics of source mechanism.

DISCUSSION

Recently,several papers are reported in regard to the acceleration in the hypocentral distance of about 10 Km (Hanks and Johnson,1976). The source parameters due to the spectral analysis and the synthetic seismograms based on the dislocation model have been investigated. These problems are important not only in the seismology but also the engineering to evaluate the seismic potential properly. Then, the following some examinations are tried using the present data.

Peak Amplitude at r=10 Km

On the data in Izu, the earthquakes of small magnitude range are observed only at a distance of about 10 Km or less and the most of large magnitude earthquakes are held in the data recorded at a distance of about 30 Km. Accordingly, the peak amplitudes at a distance of 10 Km are estimated using the data observed in common with both stations of NST and YAS.

Let A1, A2 be peak amplitudes, r1, r2 be hypocentral distances at NST and YAS respectively, the following relations are obtained.

$$A1/A2 = 1.38(r1/r2)^{-3.22} \qquad \text{----} \ (3)$$
$$\text{or} \quad A1/A2 = 1.18(r2/r1)\cdot\exp(-0.130(r1-r2))$$

These relations are consistent with the other reports mentioned about the attenuation of seismic wave in the Izu Peninsula (Ikami, 1976).

From the above relation, the all data replayed at r=10 Km are shown in Figure 9. It is obviously seen that the peak amplitudes remarkably grow up with a magnitude at least to a magnitude range of about 5, although the large scatter exists in the data due to the very rough estimation method. The average values in each magnitude range indicate from 0.02 g at M = 3 to 0.3 g at M = 5. The tendency of increase resembles to the result of Seekins and Hanks (1978) reported as to the aftershocks of the Oroville Earthquake (M=5.7) in California. For the earthquake of M 5, it is obscure whether the peak amplitudes proportional to a magnitude or not because of insufficient data.

Source Parameters and Peak Amplitude

Selecting the well recorded earthquakes with the magnitude range from 1.2 to 3.9, the amplitude spectra are calculated and corrected for the attenuation due to propagation paths. The far field spectral parameters are then related to the source parameters, seismic moment(Mo), source dimension(R) and stress drop($\Delta\sigma$), using the relationships given by Brune(1970). The attenuation factor Q which is an important factor in the correction of the seismic spectra is somewhat arbitrarily chosen as a value of 150. The events used in the analysis have the impulse natures and simple forms in both the P- and S-waves. The analyses are carried out to 1.0 sec of the S-phase of which interval is long enough to emcompass the motion of S-wave without contaminative later phase. Source parameters estimated from analyses are summarized as follows.

The relation between the seismic monent and the magnitude in this study well agrees with the results of other investigations. The seismic monent - the source dimension relations are shown in Figure 10. From this figure, the stress drops in the Izu range from about 20 to 100 bars, while those in the Iwasaki indicate about 10 bars. Then the latter is several times lower than the former.

Figure 11 shows the relation of the peak amplitude and r/R (hypocentral distance / source dimension) together with the results of the San Fernand Earthquake (M=6.5, 1971) given by Trifunac(1972). It may be sure that the peak amplitudes are inversely proportional to r/R. Comparing the results between the Izu and the Iwasaki, it seems that the peak acceleration depends on the stress drop when r/R is constant. In order to clear this tendency, the accelerations are parameterized using the stress drops and the results are given in Figure 12. As shown in this figure, this parameterization of the data significantly reduces the scatter of the data and so it should be comfired that the peak accelerations are strongly related to the stress drop Moreover, according to Sato and Hirasawa's Propagating Shear Crack Model (1973), the peak acceleration (u) can be expressed as follows.

$$u = c \cdot \Delta\sigma\,(r/R) \qquad \text{------------(4)}$$

The results mentioned above may support the theoretical results of them. It is supposed that the stress drop plays an important role in evaluating the peak amplitude and it is necessary to accumurate the data on the regional distribution of the stress drop.

Comparison between Observed and Synthetic Seismograms

Since seismograms of the Izu-Oshima-Kinkai Eathquake(main shock) observed at NST and YAS are saturated, it is difficult to discuss about the absolute value of the amplitude. However, it seems that observed seismograms keep original aspects concerning to phase of the long period. Then the obsered seismograms are compared with synthetic ones calculated from dislocation model in the period range from 1 to 3 sec.

The simulation program given by Sato(1972) , Kawasaki et al.(1972) and source parameters of the main shock by Shimazaki and Sommerville(1978) are used to calculate the synthetic waves. The results are shown in Figure 13. The observed waves are obtained by band pass filtering the original ones.

It can be generally said from comparison between the observed and the calculated seismograms that the calculated waves comparatively fit the observed ones in the initial phase of relatively long period waves. Morever,

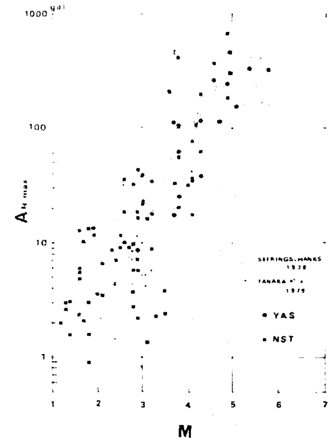

Fig. 9. Peak acceleration estimated at a hypocentral distance r = 10 Km

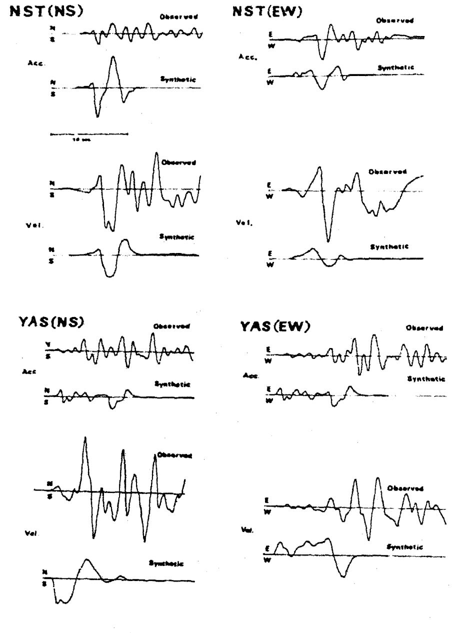

Fig. 13. Comparison between observed and calculated acceleration and velocity wave form

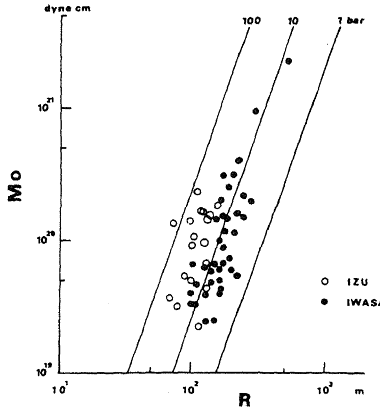

Fig. 10. Seismic moment and source dimension

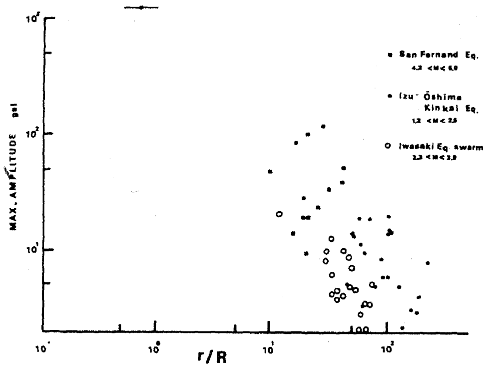

Fig. 11. Peak acceleration versus (r/R)

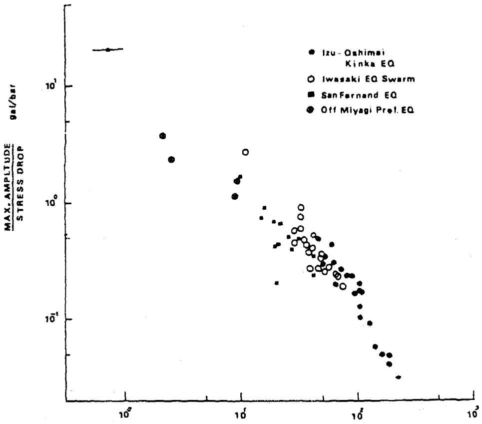

Fig. 12. Parameterized peak acceleration with stress drop versus (r/R)