PROCESSING AND ANALYSIS OF JAPANESE ACCELEROGRAMS AND COMPARISONS WITH U.S. STRONG MOTION DATA

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SUMMARY

Japanese ground-motion accelerograms were processed using updated versions of the routine computer programs developed at the California Institute of Technology. During the processing, high-frequency motions of the accelerograms were increased by up to 100 percent when the corrections for the transducer response were made. Differences in pseudovelocities (computed from the corrected records) with earthquake focal depth were not apparent for the periods examined. Comparisons with U.S. data showed that Japanese pseudovelocity data were generally higher at higher frequencies; however, at low frequencies, no significant differences were observed.

INTRODUCTION

A total of 111 components of Japanese ground-motion accelerograms were recently collected and processed by the authors. The routine computer programs listed in a publication by Trifunac and Lee (Ref. 1), with slight modifications to the subroutines dealing with the long-period errors (Ref. 2), were used to correct the accelerograms. These data were supplemented with other Japanese accelerograms processed in a similar manner by Woodward-Clyde Consultants for subsequent analyses.

Studies of the data included:

- o differences in the accelerograms before and after the processing,
- o effect of focal depth on pseudovelocity spectral ordinates,
- o comparison of U.S. and Japanese pseudovelocity data computed from accelerograms recorded under comparable conditions.

The pseudovelocity data mentioned above were at 5 percent damping for periods of 0.05, 1.0 and 3.0 sec and represent recording conditions on generally firm, shallow-soil sites.

ANALYSIS OF DATA

Data Base

Nearly all of the Japanese accelerograms processed for this study were recorded at ground level within small sheds. Figure 1 shows that most of the earthquakes producing these records were offshore and that the recording stations were generally on the coast. The local geology at these stations generally consisted of firm alluvium, less than 25 m deep, over bedrock. The earthquakes ranged from 4.9 to 7.8 in magnitude (JMA scale), 5 to 160 km in depth, and 5 to 300 km in source-site distance.

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The source-site distance used in this investigation was the distance to the center of energy release (CER). These distances were determined, where possible, from a knowledge of the location of the fault rupture as defined by aftershock distributions and/or published studies of the source characteristics. Each distance was measured to a point on the fault rupture that was considered to contribute most significantly to the character of the ground motion at the recording station. In cases where no information was available to determine the size and location of the fault rupture, which was generally true for earthquakes less than magnitude 7, the CER distance was measured to the hypocenter. This approximation was reasonable for these smaller earthquakes because the estimated source dimensions were much smaller than the hypocentral distances.

The distribution of the Japanese data with respect to JMA magnitude and CER distance is shown in Figure 2. The lack of data recorded near large magnitude earthquakes, an obvious deficiency characteristic of U.S. data as well, did not justify more detailed studies of the attenuation of ground motion than presented herein.

Processing of Accelerograms

The basic procedures used to correct the Japanese accelerograms were those developed by the Earthquake Engineering Research Laboratory at California Institute of Technology (Ref. 1). Recent advances in the correction procedures, particularly for long periods, have been developed at the Seismic Engineering Branch of the United States Geological Survey (USGS) and are described in a recent publication (Ref. 2). This updated procedure was used to correct the Japanese accelerograms. Essentially, this procedure chooses the high-pass filter parameters of an Ormsby filter based on the characteristics of the accelerogram to eliminate the long-period motions. The primary characteristic of the accelerogram considered in this approach is the duration of the record. Ideally, an iterative procedure should be used (Ref. 2) to continually adjust the long-period filter parameters until the optimal correction is reached. However, a single iteration was fully adequate for the purpose of this study. The relationship between the ranges of values chosen for these filter parameters, i.e. cut-off period (T_c) and roll-off termination period (T_t), and the duration of the accelerogram is illustrated in Figure 3.*

The major correction to the accelerograms at high frequencies was for the transducer response of the recording instrument. The natural frequency of the transducer in the SMAC-B2 accelerograph, the instrument which recorded nearly all of the accelerograms processed for this study, is about 7 cps. Thus, the transducer element filters a significant amount of the motions at about this frequency and greater, the amount of filtering increasing with increasing frequency. Hudson (Ref. 3) and Wong and Trifunac (Ref. 4) have illustrated the importance of this effect with U.S. accelerogram data.

*The parameter T_c is the period at which the high-pass filtering begins and T_t is period beyond which all longer period motions are eliminated.

An example of the differences between a corrected and uncorrected accelerogram and the corresponding response spectra are seen in Figures 4 and 5, respectively. The corrected accelerogram is richer in high frequencies due to the instrument correction, and is diminished at periods beyond 4 sec, the cut-off period, to account for the baseline drift and the uncertainties in the amplitudes of the longer period motions.

The differences in maximum acceleration between the uncorrected and corrected accelerograms processed for this study are shown in Figure 6. In every case the maximum accelerations of the corrected accelerograms are equal to or greater than those of the uncorrected records, in some cases greater by more than 100 percent. This gives some indication of the extent to which the high-frequency motions can be underestimated if the accelerograms are not corrected for the transducer response of the SMAC accelerograph. However, there is some question, particularly among Japanese earthquake engineers, whether or not the larger peak acceleration obtained from routine correction procedures (e.g. 0.77g and 0.84g in Fig. 6) are correct (Ref. 5). This and other aspects of correction procedures are currently being researched in Japan.

Effect of Earthquake Depth on Japanese Ground Motion

In a recent publication by Idriss (Ref. 6), evidence was presented which suggested that earthquake depth and travel path effects could have a significant effect on the character of recorded ground motions. However, the data in that study were too limited to isolate the effect of earthquake depth separately. In this study Japanese data recorded under similar conditions, except for focal depth, were analyzed. The depths that were considered in this analysis were determined by the International Seismological Center (ISC). These depths were thought to be more accurate than those determined by the Japan Meteorological Agency (JMA).

To investigate the effect of depth, pseudovelocity spectral ordinates at periods of 0.05, 1.0, and 3.0 sec were plotted versus CER distance for various depth ranges for magnitudes 5 to 5.9 and 6 to 6.9. Although the data are limited for depths outside the 35 to 55 km interval, Figure 7 does not indicate any appreciable differences between these data and the data within this interval. There is some suggestion of a depth effect in the magnitude 6 to 6.9 data for depths greater than 55 km. The pseudovelocities for these data appear to be higher than the general level of the other data. However, this trend is not observed for data in the magnitude 5 to 5.9 range.

Comparison of U.S. and Japanese Pseudovelocity Data

A comparison was made between Japanese and U.S. pseudovelocity spectral ordinates computed from accelerograms recorded under comparable conditions. The data were separated according to magnitude and period and were plotted versus CER distance. The U.S. data are generally from shallow-soil sites less than about 60 m in depth. To be compatible with the JMA magnitudes for the Japanese data, Richter local magnitudes (M_L) were used for the smaller U.S. earthquakes while surface wave magnitudes (M_S) were used for the larger events. The JMA magnitude scale is calibrated so as to be approximately equivalent to M_L for earthquakes up to magnitude 6 and to M_S for larger shocks (Ref. 7).

The results of the comparisons, shown in Figure 8 for magnitudes 5 to 5.9 and 6 to 6.9, indicate that the level of the Japanese pseudovelocity data is somewhat higher at a period of 0.05 sec. However, no significant differences appear to exist between the Japanese and U.S. data at the longer periods of 1.0 and 3.0 sec. Figure 9 is a comparison of the Japanese shallow-soil, pseudovelocity data in the magnitude 7-7.9 range with data from the 1952 Kern Co. earthquake of $M_S = 7.7$ or $M_L = 7.2$ (Ref. 8). All of the data shown on Figure 9 from this earthquake were from deep alluvial sites with the exception of the data from Taft (CER = 42 km), which was a shallow-soil site. The same general trends between the U.S. and Japanese data noted in Figure 8 are also seen in Figure 9.

CONCLUSIONS

Routine corrections have been made in the uncorrected Japanese accelerogram data collected for this study. Significant differences between the corrected and uncorrected accelerograms were observed at the high and low frequencies. Failure to correct these accelerograms could have a major bearing on considerations of the liquefaction potential at a site or the computed dynamic response of long or short-period structures. Furthermore, site-dependent spectra determined from uncorrected Japanese accelerograms could be overestimated at the longer periods, especially if spectral shapes are determined by first normalizing these accelerograms to the same peak acceleration (Ref. 9).

Differences in the level of the pseudovelocities with earthquake focal depth were not apparent. The scatter in the data is too large and the data are too limited to identify any effects of depth that may be present.

Comparisons between Japanese and U.S. data showed that at high frequencies, the Japanese pseudovelocity data were generally higher than the U.S. data for ranges of earthquake magnitude, CER distance and local soil conditions common to both sets of data. This observation would not have been as apparent if the Japanese accelerograms had not been corrected for the transducer response of the SMAC accelerograph. Thus, the extent these differences between the Japanese and U.S. data at high frequencies are significant depends in part on the validity of procedures used to correct the accelerograms. At the longer periods, no significant differences were observed between the Japanese and U.S. pseudovelocity data. This suggests that the attenuation of longer period ground motions may be similar in Japan and the U.S. If so, both Japanese and U.S. data could be used in a complementary manner for some applications such as determination of seismic design spectra.

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REFERENCES

1. Trifunac, M. D. and Lee, V. W. (1973), Routine computer processing of strong motion accelerograms: EERL 73-03, California Institute of Technology, 360 p.

2. Basili, M. and Brady, A. G. (1978), Low frequency filtering and the selection of limits for accelerogram corrections: Proc. 6ECEE, Dubrovnik, Yugoslavia.

3. Hudson, D. E. (1976), Interpretation of strong motion records for earthquake design criteria and structural response: Lecture No. 4, EERI and SEAOC.

4. Wong, H. L. and Trifunac, M. D. (1979), A note on an instrumental comparison of Modified Mercalli (MMI) and the Japanese Meteorological Agency (JMA) intensity scales, based on computed peak accelerations: Earthq. Eng. Struct. Dyn., v. 7, n. 1, p. 75-84.

5. Mori, K. (1979), personal communication.

6. Idriss, I. M. (1979), Characteristics of earthquake ground motions: to be published in Specialty Conference on Earthquake Engineering and Soil Dynamics, ASCE, v. III.

7. Kanamori, H. (1978), personal communication.

8. Kanamori, H. and Jennings, P. C. (1978), Determination of local magnitude, M_L, from strong motion accelerograms: Bull. Seism. Soc. Am., v. 68, n. 2, p. 471-476.

9. Crouse, C. B. (1978), Prediction of free-field earthquake ground motions: Earthquake Engineering and Soil Dynamics, Proc. ASCE Geotech. Eng. Div., v. 1, p. 359-379.

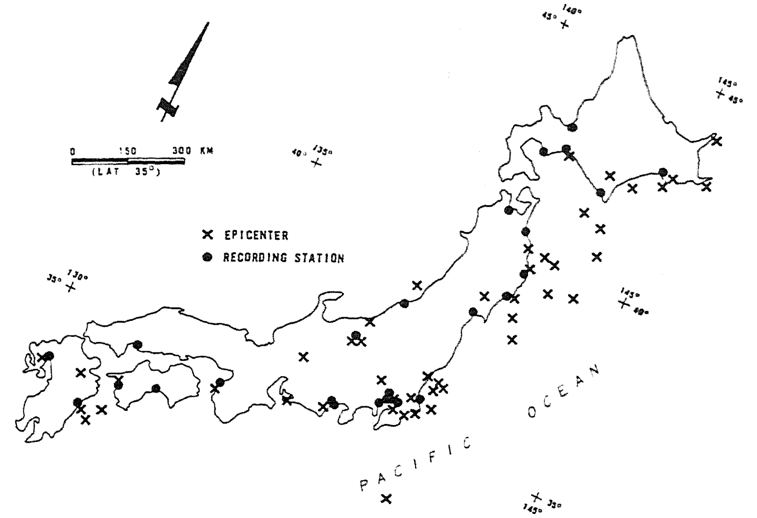

FIGURE 1. LOCATIONS OF EARTHQUAKES AND JAPANESE STATIONS WHICH RECORDED ACCELEROGRAMS PROCESSED FOR THIS STUDY

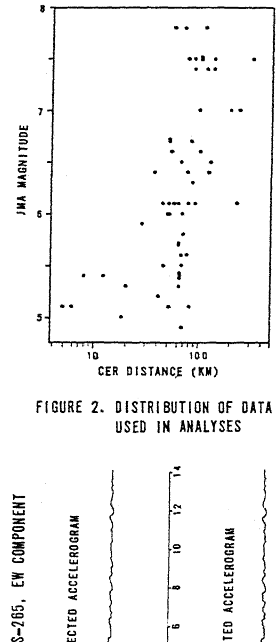

FIGURE 2. DISTRIBUTION OF DATA USED IN ANALYSES

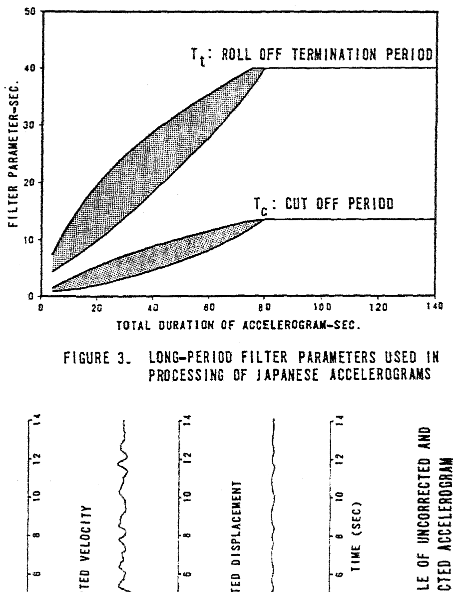

FIGURE 3. LONG-PERIOD FILTER PARAMETERS USED IN PROCESSING OF JAPANESE ACCELEROGRAMS

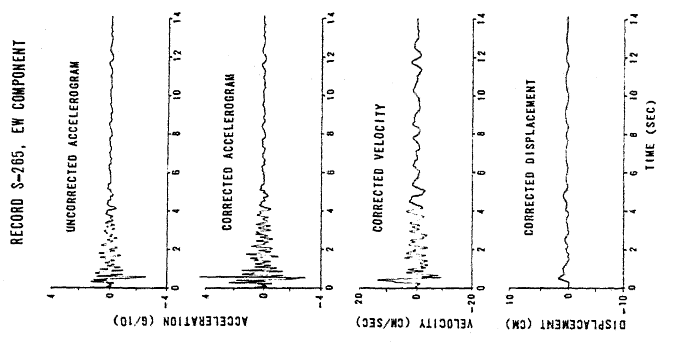

FIGURE 4. EXAMPLE OF UNCORRECTED AND CORRECTED ACCELEROGRAM

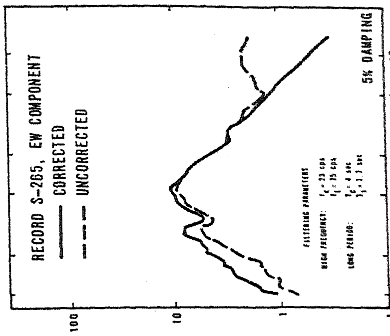

FIGURE 5. RESPONSE SPECTRA OF UNCORRECTED AND CORRECTED ACCELEROGRAM

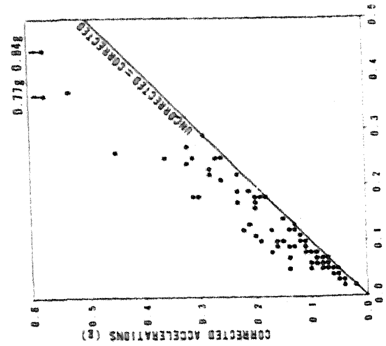

FIGURE 6. MAXIMUM ACCELERATIONS FOR CORRECTED AND UNCORRECTED JAPANESE ACCELEROGRAMS

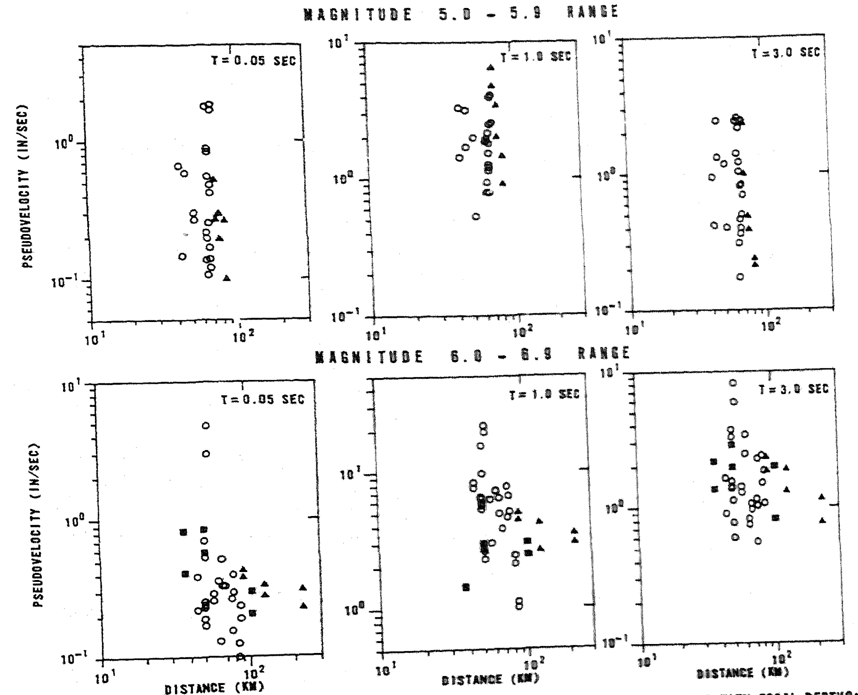

FIGURE 7. JAPANESE PSEUDOVELOCITY DATA FOR SHALLOW-SOIL SITES FROM EARTHQUAKES WITH FOCAL DEPTHS: 0–34km (■), 35–55km (○), 56–160km (▲). 5% DAMPING

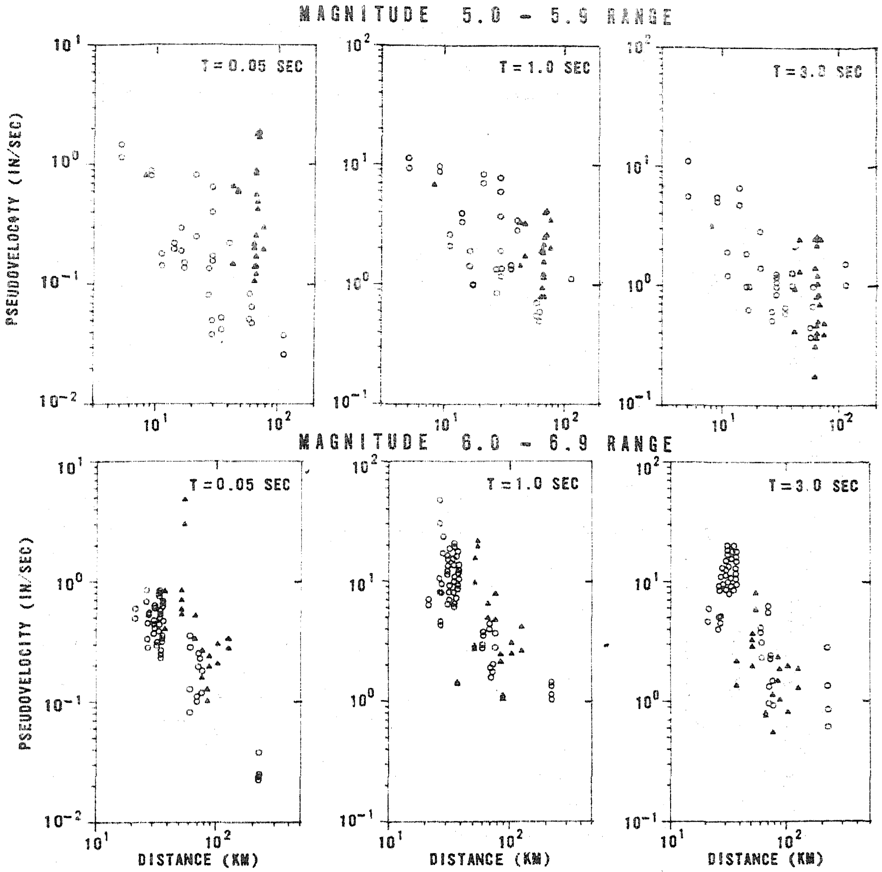

FIGURE 8. COMPARISON OF SPECTRAL ORDINATES FOR JAPANESE (▲) AND U.S. (○) SHALLOW-SOIL DATA. 5% DAMPING

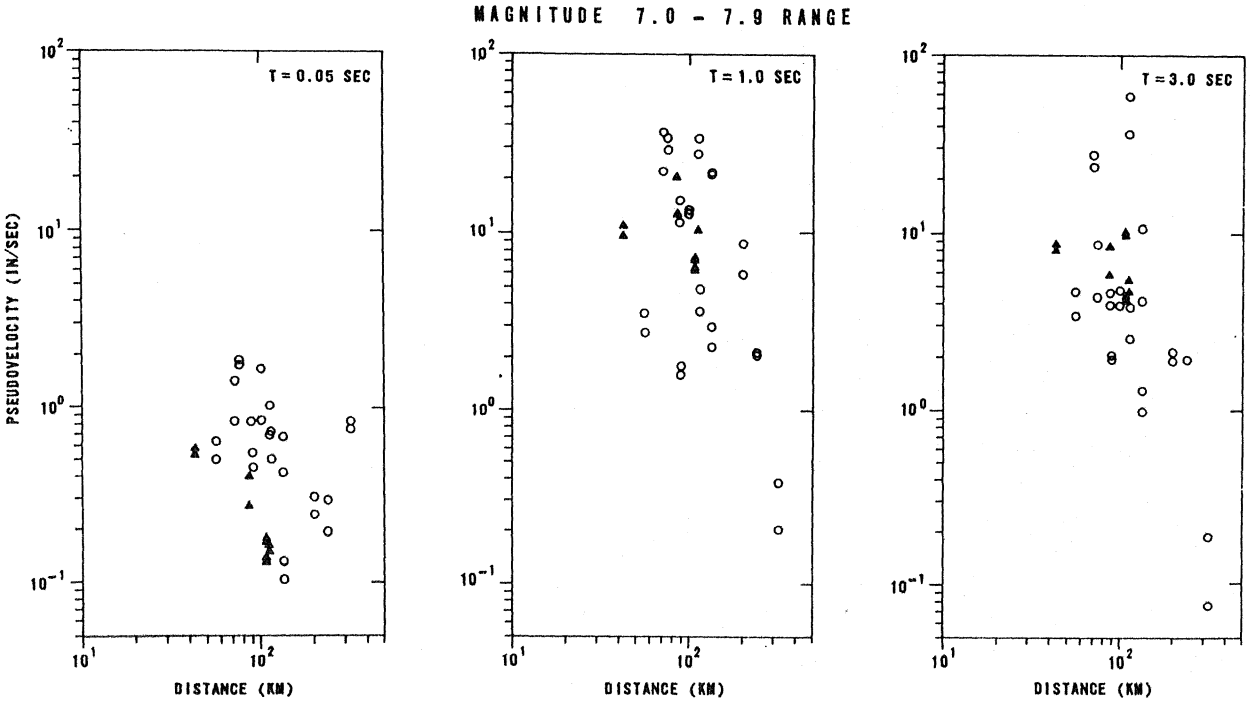

FIGURE 9. COMPARISON OF SPECTRAL ORDINATES FOR JAPANESE SHALLOW-SOIL DATA (○) IN MAGNITUDE 7.0-7.9 RANGE AND DATA FROM 1952 KERN COUNTY EARTHQUAKE (▲). 5% DAMPING