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EMPIRICAL RELATIONS AMONG AVERAGE MAXIMUM GROUND ACCELERATION, EARTHQUAKE MAGNITUDE AND EPICENTRAL DISTANCE

地震動最大加速度・マグニチュード・震央距離の関係について

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1. Introduction

The maximum ground acceleration of an earthquake motion is one of the most important factors for the practical aseismic design of structures. Most of the previous results concerning the maximum earthquake acceleration were obtained by assuming certain relations between the earthquake intensity scale and the acceleration values, or by generalizing a result determined from a small number of measured accelerations. However, strong-motion accelerograms accumulated in Japan in last twenty years can now be used to directly correlate the maximum acceleration with earthquake magnitude and epicentral distance.

2. Data Used

Acceleration values used were all recorded by strong-motion accelerographs (mostly SMAC-B2 Type) installed on the ground surface. A total of 660 horizontal maximum acceleration values from 46 earthquakes recorded in Japan during the period from 1963 to 1970 were used for the analysis. Two horizontal component accelerations recorded at a station were considered as independent quantities. The smallest magnitude was 5.1 and the 1968 Tokachi-oki earthquake gave the largest magnitude of 7.9. Table 1 shows the numbers of earthquakes for different ranges of magnitude. The effect of focal depth was not included.

Table 1 Number of Earthquakes for Different Magnitude Ranges

Magnitude Range	Number of Earthquakes
5. 1–5. 4	6
5. 5–5. 9	8
6. 0–6. 4	14
6. 5–6. 9	11
7. 0–7. 4	2
7. 5–7. 9	5

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3. Least Square Fitting

The maximum acceleration values were divided into four groups according to the magnitude ranges as shown in the first two columns of Table 2 together with the number of data. Least square fitting was carried out by assuming the following relationship between the maximum horizontal acceleration a_{max} (gal) and the epicentral distance Δ (km)

$$\log_{10} a_{max} = A - B \log_{10} \Delta. \qquad (1)$$

The results are shown in the third and fourth columns of Table 2. Approximate ranges of epicentral distance for which the proposed formulas are applicable are shown in the last column of Table 2. The ranges were determined by considering the distributions of epicentral distances of the data used and the effect of focal depth. Fig. 1 shows the original data and the straight line determined by least square fitting for the case of $6.5 \leq M \leq 7.4$. The values of constants A and B are plotted in Fig. 2 against the approximate average magnitude.

Table 2 Results of Least Square Fitting

Magnitude Range	Number of Accel. Data	Constants in Eq. (1)		Range of Δ for Which Eq. (1) is Applicable (km)
		A	B	
5. 1-5. 4	60	2. 824	0. 868	30-200
5. 5-6. 4	238	3. 172	0. 993	30-400
6. 5-7. 4	220	3. 891	1. 184	50-1000
7. 5-7. 9	142	4. 989	1. 470	70-1000

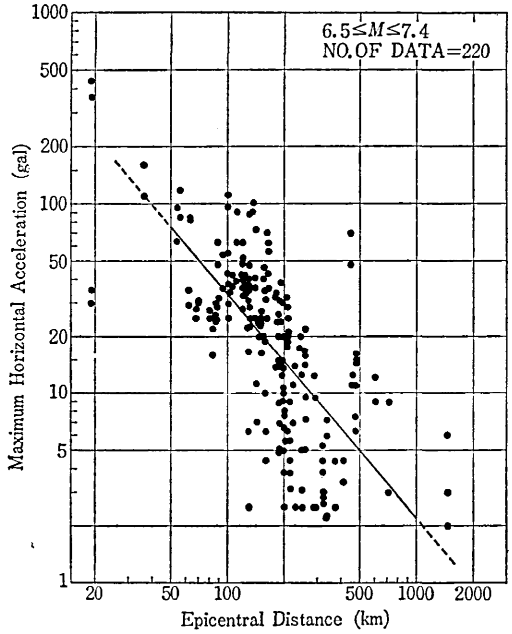

Fig. 1 Maximum Horizontal Acceleration Vs. Epicentral Distance for $6.5 \leq M \leq 7.4$

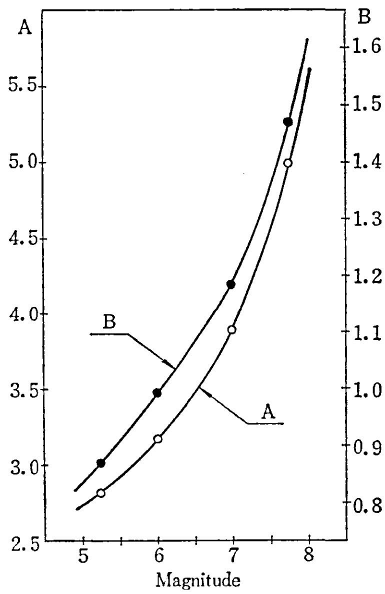

Fig. 2 Constants A and B in Eq. (1) Vs. Average Magnitude

4. Distribution of Maximum Ground Acceleration

The acceleration value determined by Eq. (1) for a given epicentral distance and a prescribed range of magnitude (or, possibly, for an arbitrary value of magnitude by use of the relations shown in Fig. 2) shall be called the average maximum acceleration. As can be seen from Fig. 1, the

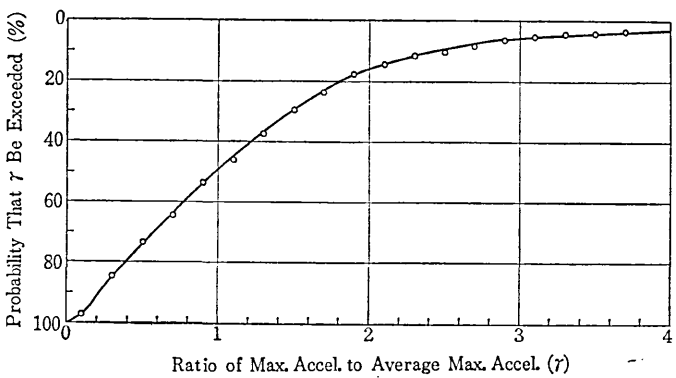

Fig. 3 Distribution of Maximum Ground Acceleration

actual measured values are greatly deviated from the least square fitted line. Hence, the values of the ratios

$$\gamma=\frac{\text{measured max. acceleration}}{\text{average max. acceleration}}$$

were calculated and their distribution was obtained. Here, the denominators were computed by using the constants A and B in Table 2 for each of the ranges indicated. The result is shown in Fig. 3.

The following example illustrates the meaning of the distribution given in Fig. 3. Let us find the maximum ground acceleration of an earthquake of $M=7$ at an epicentral distance of 50 km for which the probability of being exceeded is 10%. For $M=7$ and $\Delta=50$ km, from Eq. (1) together with the values of constants A and B in Table 2 the average maximum acceleration can be computed as 76 gal. Since, from Fig. 3, the value of γ for the 10% probability of being exceeded is approximately 2.4, the desired maximum acceleration is $76\times2.4=182$ gal.

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