

STUDY OF REGIONAL CHARACTERISTICS OF EARTHQUAKE MOTIONS  
BASED ON ACTIVITY IN JAPAN

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SUMMARY

This paper deals with the expected maximum values of the intensity of future earthquakes in and near Japan, utilizing the following earthquake data and method of analysis.

- (1) The earthquake data measured and estimated in and near Japan for the period of 1644—1972.
- (2) Dr. Kanai's formula which estimates maximum velocity on the base rock from the epicenter distance and the earthquake magnitude.
- (3) Gumbel's Second Asymptotic Distribution in the statistics of extremes.

Regional distribution of the expected maximum velocity on the base rock is estimated for the return periods 50, 100 and 200 years in and near Japan.

INTRODUCTION

It is one of the most important problems in earthquake engineering to predict the intensity of future earthquakes statistically from the past available earthquake recording data, as precise earthquake forecast is difficult in the present stage. In the process of the prediction, the selection of the past earthquake data and statistical method of analysis are the most essential, because the available earthquake data are not sufficient.

This paper deals with the expected maximum values of the velocity of future earthquakes on the base rock in and near Japan vs. return periods 50, 100 and 200 years by utilizing the most reliable earthquake data for the period of 1644—1972 and Theory of Extremes developed by E. J. Gumbel.

EARTHQUAKE DATA

Two kinds of earthquake data are used in this paper as follows,  
1) Period 1644—1925: It is considered that the distribution of the population in Japan was relatively even and stable for the period of 1644—1925 and the number of the destructive earthquakes listed in the Science Calendar of Japan is relatively large in that period (166 destructive earthquakes) compared with the time before the period. Therefore, the destructive earthquake data in the period are presumed to be reliable.  
2) Period 1926—1972: The earthquake data obtained by instrumental observation for the period of 1926—1972 are reported in the Catalogue of Major Earthquakes or the Seismological Bulletin by Japan Meteorological Agency in which all the earthquakes with the magnitude  $M \geq 5.0$  are considered to be included.

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## ESTIMATION OF EARTHQUAKE INTENSITY

Many empirical formulae concerning the relationship of intensity, magnitude and epicentral distance have been proposed by many investigators.

In this paper, the following Dr. Kanai's Formula which indicates the maximum velocity of earthquake motion on the base rock was used for the estimation of earthquake intensity.

$$\log_{10} V_0 = 0.61M - \left(1.66 + \frac{3.60}{r}\right) \log_{10} r - \left(0.631 + \frac{1.83}{r}\right) \dots \dots \dots (1)$$

where  $V_0$ : Maximum amplitude of velocity of earthquake motion on the base rock

$M$  : Magnitude of earthquake

$r$  : Epicentral distance

### THEORY OF EXTREMES

E. J. Gumbel's Second Asymptotic Distribution was utilized to predict the expected values of earthquake intensity vs. return period.

The cumulative probability  $\phi_m(x)$  corresponding to Gumbel's Second Asymptotic Distribution is given by

$$\phi_m(x) = \exp \left( - \left[ \frac{v - \xi}{x_m - \xi} \right]^K \right) \dots \dots \dots (2)$$

where  $x_m$  is the variable,  $\xi$  its limiting value,  $v$  its characteristic value and  $K$  an exponent.

The reduced variate  $Z_m$  for the Second Asymptotic Distribution is

$$Z_m = - \ln \left( \frac{v - \xi}{x_m - \xi} \right)^K \dots \dots \dots (3)$$

The return period  $T_r$  in years corresponding to the reduced variate  $Z_m$  is given by

$$T_r = \exp(Z_m) \dots \dots \dots (4)$$

In the calculation of the mean expected values for the maximum velocity of earthquake motion vs. return period, an iteration method introduced by Prof. M. St. Denis was used.

### EXPECTED MAXIMUM VALUES OF FUTURE EARTHQUAKES AT THE CENTER OF TOKYO

The expected maximum values of future strong earthquakes are predicted at the center of Tokyo (35.7°N, 139.8°E) using Dr. Kanai's Formula (1) and Gumbel's Second Asymptotic Distribution based on the past available earthquake data for the period of 1644—1972.

The maximum values of velocity on the base rock in each year for the period of 1926—1972 at the center of Tokyo are estimated by using the earthquake recording data obtained by instrumental observation. However, every maximum value in each year for the period of 1644—1925 is not able

to estimate, because of the lack of earthquake recording data for that period.

Table 1 shows several maximum values of velocity with  $V_0 > 2.5$  cm/sec. on the base rock at the center of Tokyo estimated by the most effective earthquakes among all the destructive ones during 1644—1925 which were described in the Science Calendar of Japan. The distribution of the strongest earthquakes in each year at the center of Tokyo during 1644—1925 was considered to have the same distribution for the period of 1926—1972 except the eleven earthquakes in Table 1.

Fig. 1 at the end of this paper shows the expected values  $\bar{X}$  of maximum velocity with standard deviation  $\sigma$  vs. return period on the base rock at the center of Tokyo predicted by Gumbel's Second Asymptotic Distribution.

Table 1 Most effective earthquakes for Tokyo (1644—1925)

A. D.	Epicentral Distance (km)	Magnitude	Maximum Velocity on Base Rock (cm/sec)	Earthquake Name
1648	77.59	7.10	2.83	Genroku Earthquake
1649	54.37	7.10	4.69	
1697	60.06	6.90	3.08	
1703	115.08	8.20	7.40	
1782	83.16	7.30	3.39	
1812	48.34	6.60	2.73	Ansei Earthquake
1854	255.03	8.40	2.86	
1855	31.99	6.90	7.13	Edo Earthquake
1894	31.33	7.00	8.42	
1921	41.90	6.60	3.30	
1923	77.59	7.80	7.56	Kwanto Earthquake

#### REGIONAL DISTRIBUTION OF EXPECTED MAXIMUM VELOCITY AT THE BASE ROCK IN JAPAN

Regional distribution of the expected maximum velocity of earthquake motion on the base rock are estimated for the return periods 50, 100 and 200 years in and near Japan, as seen in Figs, 2, 3 and 4.

#### REFERENCES

- 1) "Science Calendar", Tokyo Astronomical Observatory, Maruzen, 1976
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- 3) M. St. Denis and M. Ozaki; "Application of the Prediction of Extreme Values", Transaction of A.I.J., No. 228, Feb., 1975
- 4) M. Ozaki, Y. Kitagawa and S. Hattori; "Study on Regional Distribution of Maximum Earthquake Motions in Japan", 9th Joint Meeting, U.S.-Japan Panel on Wind and Seismic Effects (UJNR), May, 1977

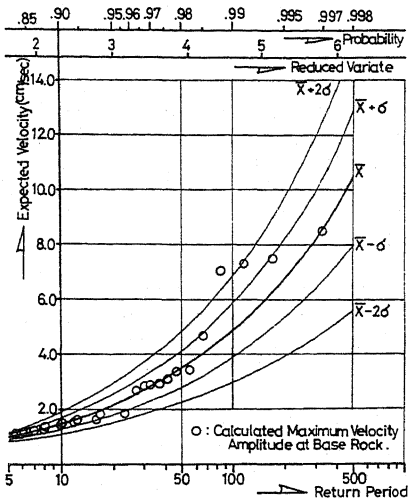


Fig. 1 Expected maximum velocity on the base rock of Tokyo vs. return period

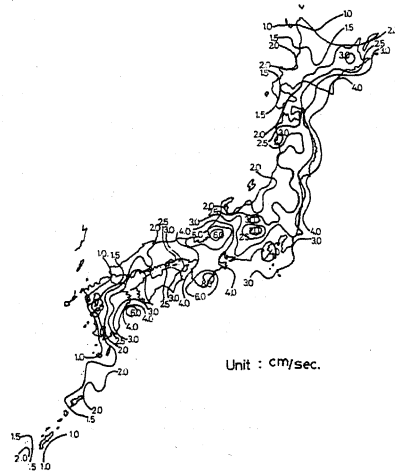


Fig. 2 Expected maximum velocity (Return period 50 years)

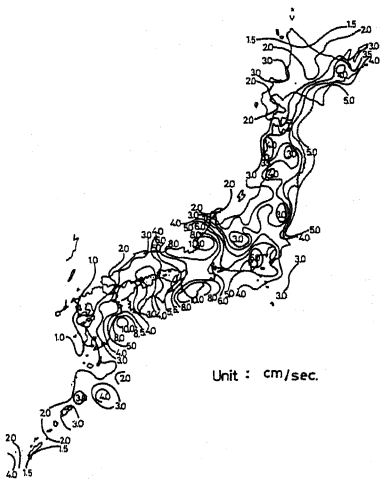


Fig. 3 Expected maximum velocity (Return period 100 years)

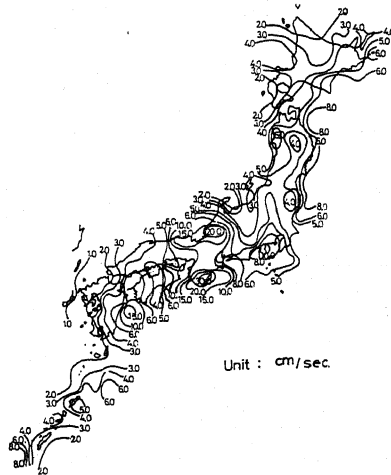


Fig. 4 Expected maximum velocity (Return period 200 years)