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AN ONLINE GRAPHIC COMPUTER PROGRAM <ERISA-G> AND ITS APPLICATION TO SEISMIC MACRO-ZONATION OF JAPAN

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SUMMARY

An online computer graphic program <ERISA-G> has been developed to facilitate engineering decision making at an arbitrary site. The macro-zonation of the seismic hazard is carried out for Japan, as one of the most practical application of the system. Nine indexes for seismic macro-zonation are considered in this study including the expected peak ground acceleration(PGA). Close examination of the differences was carried as well as the similarities among the distribution of these indexes in the whole of Japan. Because the distribution of the expected PGA was found to be correlated to those of other indexes, it is reasonable to describe the general level of seismic hazard of a region by means of the expected PGA.

INTRODUCTION

The basic parameter for designing an earthquake-resistant structure and for forecasting the structure damages due to possible future earthquake is that what is the strength the possible earthquake shaking that will attack the particular site. This kind of problem has been treated by a lot of researchers in the earthquake engineering with the accumulating data of earthquake observation records. The authors developed an online graphic computer system <ERISA-G>(Ref.1) which can analyze the earthquake risk in whole area of Japan, and can be used to facilitate engineering decision making with concerning seismic design load at an arbitrary site by furnishing, in real time, an engineer with as many possible relevant informations in the form of various graphs and tables. The basic object of this paper is to present the working of the system <ERISA-G>, and as one of the most practical applications of the system to analyze the seismic hazard of Japan.

OUTLINE OF THE SYSTEM <ERISA-G>

The hazard assessment in <ERISA-G> is basically dependent on the data of historical seismicity due to the availability of well documented catalogues of historical earthquake data in Japan. The system contains the files of different kinds of earthquake catalogues, active fault data, and mapping data. A simple Poisson model is adopted for earthquake recurrence and a regression analyses is performed at the particular site under consideration of the chosen ground motion parameter, such as the peak ground acceleration (PGA) and the acceleration response spectrum, to obtain practical indexes of engineering importance such as the expected value. By using a small number of initial input data, <ERISA-G> can display about 40 figures as well as many line-printerd output. Besides, <ERISA-G> is the name of Earthquake RISk Analysis - Graphics in terms of the capital letter part.

In this section, only the working of <ERISA-G> system is explained by showing an example of finding the expected PGA at a site. A sample site is chosen at Tokyo. The epicenter distribution map of which is plotted in Fig. 1. 325 earthquakes, of magnitudes 6.0 or more, are found to have occurred from 1885 to 1984 (period of 100 years) within a radius of 300km. The attenuation equation by which PGA is forecast from the magnitude of the earthquake and the epicentral distance is chosen from some typical currently used equations which are built in the system. Average earthquake generation frequency in a year Y was found by dividing the cumulative frequency distribution of PGA X by the record period of 100 years. Figure 2 shows the cumulative frequency curve and recurrence straight line on logarithm coordinates. The equation of recurrence is given below.

$$\log Y = 4.21 - 2.76 \log X$$

It becomes evident that "The maximum PGA is X cm/s^2 by which the return period of the earthquake shaking is T years", by requesting Y=1/T. The PGA for a return period of 100 years is 180 cm/s^2 from the above equation.

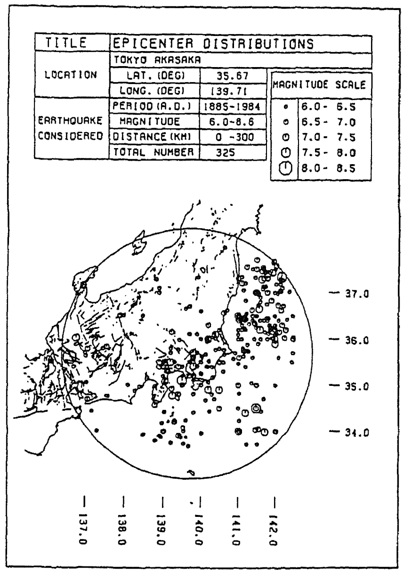


Fig.1 Epicenter Distribution Map

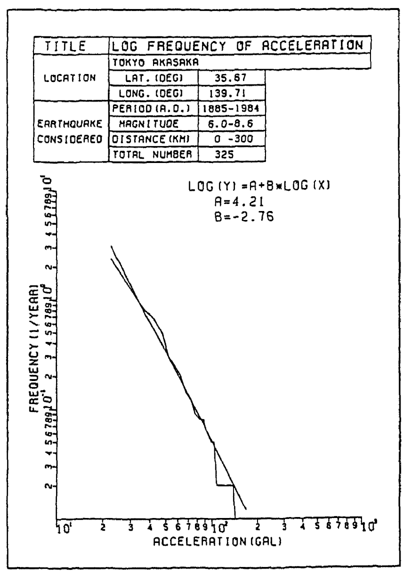


Fig.2 Recurrence Curve of Acc.

The analysis with respect to PGA, which has been described here, can be executed similarly for the acceleration response spectrum, even if the attenuation equation is assumed differently.

CONDITIONS OF MACRO-ZONATION ANALYSIS IN JAPAN

Various indexes can be considered in evaluation of the seismic hazard of the region. The question to be answered is "What may be the most appropriate index(es) to best represent the seismic hazard distribution in Japan?" The distribution of various indexes concerning the seismic hazard will be compared with each other. The conditions used for the calculation in this paper are shown below.

(1) The earthquake data is selected for last 100 years after 1885 and have magnitudes of 6 or more. Here, 1885 corresponds the year when mechanical measurement records of earthquakes started in Japan. The total number of earthquakes is about 1800 in and near Japan from Utsu catalog (Ref.2). The earthquakes whose depth exceed 100 km, and whose distance from the particular site exceed 300 km are excluded. These kind of earthquakes have generated little damage in Japan (Ref.3).

(2) The following expression for the attenuation equation of PGA is used.

$$X = 59.0 \times 10^{0.261 \times M} \times (\Delta + 10)^{-0.886}$$

This equation stands from the Design Specifications of Highway Bridge in Japan (Ref.4) for the ground condition of alluvium.
(3) The attenuation of the acceleration response spectrum is introduced by Katayama (Ref.5), which is based on a statistical analysis of the strong earthquake records in Japan.
(4) The calculation is executed on 516 intersection points which divide the whole area of Japan into the mash points of 1/3 degrees in both latitude and longitude on land. The point in the part of sea regions are not included to get statistics.
(5) The ground condition of each point is assumed as the ground of alluvium (third group of ground condition in the Design Specifications of Highway Bridge).

The distribution maps such as expected PGA and the expected acceleration response are shown by dividing them into four ranks. The shape of distribution changes largely by the values of the rank division. These values are so defined so that the numbers of points of each type is almost the same.

THE DISTRIBUTION OF PEAK GROUND ACCELERATION

The distribution of expected PGA in Japan is shown in Fig. 3. The region of the highest expected PGA can be seen to be in the regions of the Pacific Ocean shore and in a part of Japan Sea. The PGA value changed by the variation of the attenuation equation. But, as for the tendency of the distribution of the ranks of PGA, it is not affected by the variation of the attenuation equations too much.

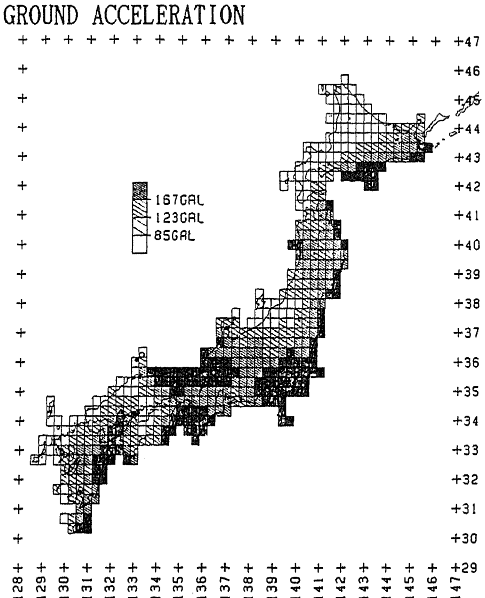


Fig.3 Distribution of Expected PGA (Tr=100 years)

The distribution of expected values is largely affected within the time period of the earthquake data. More older earthquake data than described above are not completed enough to analyze expected value statistically. But these older data may be used to estimate past maximum PGA, because the fact of earthquake occurrence in history (Ref.6) is useful information. We use these older data only to estimate past maximum PGA. Figure 4(a) and (b) shows the resulting distribution of past maximum PGA and reflects the effect of the time period of chosen earthquake data. Figure 4(a) shows the distribution by which the estimated values of past maximum PGA are calculated by the data of past 100 years. In this figure, large values are obtained in the Pacific Ocean shore of northeast Japan and it is similar to Fig. 3. This figure indicates some other regions of high rank due to the effect of large intraplate earthquakes, for example Nobi Earthquake(M=8.0), Niigata Earthquake(M=7.5), etc. In Fig. 4(b) an increase of chosen recording period by 1200 years,

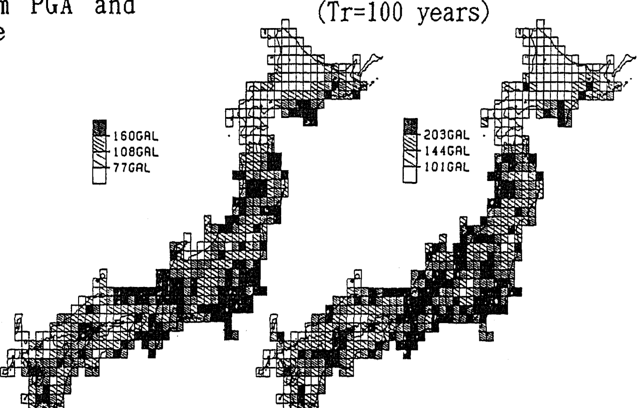
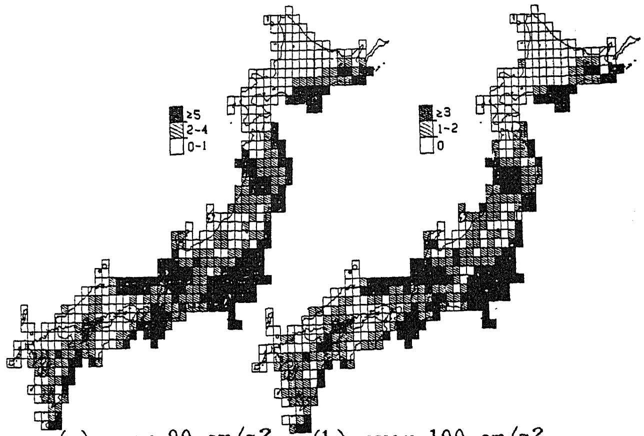


Fig.4 Distribution of Estimated Past Maximum PGA

leads to 300 additional earthquakes and results in a more separated and complicated tendency than Fig. 4(a).

The distributions of the number of earthquake shaking are analyzed. Figures 5(a) and (b) show whether earthquake shaking exceeded a certain level of maximum PGA or not and how many times this accedence occurred in past 100 years since 1885. The threshold values are set as 80 cm/s^2 (Fig. 5(a)) and 100 cm/s^2 (Fig. 5(b)). Where 80 cm/s^2 correspond to lower limit of Japan Meteorological Agency (JMA) intensity 5. The calculated values of rank division are different in two maps but both distributions have similarly looking to Fig. 3.



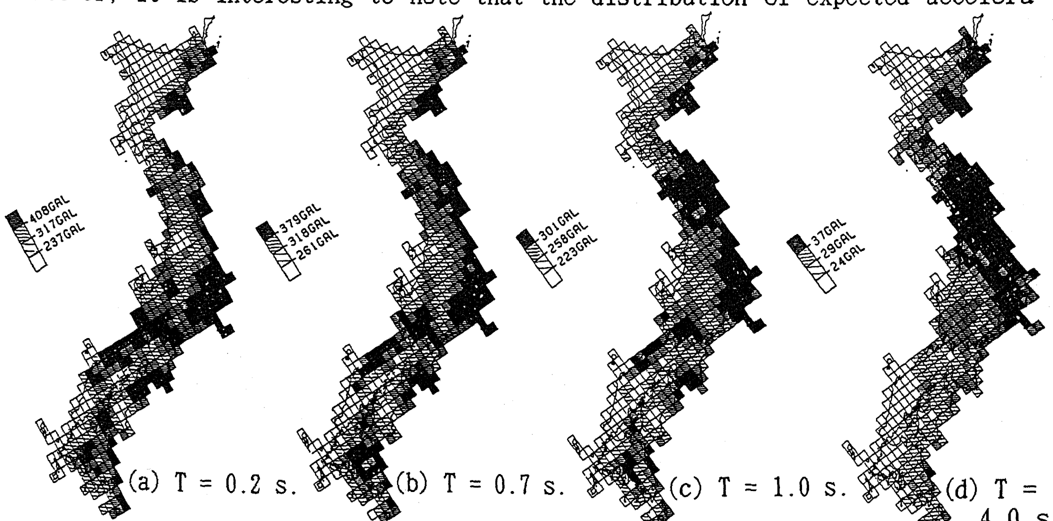
(a) over 80 cm/s^2 (b) over 100 cm/s^2

Fig.5 Distribution of Number of Earthquakes

DISTRIBUTION OF RESPONSE ACCELERATION

An earthquake of large magnitude has a possibility to cause the effect to a long period structure located at far distance. Acceleration response spectrum SA(T,h) of a structure of single degree of freedom (SDOF) system is calculated from the data of magnitude and epicentral distance, where T is the natural period and h is the damping ratio of SDOF system. The expected acceleration response of SDOF system at h=0.05 was calculated for the natural periods of 0.2, 0.7, 1.0, and 4.0 second. The earthquake data for this expected response analysis is based on JMA catalog (Ref.7)(M=5.0-5.9, since 1926) in addition to the data of Utsu catalog, and take count of 5300 earthquakes.

Figure 6 shows the distributions of expected acceleration response for a return period of 100 years. It is understood, by comparing the four maps in Fig. 6, that the shape of the highest intensity blocks becomes concentrated in northern part of Honsyu Island, as the natural period of the structure increases. Moreover, it is interesting to note that the distribution of expected accelera-



(a) T = 0.2 s. (b) T = 0.7 s. (c) T = 1.0 s. (d) T = 4.0 s.

Fig.6 Distribution of Expected Acceleration Response tion response at 0.2 and 0.7 second similar to the distribution of expected PGA in Fig. 3. The values of expected acceleration response (T=0.7s) are amplified about 2 to 3.5 times compared with expected PGA's in average.

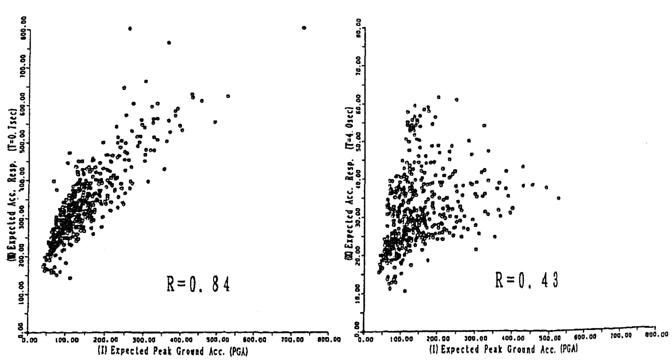
CORRELATION BETWEEN VARIOUS INDEXES

The following indexes are considered in this study.

(Ⅰ) Expected PGA as 100 years
(Ⅱ) Estimated past maximum PGA in 100 years
(Ⅲ) Estimated past maximum PGA in history
(Ⅳ) Number of earthquakes over 80 cm/s^2 in 100 years
(Ⅴ) Number of earthquakes over 100 cm/s^2 in 100 years
(Ⅵ) Expected acceleration response (T=0.2s) in 100 years
(Ⅶ) Expected acceleration response (T=0.7s) in 100 years
(Ⅷ) Expected acceleration response (T=1.0s) in 100 years
(Ⅸ) Expected acceleration response (T=4.0s) in 100 years

These indexes are considered to show the several aspects of the seismic hazard. Close examination of correlation coefficients among the distributions of these indexes supplies basic information which makes it possible to establish more quantitative and rational seismic macro-zonation for Japan.

The correlation coefficients between two indexes are calculated and shown in Fig. 7 for examples. Figure 7(a) shows good correlation relation between expected PGA and expected acceleration response (T=0.2s). It is able to presume the expected acceleration response (T=0.2s) from this relation, if expected PGA is known. Figure 7(b) shows low correlation relation between expected PGA and expected acceleration response (T=4.0s).



(a) Exp. Acc. Resp.(T=0.2s) (b) Exp. Acc. Resp.(T=4.0s)

Fig.7 Correlation Relations to Expected PGA

The correlation coefficients about all of nine indexes are shown in Table 1. The emphasized part in this table indicates indexes having correlation coefficient exceeding 0.8 or below 0.5. The expected PGA has high correlation coefficients with other indexes and major findings are as follows:

(1) The expected PGA was found to have medium correlation with the past maximum PGA though the richness of historical earthquake data in Japan.
(2) The distribution of the expected PGA's is similar to that of the numbers of ground shaking with PGA ≧ 100 cm/s^2, and also to the numbers of ground shaking with JMA intensity ≧ 5.
(3) The distribution of the expected PGA's is in good agreement with that of the expected acceleration response of a SDOF system if its period T is properly chosen. For the alluvial ground site, the agreement is best when T ≒ 0.7 s.

The low correlation part is concentrated to the past maximum PGA in history and to the expected acceleration response of structures with T=4.0 s. Hence, it is appropriate to consider the expected PGA as the basic index to evaluate the seismic hazard at a particular site. The expected response of long period structures has information which cannot be expressed by the expected PGA.

Table 1 Correlation Coefficients between Nine Indexes

Expected PGA As 100 year	Past Max. PGA in 100yrs.	Past Max. PGA in history	Number over 80 cm/s² in 100 years	Number over 100 cm/s² in 100 years	Expected Acc Response T=0. 2sec	Expected Acc Response T=0. 7sec	Expected Acc Response T=1. 0sec	Expected Acc Response T=4. 0sec		
Fig. 3	Fig. 4(a)	Fig. 4(b)	Fig. 5(a)	Fig. 5(b)	Fig. 6(a)	Fig. 6(b)	Fig. 6(c)	Fig. 6(d)		
I	II	III	IV	V	VI	VII	VIII	IX		
1. 0	0. 68	0. 53	0. 83	0. 84	0. 80	0. 84	0. 72	0. 43	I	Expected PGA As 100 year
	1. 0	0. 74	0. 66	0. 69	0. 69	0. 69	0. 64	0. 42	II	Past Max. PGA in 100 years
		1. 0	0. 53	0. 60	0. 53	0. 49	0. 46	0. 27	III	Past Max. PGA in history
			1. 0	0. 95	0. 70	0. 72	0. 64	0. 56	IV	Number > 80 cm/s² in 100 years
				1. 0	0. 72	0. 75	0. 68	0. 60	V	Number > 100 cm/s² in 100 years
					1. 0	0. 92	0. 79	0. 42	VI	Expected Acc Resp. T=0. 2 sec
						1. 0	0. 90	0. 57	VII	Expected Acc Resp. T=0. 7 sec
							1. 0	0. 80	VIII	Ecpected Acc Resp. T=1.0 sec
								1. 0	IX	Expected Acc Resp. T=4.0 sec

R ≧ 0. 8

R ≧ 0. 8 But less meaning

R < 0. 5

CONCLUSION

The seismic hazard has been calculated with using the system <ERISA-G>. Nine indexes related to the seismic hazard are calculated and the characteristics of these distribution are examined in Japan. From discussions the expected PGA has good correlation to almost all indexes with excluded the expected acceleration response of long period structure. Therefore, it is understood that the expected PGA is the basic index to evaluate the seismic hazard. But, the expected acceleration response of long period structures has low correlation to the expected PGA. At the end of paper, we should note that the strength of expected PGA calculated by the attenuation equation is largely affected by its equation variation. And, further studies are needed to obtain an index, which reflects the period of a structure, from the earthquake-resistant-design point of view.

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