Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.II)

2-2-11

SEISMIC ENVIRONMENT ANALYSIS THROUGHOUT JAPAN

Gengo MATSUI[1], Akira NISHITANI[1] and Yoshihiko KOMATSUBARA[2]

[1]Department of Architecture, Waseda University,
Shinjuku-ku, Tokyo, Japan
[2]Goldman Sachs & Co., Minato-ku, Tokyo, Japan

SUMMARY

This paper discusses substantial seismic risk assesment throughout Japan based on the latest historical records of earthquakes applying the extreme value distribution analysis. The seismic risk maps are obtained in terms of the expected maximum ground accelerations.

INTRODUCTION

It has been more than 30 years since "Kawasumi Map" (1) was published in 1951. Seismic risk zoning for structural design of architecture in Japan is still basically based on this map. However, many of the historical record informations of earthquakes in Japan have been modified. Additionally, reliability-based seismic design is required for some kind of structures such as atomic plants, etc. It is essentially associated with the seismic risk assessment i.e. the probability of earthquake occurrences. This paper analizes the earthquake occurrence probability in terms of the expected maximum ground accelerations on the basis of the latest historical data of earthquakes.

HISTORICAL RECORDS OF EARTHQUAKES

Figure 1 shows the locations of the epicenters of the historical earthquake records provided by Chronorogical Scientific Tables (2). Significant increase of the number of earthquakes after 1603 is recognized. This is because less historical records are available before 1603. Therefore, this paper discusses the probability of earthquake occurrences based on the latest historical data after 1603 including the recently modified data.

METHODS AND RESULTS

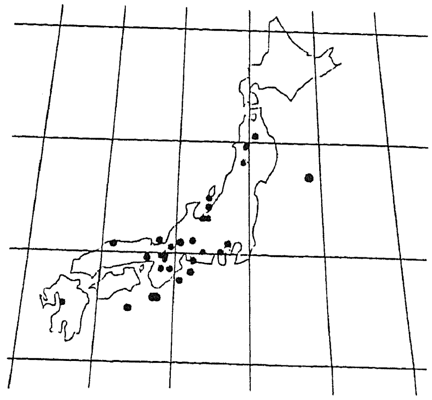
The relationship between Seismic Scale (I) and Magnitude (M) at an arbitrary point Δ km away from the epicenter is given by the following (3) :

$$I = I_{100} - b\ (\Delta - 100) \tag{1}$$

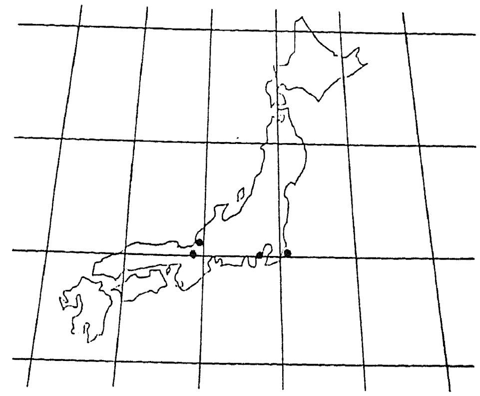
where

$$I_{100} = 1.45\ M - 5.8 \tag{2}$$

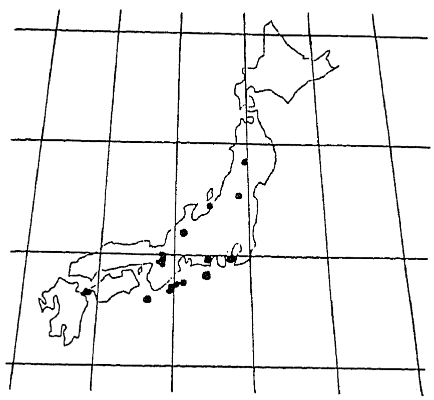
and



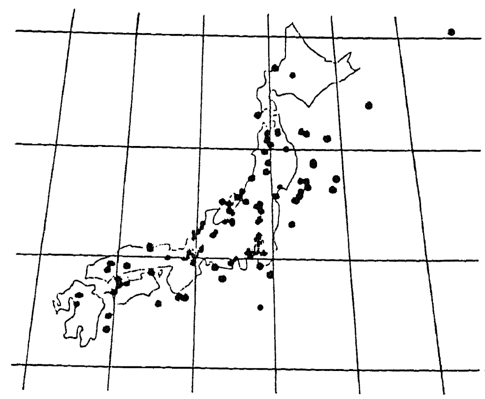
Yamato, Nara, Heian Era
(679 - 1191)



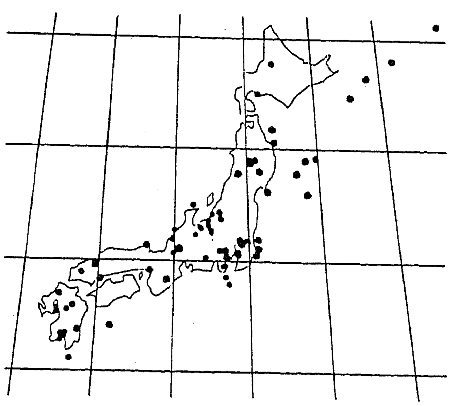
Kamakura Era (1192 - 1333)



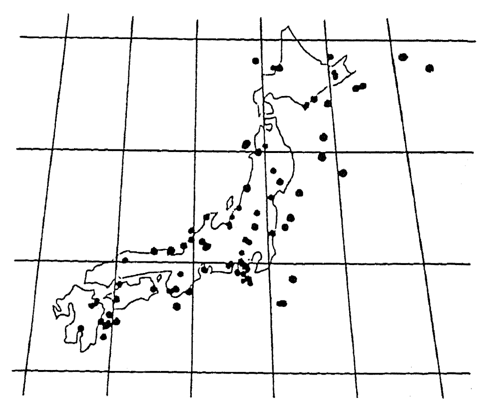
Muromachi Era (1334 - 1602)



Edo Era (1603 - 1866)



Meiji, Taisho Era (1867 -1925)



Showa Era (1926 - 1983)

Fig. 1 Number of Earthquakes from Historical Records

$$b = .121 - .026\ M + .015\ M^2 \quad (3)$$

Using the above relationship, Seismic Scale at a certain site canbe estimated from each hiatorical record. Then the extreme value distribution analysis is applied to these estimated values.

Suppose there are annual maximum records of Seismic Scales during N years : $X_1, X_2, \cdots, X_N$. These data are rearranged in increasing order as follows :

$$X_{(1)} \leqq X_{(2)} \leqq \cdots \leqq X_{(R)} \leqq \cdots \leqq X_{(N)}$$

The cummurative distribution of $X_{(R)}$ is estimated by

$$F(X_R) = R\ /\ (N + 1) \quad (4)$$

Since $F(X_R)=\exp[-\exp(-y_R)]$ with $y_R=\alpha(X_R-u)$ for the extreme value distribution, y_R is given by the following :

$$y_R = -\ln\ [-\ln\{R/(N+1)\}] \quad (5)$$

By plotting (X, y) on the probability paper with one axis for X and the other axis for y and drawing the straight line by the least square method, the values of α and u can be determined. In this case it has been known that the variaion of X is Gaussian distributed with the standard deviation given by (4,5)

$$\sigma = [(.7100 + .1667\ y + .6687\ y^2)\ S_X{}^2/N]^{1/2} \quad (6)$$

where

$$S_X = \pi/(\sqrt{6}\,\alpha) \quad (6)$$

Hence, the variation of X is also estimated for given y. Figure 2 shows these relationship based on the historical data during 380 years after 1603 for ten cities : Kyoto, Tokyo, Nagoya, Fukui, Osaka, Hiroshima, Kochi, Niigata, Sendai and Kagoshima. The locations of these ten cities are shown in Fig. 3.

In Fig. 2 the middle solid straight lines have been determined by the method of least squares, whereas the envelop lines represent the band widths of $\pm 2\sigma$ from the middle lines.

Provided an average return period is T_X, then the cummurative distribution function is evaluated by

$$F(X) = 1.0/\ [1.0 - \exp\{-\ \exp(-y)\}] \quad (7)$$

where

$$y = \alpha\,(\ X - u\ )$$

with α and u already obtained.

From both envelope lines in Fig. 2 two Seismic Scales are obtained for each city concerning given T_X. Furthermore, there is a relationship between Seismic Scale (I) and the maximum ground acceleration (a) as follows (1) :

$$a = 0.45 \times 10^{0.5I}, \qquad I \leqq 5.5 \quad (8)$$

$$a = 20 \times 10^{0.2I}, \qquad 5.5 \leqq I \leqq 6.5 \quad (9)$$

From the above relationship two values of the maximum ground accelerations for each city are also obtained. They are shown in Table 1.

On the basis of the analysis above mentioned the expected maximum ground accelerations for 75 year and 100 year return periods are demonstated throughout Japan in Figs. 4 and 5, respectively. In these figures the values are calculated without considering the variation.

CONCLUDING REMARKS

The seismic risk assessment throughout Japan has been discussed in terms of the expected maximum ground accelerations by applying the extreme value distribution analysis.

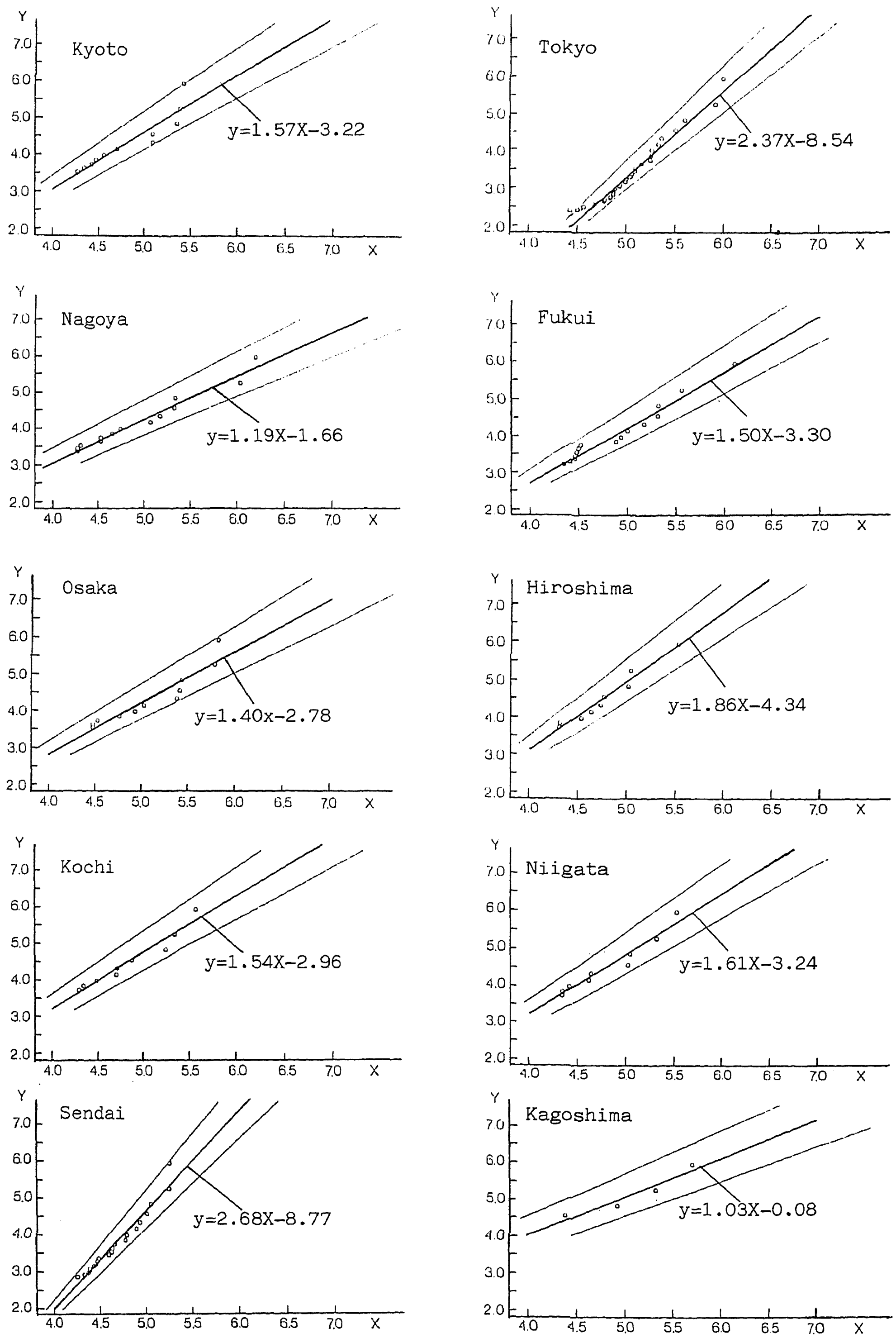


Fig. 2 Plotting Seismic Scales

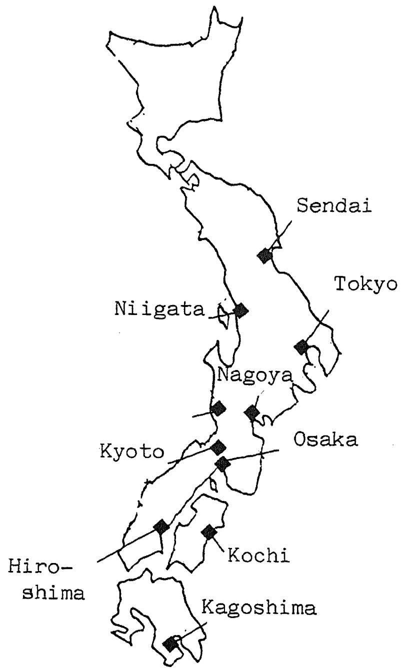


Fig. 3 Locations of Ten Cities

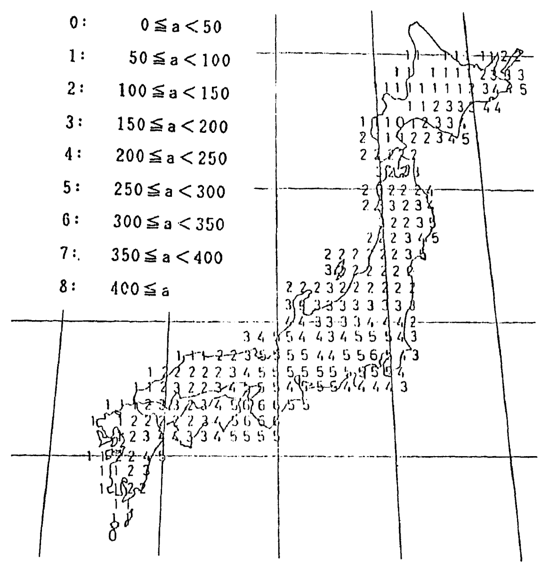


Fig. 4 Expected Maximum Ground Accelerations for 75-year Return Period

Table 1 Expected Maximum Ground Accelerations

Return Period		50		75		100	
Kyoto	a(gal)	88	191	121	263	152	294
Tokyo	a(gal)	155	238	185	268	210	285
Nagoya	a(gal)	66	155	94	241	120	280
Fukui	a(gal)	79	156	105	220	128	263
Osaka	a(gal)	77	159	104	231	129	270
Hiroshima	a(gal)	56	97	71	129	83	157
Kochi	a(gal)	54	105	71	147	86	186
Niigata	a(gal)	54	101	70	140	84	175
Sendai	a(gal)	86	125	100	152	112	174
Kagoshima	a(gal)	24	63	36	105	47	150

When the variation is considered, the maximum ground accelerations show the significant differnces even for the same average return period.

Additionally, it is expected that the seismic risk differs from site to site even in the same city when the ground features are considered. The analysis including the ground feature effects will be in future studies.

REFERENCES

1. Osaki, Y., Earthquake and Architecture, Iwanami, Tokyo, 1983
2. Chronorogical Scientific Tables, Tokyo Astronomical Observatory (ed.), Maruzen, Tokyo, 1987
3. Utsu, T., "Relation between Seismic Intensity, Epicentral Distance and Magnitude, Part 1," Bulletin of the Earthquake Research Institute, Vol.59, Part 2, University of Tokyo, 1984
4. Lawson, T.V., Wind Effects on Buildings Vol. 2, Applied Science Publishers, London, 1980
5. Ang, A.H-S., and Tang, W.H., Probability Concepts in Engineering Planning and Design Vol. 1, Wiley, New York, 1975

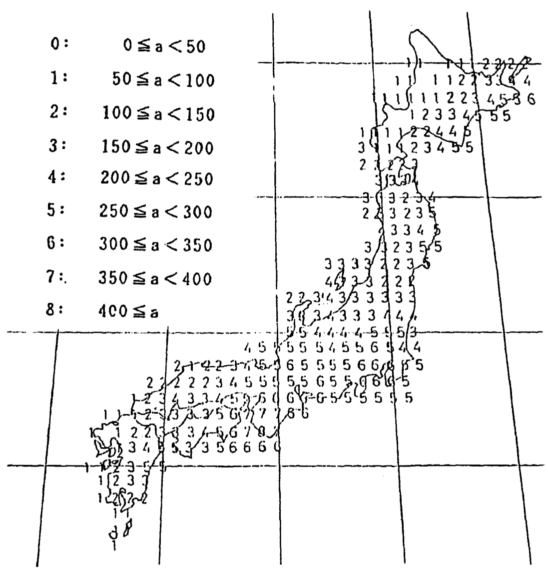


Fig. 5 Expected Maximum Ground Accelerations for 100-year Return Period