Earthquake Engineering, Tenth World Conference © 1992 Balkema, Rotterdam. ISBN 90 5410 060 5

Development of seismic acceleration map for Central Japan

K.Ishii
Ohsaki Research Institute, Inc., Tokyo, Japan
T.Sugiyama, K.Maeda & T.Okumura
Electric Power Research Center of Chubu Electric Power Co., Inc., Nagoya, Japan

ABSTRACT: This paper describes the development of a seismic hazard map for the Central region of Japan by combining the seismic hazards which are independently evaluated based on two different databases: historical earthquake catalog and active fault data. To combine the two results, the seismic hazard based on historical earthquake catalog is adopted as the basis considering the quantitative accuracy of the two databases. Then, when the seismic hazard based on the active fault data is greater than that, the expected hazard is modified accounting for the result based on the active fault data so that the earthquake with long recurrence time are taken into consideration in the seismic hazard map.

1. INTRODUCTION

The purpose of this study is to develop a seismic hazard map for the Chubu region of Japan. The Chubu region locates in the central part of Honshu island where several destructive earthquakes have occurred in the past centuries. These destructive earthquakes are categorized into two groups: large earthquakes along the plate boundary (Nankai trough); and moderate to large ones occurred in the crust of the inland area. Although a historical earthquake catalog which covers more than 1,000 years of period is available for this district, the latter type of earthquakes are not completely covered by the catalog because of their longer recurrence time. In other words, in some of the areas in the region, only a few major earthquakes are recorded in the catalog whereas many active faults are found there.

In this study, taking into account the fact mentioned above, the seismic hazards are first evaluated based on the two independent databases: historical earthquake catalog and active fault data. The seismic hazards based on the historical earthquake catalog and on the active fault data are then combined in the following manner. First, the seismic hazard based on the historical earthquake catalog is used as the basis considering the quantitative accuracy of the databases. Then, when the seismic hazard based on the active fault data is greater than that, the expected hazard is modified accounting for the result based on the active fault data so that the earthquakes with long recurrence time are taken into consideration in the seismic hazard map.

In this manner, the combined seismic hazard map in terms of the peak ground acceleration at a stiff ground surface with the probability of exceedance of 63% in 75 years is developed.

2. SEISMIC HAZARD ANALYSIS MODELS

2.1 Historical earthquake catalog model

Three earthquake catalogs (T.Usami,1979, T.Utsu,1982, JMA,1982 and JMA, 1961-1983) are combined and used in this study. They cover approximately 400 years (1600~1983). The data prior to the period are not used since even large earthquakes are not completely recorded in that period. These catalogs are composed of the magnitude of earthquake, location of epicenter, depth of hypocenter and time of occurrence.

In this model, area sources are used throughout the region. The seismic activity parameters of each area source are statistically determined based on the catalog, and the distribution of magnitude is obtained using Gutenberg-Richter's equation. The upper bound of magnitude in each area source is the maximum one in the historical earthquake catalog, and the lower bound is 5.0 for all sources. The occurrence of earthquakes is assumed to follow the Poisson process.

The seismic hazard analysis is carried out following the methods proposed by ANS/IEEE(1983) and C.A. Cornell(1968).

2.2 Active fault data model

Many active fault data have been

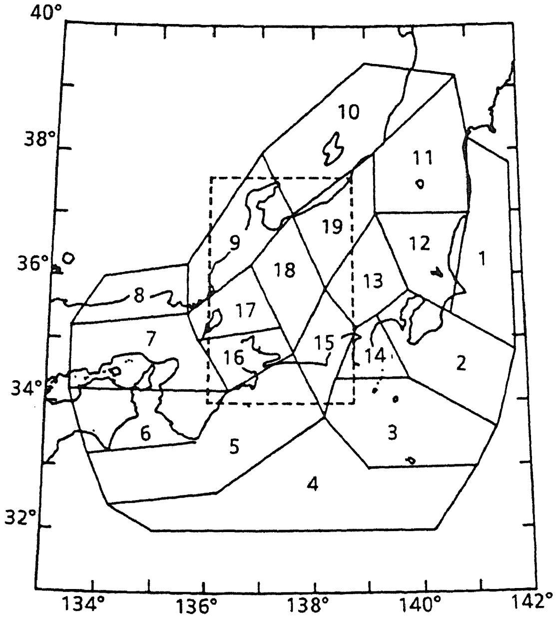

Fig.1 Area Sources for Historical Earthquake Catalog Model

accumulated in resent years. Active Faults in Japan (1980) classifies the Quaternary active faults on land into three ranks of certainty. The faults with the first and second rank of certainty are used in this study. The on-land fault data is composed of location of fault, fault length and average slip rate as well as the rank of certainty. In addition to these on-land faults, "well defined" and "inferred" offshore faults drawn on the seabed geological map by Maritime Safety Agency are used. Since the degree of activity is not available for these offshore faults, high degree of activity is assumed for them.

In this model, line sources are used to represent the faults, assuming that each fault is an independent source of earthquakes. The mean occurrence rate of an earthquake on each fault is calculated from the average slip rate of the fault through the earthquake energy by employing the following equations (Matsuda,1975, Gutenberg & Richter,1956):

$$\log D = 0.6\,M - 4.0 \quad (\mathrm{m}) \qquad (1)$$

$$\log E = 1.5\,M + 11.8 \quad (\mathrm{erg}) \qquad (2)$$

where D is the slip dislocation and E is the earthquake energy. The maximum magnitude is calculated from the fault length L by using the next equation (Matsuda,1975):

$$\log L = 0.6\,M - 2.9 \quad (\mathrm{km}) \qquad (3)$$

The lower bound of magnitude is 5.0 for all faults. The distribution of magnitude is evaluated by assuming the "b" value of Gutenberg-Richger's equation to be 1.0 for each fault.

Basically, the analytical procedure employed in this study follows the method proposed by Tomatsu et.al. (1983).

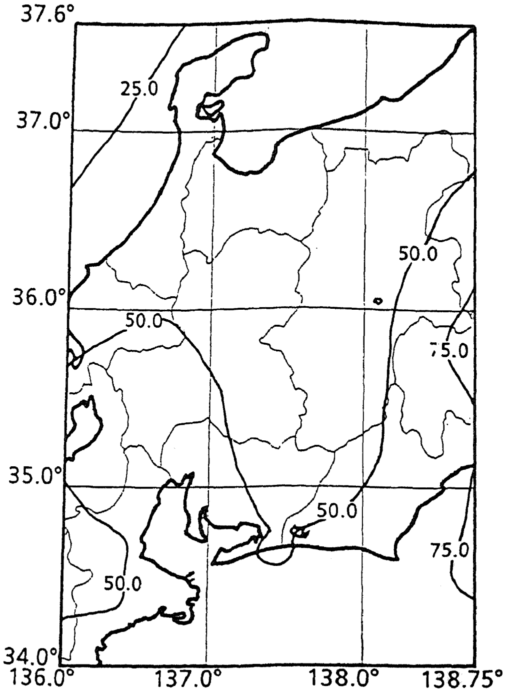

Fig.2 Seismic Hazard Map Based on Historical Earthquake Catalog (75 years)

2.3 Attenuation law

The seismic hazard is represented in terms of the peak ground acceleration at the free surface of base stratum whose shear wave velocity is greater than or equal to 700 m/s. The peak ground acceleration at the base stratum is determined by Kanai's empirical equation:

$$A = \frac{1}{T}10^{\left\{0.61\,M - \left(1.66 + \frac{3.60}{r}\right)\log r + \left(0.167 - \frac{1.83}{r}\right)\right\}} \qquad (4)$$

where, M is the magnitude of earthquake, and r is the hypocentral distance (km). The predominant period T of the ground motion is assumed to be 0.35 seconds, and the peak ground acceleration has the upper limit of $9M^2$ in the epicentral region.

3. RESULTS OBTAINED FROM TWO DIFFERENT MODELS

3.1 Results based on historical earthquake catalog

The seismic hazard is calculated at 228 grid points whose intervals are 0.20° (28km) in latitude and 0.25° (23km) in longitude in the Chubu region.

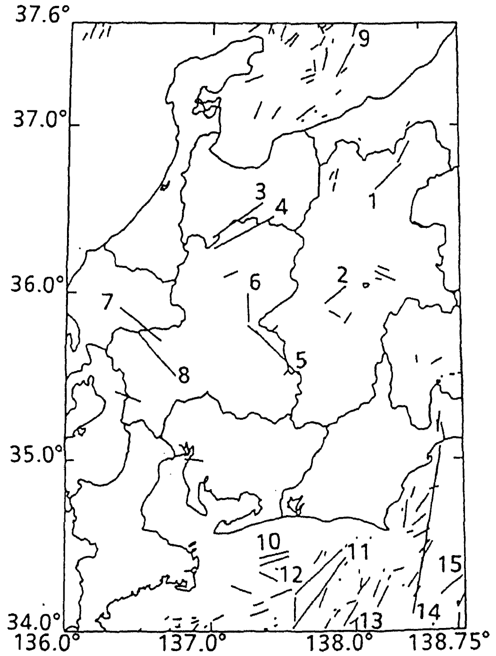

Fig.3 Major Active Faults

Considering the seismotechtonic zone and distributions of epicenter and active faults, the Chubu region is divided into 19 area sources as shown in Fig.1. In the figure, the dotted line represents the limit line of the grid points at which the seismic hazard is evaluated.

The seismic hazard map in terms of the peak ground acceleration with the probability of exceedance of 63% in 75 years based on the historical earthquake catalog is shown in Fig.2. The seismic hazard varies gently over the Chubu region ranging from 30 to 80 cm/sec^2, reflecting the seismic activity in each area source. The seismic hazard in the source area No.13 is the highest in the region, and those in areas No.15, 16 and 17 are relatively higher than in No.9, 10 and 18.

3.2 Result based on active fault data

Major active faults with high degree of activity in the Chubu region are drawn in Fig.3.

The seismic hazard map based on the active fault data is shown in Fig.4. The expected seismic hazard varies from 30 to 130 cm/sec^2 over the inland area. The shape of the contour line is apparently affected by the location of active faults. It should be noted that the seismic hazard in the sea area is relatively high since the high degree of activity is assumed for the offshore faults as described in 2.2.

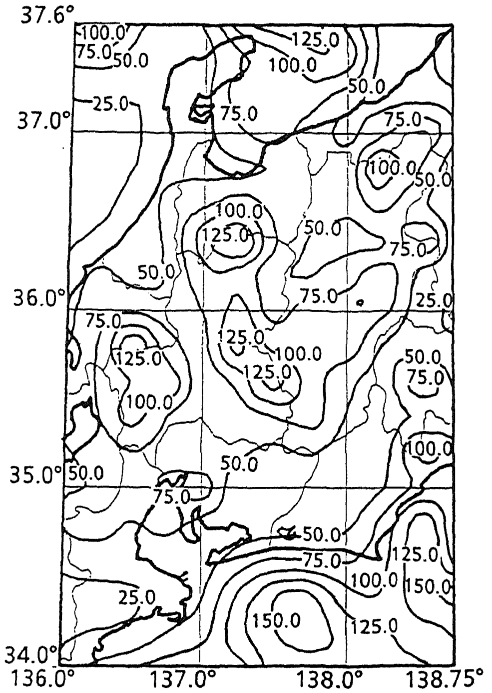

Fig.4 Seismic Hazard Map Based on Active Fault Data (75 years)

3.3 Comparison of two results

Comparing Figs.2 and 4, there is a great difference in the hazard level especially in the central area, which is roughly the area of source No.18 shown in Fig.1. In this area, the average seismic hazard based on the active fault data is about 2.4 times the hazard based on the historical earthquake catalog because several active faults with high degree of activity are found in this area as shown in Fig.3, while the area is judged to be a low seismicity area from the historical earthquake catalog. The estimated annual energy released from major active faults is about 11 times as great as that calculated from the earthquake catalog.

On the contrary, the average seismic hazard as well as the estimated energy release based on the active fault data is almost same as those based on the historical earthquake catalog in the area of source No.17. Since the sources No.17 and 18 belong to the same seismotechtonic zone, several major faults with high degree of activity locate in the source No.17 as in No.18. However, different from the source No.18, moderate to large earthquakes have occurred in No.17.

There is small difference between the two results in other inland areas.

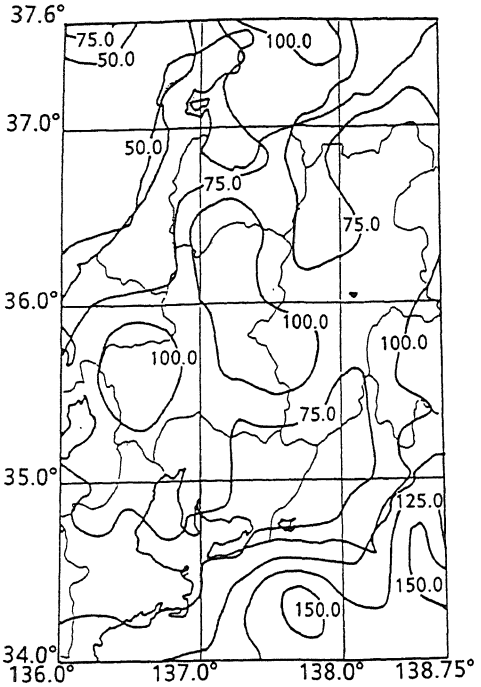

Fig.5 Combined Seismic Hazard Map
(75 years)

4. COMBINATION OF TWO RESULTS

The seismic hazards based on the historical earthquake catalog and on the active fault data are combined in the following manner. In the procedure, the area No.18 which exhibits the greatest difference between the two hazards is treated separately.

(a) The seismic hazard based on the active fault data is smoothed with the band width of 20 km since the seismic hazard is strongly affected by the locations of the major faults.

(b) In the areas except No.18, the seismic hazard based on the historical earthquake catalog is adopted as the basis considering the quantitative accuracy of the databases. Then, when the seismic hazard based on the active fault data is greater than that, the expected hazard is modified by the following equation:

$$(A_{history} + A_{fault})/2 \qquad (5)$$

where $A_{history}$ is seismic hazard based on the historical earthquake catalog, and A_{fault} is that based on the active fault data.

(c) In the area No.18, considering that the areas No.17 and 18 belong to the same seismotechtonic zone, the smoothed seismic hazard based on the fault data (obtained in (a)) is reduced so that the average seismic hazard in this area is equal to No.17.

The combined seismic hazard map is shown in Fig.5. The obtained seismic hazard level in the area No.18 is about twice the level based on the historical earthquake catalog, and in other inland areas, the former is 1.0 to 1.3 times as high as the latter. The combined seismic hazard is also higher than that based on the historical earthquake catalog in the Pacific Ocean.

5. CONCLUSIONS

This paper describes how we develop the seismic hazard map for the Chubu region of Japan by combining the seismic hazards which are independently evaluated based on two different databases: historical earthquake catalog and active fault data. This result will provide the fundamental information for the seismic design of the major facilities of the electric power supply network in the region.

REFERENCES

ANS/IEEE. 1983. *PRA Procedures Guide.* NUREG/CR-2300.

Cornell,C.A. 1968. Engineering Seismic Risk Analysis. *BSSA.* 58:1583-1606.

Gutenberg,B. & Richter,C.F. 1956. Magnitude and Energy of Earthquakes. *Ann.Geofis.* 9.

JMA(Japan Meteorological Agency). 1982. Catalogue of Relocated Major Earthquakes in and near Japan (1926-1960). *Seismological Bulletin of the JMA.* 1-6(Supplementary).

JMA. 1961-1983. *Seismological Bulletin of the JMA.*

Kanai,K. & Suzuki,T. 1968. Expectancy of the Maximum Velocity Amplitude of Earthquake Motions at Bed Rock. *Bulletin of the Earthquake Research Institute.* 46:663-666. Univ. of Tokyo.

Matsuda,T. 1975. Magnitude and Recurrence Interval of Earthquakes from a Fault. *Zisin.* 28:269-283.

Research Group for Active Faults of Japan. 1980. *Active Faults in Japan.* Univ. of Tokyo Press.

Tomatsu,Y. Yasuda,M. & Katayama,T. 1983. Seismic Hazard Mapping Based on Active Fault Distribution in Japan. *Seismic Risk and Its Use In Code Formulation.* 6:1-26.

Usami,T. 1979. Study of Historical Earthquakes in Japan. *Bulletin of the Earthquake Research Institute.* 54:399-439. Univ. of Tokyo.

Utsu,T. 1982. Catalog of Large Earthquakes in the Region of Japan from 1885 through 1980. *Bulletin of the Earthquake Research Institute.* 57:401-463. Univ. of Tokyo.