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Estimation on the distribution of seismic intensity expected by ground condition for the seismic microzoning

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ABSTRACT: It is very important to estimate the influence of surface ground condition for the seismic motion exactly in order to do earthquake resistant design and to decrease the earthquake disasters. In this paper, we investigated the estimation method concerned to the intensity of seismic motion in the Central Tokyo Metropolis considering seismic source mechanism and underground condition, especially the surface ground condition.
The seismic intensity distribution of the 1985 October 4 Border of Chiba and Ibaragi Pref. Earthquake (M=6.1) in the central Tokyo Metropolis was evaluated by using the questionnaire survey. Then we calculated the seismic intensities by using the simple seismic fault model of this earthquake theoretically and compared the calculated intensities with the estimated seismic intensities by questionnaire survey. The both results of seismic intensity distribution are comparatively well corresponded each other, then we summarized the results.

1 INTORDUCTION

In the consideration of the characteristics of seismic motion or regional seismic motion intensity that are input to structures, it is very important, in the first instance, to have a full understanding of the characteristics of underground condition of that particular region. The Institute of Civil Engineering of the Tokyo Metropolitan Government has therefore prepared and published the "General Map for Underground Condition in Tokyo I" for the various wards in Tokyo.
Moreover, in the "Report on Regional Seismic Damage Potential Survey (1984)" prepared by the Department of Urban Planning of the Tokyo Metropolitan Government, the 2,400 meshes resulted from the dividing of the underground structure into regions of 500m x 500m were classified and represented in 22 types in the "Distribution Map of Underground Classification". Making use of these results, it is possible to understand qualitatively the circumstances of the surface ground of the Tokyo wards. It is also made possible to figure out which of the 22 types classified from detailed topography does each individual mesh belong to. The proper underground condition characteristics of each individual mesh, however, cannot be understood in full detail.

In this study, the underground structure of each mesh are made clear. Moreover, a high density underground condition characteristics distribution map, having taken into consideration the characteristics of ground shaking, is prepared. The characteristics of surface ground can therefore be understood quantitatively. Furthermore, using these results, the distribution of seismic motion intensity for the 23 wards of Tokyo is estimated, and basing on this estimation, the relative damage potential is evaluated. Referring to the underground structure of the surface layer mentioned above, the simulation technique is used and the distribution of seismic intensity in real earthquakes is simulated. In this study, in particular, we have paid special attention to the distribution of seismic intensity and have made an attempt to compare the simulated results by fault models (Haskell, 1969 and Papageorgiou, 1983), in which these models have taken into consideration the source characteristics, with the results obtained in real earthquakes. The results used are obtained from the investigation case (1985.10.4 Border of Chiba and Ibaragi Pref. Earthquake) in real earthquakes in which the seismic intensity distribution investigation method using questionnaires (Ohta et al., 1979 and Okada et al., 1985), a high density evaluation method, was adopted.

2 GROUND SKAKING CHARACTERISTICS

Firstly, the 23 wards of Tokyo are divided into meshes of size 500m x 500m. From the boring data (edited by the Institute of Civil Engineering of the Tokyo Metropolitan Government) extracted from each mesh, the soil, depth and N-value were obtained. For meshes that cannot have the boring data be obtained, the data of the nearest neighboring mesh is used. Using these data, and by assuming the horizontal multi-layered model, the S wave velocity for each layer is estimated. Secondly, the depth of basement of each mesh is obtained from the distribution map for support stratum (N-value is 50 and much more), in which this map is also edited by the above institution. From the depth of basement and the S wave velocity, and by using the multi-reflection theory, the response magnification curve of each mesh is thereby obtained. On reading the response magnification curve, the maximum magnification of response and the predominant frequency are worked out. Since the ground shaking characteristics might not be able to be assessed simply by the single index calculated from the values of predominant frequency and the maximum magnification of response, the product of the predominant frequency of underground and the maximum magnification of response in this study is computed as one index. This index is considered as a value comparable to the magnification energy density (abbreviated as Ren thereafter) caused by ground shaking during earthquakes. For grounds with large amplification of seismic wave energy, the intensity of the seismic motion (seismic intensity) will be relatively higher and are estimated to have higher damage potential to structures in general. From the above results, the distribution of the characteristics of underground conditions is obtained and the relative damage potential of the 23 wards of Tokyo (expressed as relative damage potential thereafter) is estimated.

3 RESULTS OF ANALYSIS

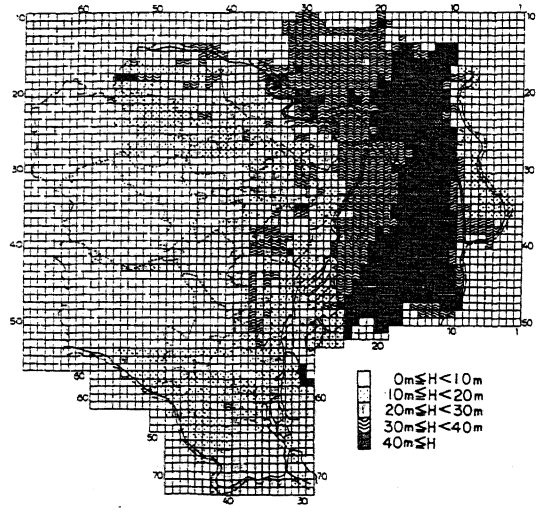

Fig.1 Regional distribution of the depth to basement of surface ground (H) in Central Tokyo.

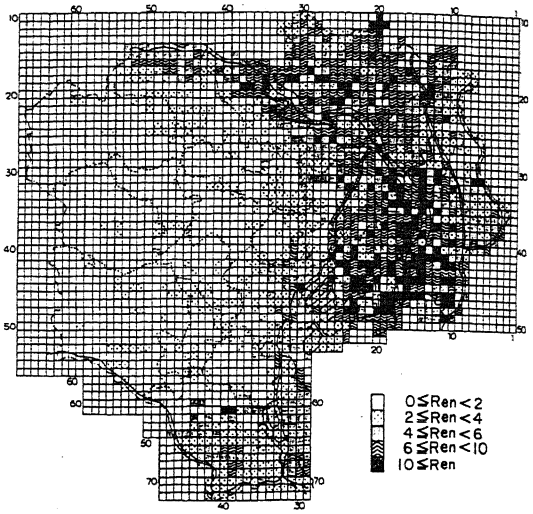

Fig.2 Regional distribution of the energy density magnification of seismic wave (Ren) in Central Tokyo.

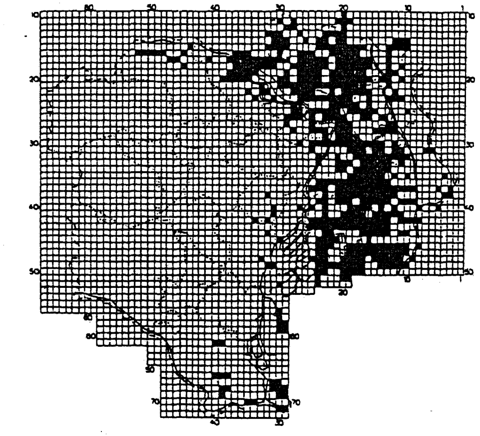

Fig.3 Distribution of high class zone of relative damage potential.

The distribution maps of the results of analysis are shown in Fig. 1 and 2. According to the basement-depth distribution map, areas particularly deep in basement depth are distributed in the basins of the Ara River and the Shin Naka River. Regions that are shallow in basement depth are distributed in the Suginami Ward, the Nakano Ward and the Musashino Plateau of the Setagaya Ward. From the distribution map of Fig. 2, the relative damage potential of the 23 wards of Tokyo is estimated (Fig. 3,4 and 5). The predominant frequency is on the low frequency side, and bigger the maximum magnification factor, the larger the Ren value indicated. The amplification of seismic wave energy intensity is divided into 3 classes as $\text{Ren} \geq 6$, $6 > \text{Ren} \geq 4$ and $4 > \text{Ren}$. These refer to the high, medium and low relative damage potential of the various regions. Regions of high relative damage potential are distributed in the eastern part of Tokyo including the Ara River basin, and the Kita Ward and part of the Ota Ward where these regions are predominated by regions of soft soil such as sandbank, delta and reclaimed land. Regions low in relative damage potential are found

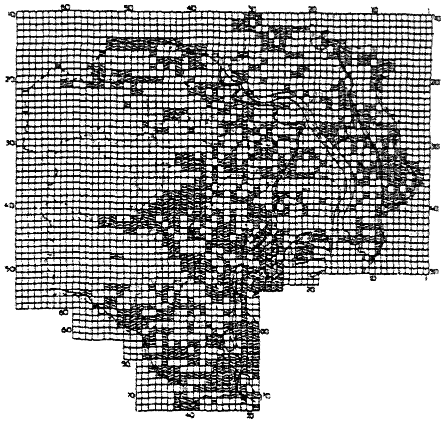

Fig.4 Distribution of medium class zone of relative damage potential.

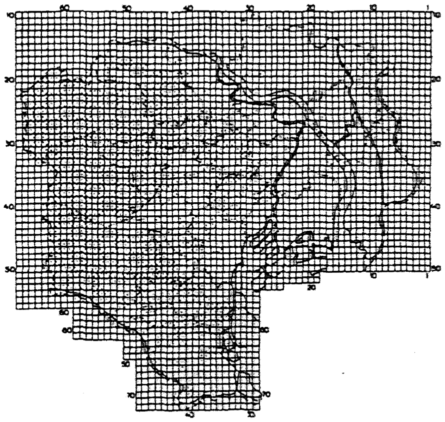

Fig.5 Distribution of low class zone of relative damage potential.

distributed in the tableland topography of the western part of Tokyo.

4 RESULTS OF RELATIVE DAMAGE POTENTIAL

The eastern part of Tokyo is classified as regions of high relative damage potential because these regions are deep in basement depth (depth of basement over 30m), with high Ren value and are spreaded with low land topography such as deltas, coastal plains, flood plains, sandbanks and reclaimed lands.

The western part of Tokyo, on the other hand, is classified as regions of low relative damage potential as these regions are relatively shallow in basement depth (depth of basement less than 10m), with low Ren value, and are spreaded with tableland topography such as tableland, tableland slopes and valley bottoms. The regions in between regions of high damage potential and regions of low damage potential have relatively shallow basement depth (depth of basement 10m - 30m) and the underground structures consist mainly the alluvium layers. Such regions are classified as regions of medium relative damage potential.

5 COMPARING THE SEISMIC INTENSITY DISTRIBUTIONS

Regarding the Border of Chiba and Ibaragi Pref. Earth-

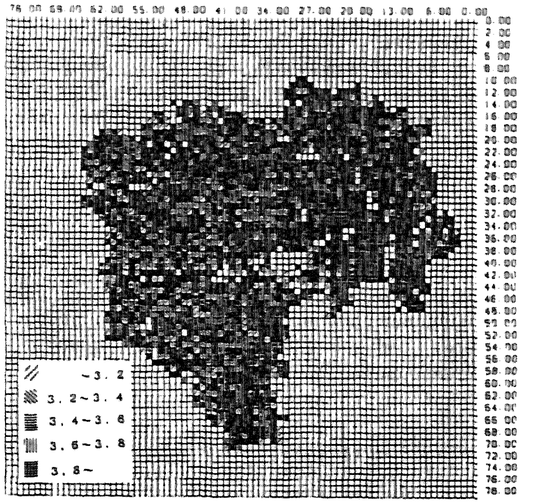

Fig.6 Non-smoothed evaluation of seismic intensity distribution in JMA Intensity Scale. (1985 Oct. 4 Border of Chiba and Ibaragi Pref. Earthquake)

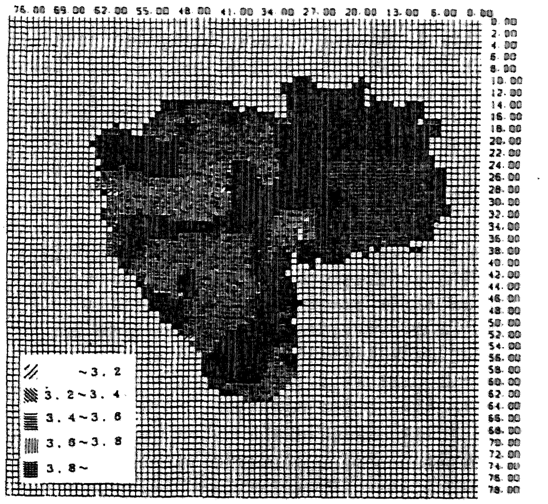

Fig.7 Smoothed evaluation of seismic intensity distribution in JMA Intensity Scale. (1985 Oct. 4 Border of Chiba and Ibaragi Pref. Earthquake)

quake on October 4, 1985 (M6.1), a questionnaire survey relating to this earthquake was conducted in the 23 wards of Tokyo (Mochizuki et al., 1986 and Mochizuki et al., 1987). From the results of this research, the distribution of seismic intensity is estimated and the seismic micro-zoning map (500m x 500m) is prepared (Fig. 6 and 7). Basing on this seismic intensity, simulation of the seismic motion using the fault model created from other parameters is executed. The acceleration and the maximum value of velocity wave form thereby obtained are converted to seismic intensity, and a seismic intensity distribution is made. This simulated distribution is then compared with the above seismic intensity distribution obtained in actual situations mentioned above. From the results of this comparison, the differences in the seismic intensity distribution of various regions are clarified, and the characteristics of seismic motion resulted from the differences in source characteristics, hypocentral distance and the characteristics of underground condition and studied.

6 PARAMETERS AND THE FAULT MODELS

For the purpose of comparison, 2 fault models are used. One is the Haskell Model. This model adopts the spectrum which is usually calculated by using the following formula. In the computation of the seismic motion,

$$Uc(\omega) = R(\theta,\phi,\rho) \,.\, \mu AD \,.\, G(\omega) \,.\, F(\omega,\tau_\theta \,.\, \omega) \quad ..(1)$$

Where μ : rigidity of medium, A : area of fault plane, D (θ,ϕ,r) : final dislocation, G (ω) : spectrum of dislocation time function and F (ω,τ_θ) : a function determined by fault length, fracture propagation velocity, and the angle achieved with the observation site.

The other model is the Specific Barrier Model introduced by A.S. Papageorgiou et. al. (1983), which is a fault model that adopts the heterogeneity of fault planes. The spectrum calculated from a simple crack of basic circular shape will be as follows, if using r to represent the distance between the hypocenter and the observation site :

$$G_0(\omega) = (Fs/(4\pi\beta r)) \cdot A(\omega) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where β : S wave velocity of medium, Fs : the Radiation Pattern of double couple point source model and A (ω) : the Fourie Transform of the acceleration wave form. On converting the above formula to the time domain, and by superimposing all the contributions from each crack within the time domain, the whole of seismic motion is thus calculated. The damping factor Q (ω) between the hypocenter and the basement, and the transfer function H (ω) due to the underground structure between the basement and the ground surface are also considered in actual calculations. Moreover, since the hypocenter parameters can be estimated as shown in Table 1, by using those values, the Fault Model is therefore established as illustrated in Fig. 8.

Table 1 Fault parameters of the 1985 Border of Chiba and Ibaragi Pref. Earthquake.

Magnitude	: $M = 6.1$
Source Mechanism	: Right-lateral, Strike Slip
Fault Length	: $L = 7.0$km
Fault Width	: $W = 10.0$km
Direction of Rupture Propagation	: WNW -> ESE
Dip Direction	: N75° W
Dip Angle	: 45°
S Wave Velocity	: $\beta = 4.30$km/s
Density	: $\rho = 3.3$
Rupture Velocity	: $Vr = 3.1$km/s
Rise Time	: $\tau = 0.45$ sec
Dislocation	: $D = 0.44$m
Damping	: $Qs = 381.0$
Stress Drop	: $\Delta\sigma = 53.6$ bar
Radius of Crack	: $\rho 0 = 0.99$km
Number of Cracks	: $n = 21$
Local Stress Drop	: $\Delta\sigma = 332.4$ bar

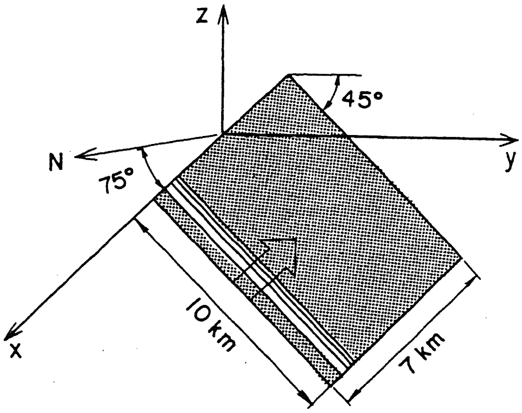

Fig.8 Conceptional profile of seismic fault model.

7 EVALUATION AND COMPARISON OF SEISMIC INTENSITY

By way of the simulation technique making use of the above Fault Models, the intensity of seismic motion (seismic intensity) thus calculated is evaluated by the maximum acceleration value (Amax) and the maximum velocity value (Vmax). In order to compare with the distribution of seismic intensity of the 1985 Chiba-Ibaragi Border Earthquake, the above mentioned Amax and Vmax values are converted to seismic intensities. The following formulas suggested by Dr. Kawasumi and Dr. Muramatsu are used in the calculation.

$$I = 2.0\,(\log_{10} \mathrm{Amax} + 0.35) \quad \dots\dots\dots\dots\dots\dots \tag{3}$$
$$I = 2.0\,(\log_{10} \mathrm{Vmax} + 1.40) \quad \dots\dots\dots\dots\dots\dots \tag{4}$$

The map of seismic intensity distribution thus calculated is shown in Fig. 9 and 10.

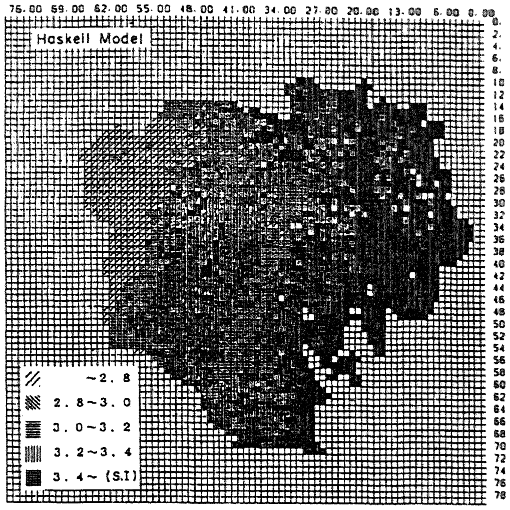

Fig.9 Distribution of calculated seismic intensities by the Haskell Model.

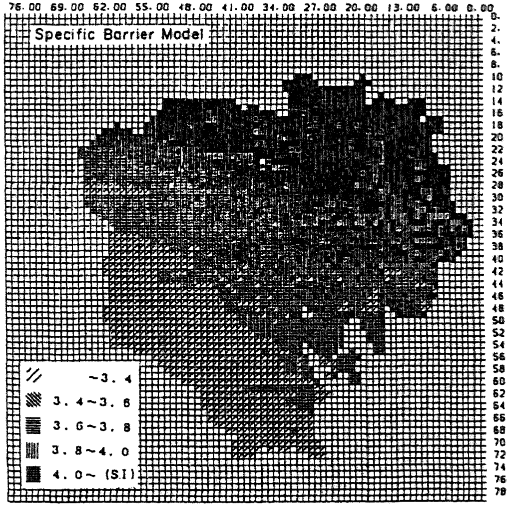

Fig.10 Distribution of calculated seismic intensities by the Specific Barrier Model.

8 CONCLUSION

Using the simulation results of the Haskell Model (Fig. 9), the general seismic intensity distribution for the 23 wards is found to be lower in seismic intensity in the western areas. This tendency is particularly remarkable in the north western part. The eastern part has high seismic intensity especially along the gulf of the south eastern part of Tokyo Bay. The tendency of the seismic intensity distribution obtained from these results matches fairly well with the seismic intensity distribution (abbreviated) in actual situations. On the contrary, however, the simulated results obtained from the Specific Barrier Model indicate in general a low seismic intensity in the south western part, whereas in the north eastern regions, the seismic intensity is found to be

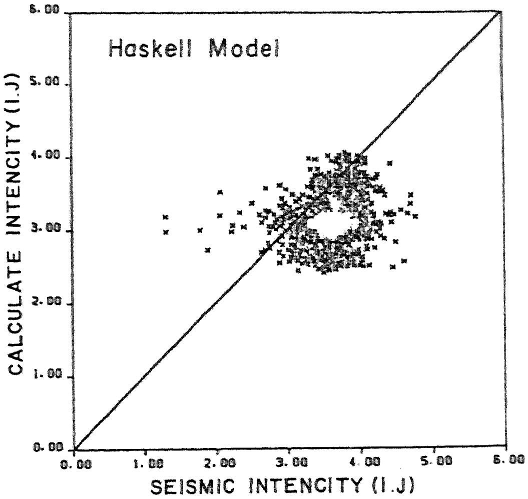

Fig.11 Comparison between evaluated seismic intensities and calculated seismic intensities by the Haskell Model.

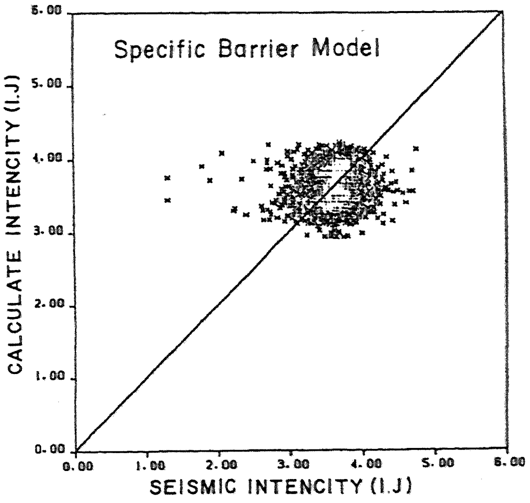

Fig.12 Comparison between evaluated seismic intensities and calculated seismic intensities by the Specific Barrier Model.

high. Such a result is suspected to be the reflection of the influence caused by the hypocentral distance. The results of the comparison between the seismic intensity evaluated in actual earthquakes and the seismic intensity obtained from the calculated results using the simulation technique are shown in Fig. 11 and 12. Despite both the results of the two models indicate a comparatively well correspondence relation, the results of the Specific Barrier Model are less scattered than that of the Haskell Model. Basing on the above results, the seismic intensity distribution in actual earthquakes can then be simulated to a certain extent. Regarding the relation between this simulated result and the method of evaluating the damage potential due to the underground condition of surface layer, investigations focusing more on quantitative results are recommended.

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