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Evaluation of earthquake motion in Muroran and Tomakomai areas

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ABSTRACT: The puropose of present paper is to obtain the regional distributions of maximum acceleration or intensity in the main area of Muroran and Tomakomai cities, Hokkaido Japan regarding 1968 Tokachi-oki earthquake as a future coming earthquake. The main area of Muroran and Tomakomai cities were divided into a lot of segments with an area of 500m*500m and analyses were made for about 150 smegments in Muroran city and about 100 segments in Tomakomai city. The analized areas include densely populated residential districts for which estimations of earthquake motion are essential. The regional distributions of maximum acceleration on the ground surfac were consistent with the intensity distributioins of past earthquakes in both cities. The present result is expected to be useful for taking counter-measure against earthquake disasters due to the coming earthquake.

1. INTRODUCTION

For mitigation and prevention of earthquake disasters, it is essential to evaluate disasters for a coming earthquake and to make the countermeasures, when earthquake mechanism, propagation of seismic waves and ground condition in related area must be taken into considerations.

Though these kinds of investigation and research have been so far executed for the metropolitan area or the large city, the regions of overcrowded population (Kanagawa prefecture (1985), Kawasaki city (1988), Miyagi prefecture (1985), Saitama prefecture (1981)), the researches are very few for such local cities as Muroran and Tomakomai with small population. In this report, evaluations of earthquake motion, which means maximum acceleration on the ground surface for a coming earthquake, are obtained for Muroran and Tomakomai cities which are located in the southern part of Hokkaido, Japan (Fig. 1).

This report ia one part of a series for assessment of earthquake disasters in small cities and the countermeasures. Muroran city has around 120,000 population and covers an area of 12 km*15km. On the other hand, Tomakomai city has a population of more than 150,000 and covers an area of 20km*35km. Both cities have been fairly badly damaged by 1968 Tokachi-oki earthquake.

2. SEISMIC ENVIRONMENT OF MURORAN AND TOMAKOMAI AREAS

2-1. Seismic activity

The highest seismic activity in and around Hokkaido is due to huge earthquakes in the Kuril and Japan trenches which are the boundary between Pacific Ocean plate and North American plate. In this region, we have 1952 Tokachi-oki (offshore) earthquake (M:8.2), 1968 Tokachi-oki eq. (

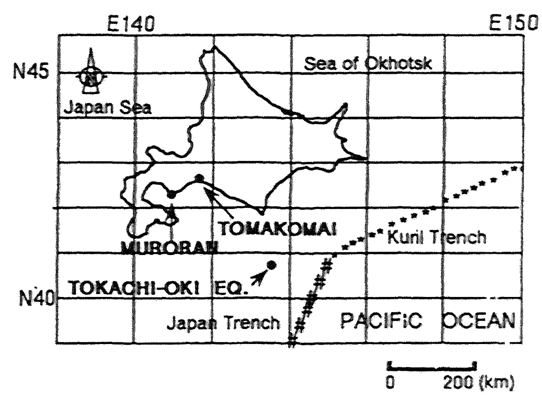


Fig. 1 Location of Muroran and Tomakomai cities

earthquake) (M7.9), Ostrov-oki eq. (1958, M8.1) and Hokkaido thoho-oki (east offshore) eq. (1969, M 7.8) and so forth. It is said that the active period of about 20 years and the calm periods of about 30-60 years have been repeated a few times in the resent centuries (Uthu (1977)).

Moreover, in the inland part of Hokkaido, Sea of Japan, and Sea of Okhotsk, big and small earthquakes have been occurred and various damages were given to many cities in Hokkaido. Fig. 2 shows epicentral distribution of earthquakes by which some cities of Hokkaido were damaged for the period 1611-1986 (Okada (1987)) and three concentric circle with radii of radius 100km, 200km and 300 km which were drawn round Muroran city. There is no huge earthquake which has occurred at the very near region of Muroran, because Muroran is located a little remote from the plate boundary. However, the occurrence of earthquake of M 5.1 which is due to the eruption of the Usu Mt., and others have been recorded.

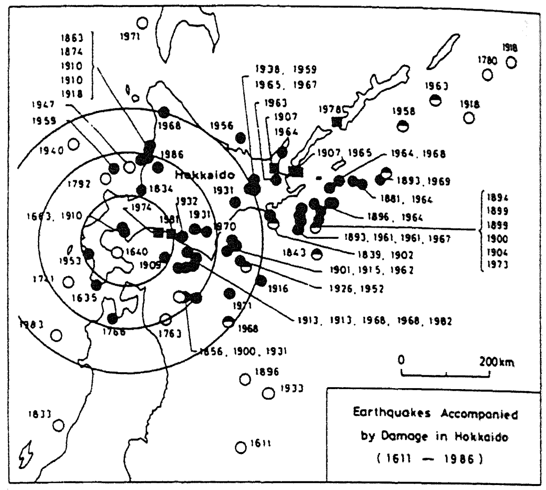


Fig. 2 Epicentral distribution of earthquakes (1611-1986) by which some districts of Hokkaido were damaged [Okada (1987)]. Three concentric circles with radii of 100 km, 200km and 300km are drawn round Muroran city. The meanings of symbol in the figure are as follows:

●: Earthquakes accompanied by damages due to seismic motions,

○: Earthquakes accompanied by damages due to Tsunami and

◓: Earthquakes accompanied by damages due to seismic motions and Tsunami.

2-2. Example of earthquake damages in Muroran and Tomakomai cities

The seismic intensity of the Muroran city due to 1952 Tokachi-oki eq. (March, 4, 1952, M 7.9, epicenter: 41.8°N, 144.1°E, huge damages in the Pacific Ocean side of Hokkaido, height of Tsunami: about 3m at Hokkaido, the killed 28, the missing 5, completely destructed buildings 815 and partially destructed buildings 1324) were distributed from III to IV in JMA intensity (JMA: Japan Meteorological Agency) (Seismic Section of Japan Meteorological Agency (1954)). Damages in Muroran city are as follows; Partially destructed buildings 241, destructed chimneys 49 and so forth. The maximum height of Tsunami at Muroran bay was 15cm (period: 55 minute). On the other hand, the seismic intensity of Tomakomai city due to the above earthquake was IV in JMA intensity and the following damages were recorded: damaged non-residential buildings 4, damaged roads and bridges 2 and 1, destructed chimneys 8.

The seismic intensity at Muroran city due to 1968 Tokachi-oki eq. (May 16, 1968, M 7.9, epicenter: 40.7°N, 143.6°E, heavy damages in southern part of Hokkaido and Tohoku district, the killed 52, the injured 330, completely destructed buildings 673, partially destructed buildings 3004, height of Tsunami; 3-5m at Sanriku coast and 3m at Erimo cape of Hokkaido) were distributed from III to V in JMA intensity. The damages of Muroran city due to this earthquake are as follows; the killed 1, the injured 32, completelly burned building 1, fairly heavy destriuction of port facilities, a few ground damages and so forth. The maximum accelerations estimated by damages were distributed between 220cm/sec^2 and 390 cm/sec^2. The intensity in Tomakomai city by the above earthquake were between IV and V, and the following damages were observed; the killed 1, the injured 25, partially collapsed buildings 14, a few damages of road and port facilities.

Besides the above-mentioned earthquakes, the earthquakes which recorded higher than JMA intensity III in the areas concerned during the past 20 years are as follows: Nemuro hantho (peninsula)-oki (offshore) eq. (June 17, 1973, epicenter 43.0°N, 140.0°E and M 7.4), Urakawa-oki eq. (March 21, 1982, epicenter: 42.1°N, 142.6°E and M 7.1), Nihonkai-chubu (central part of Japan Sea) eq. (May 26, 1983, epicenter: 40.4°N, 139.1°E and M 7.7), and Hidaka-sanmyaku (mountain) hokubu (northern part) eq. (January 14, 1987, epicenter: 42.5°N, 142.9°E and M 7.0).

3. COMING EARTHQUAKES AND GROUND STRUCTURE

3-1. Assumption of a coming earthquake

Abe (1987) proposed assumptions of six coming earthquakes in and around Hokkaido (Hokkaido east part, Kushiro northern part, Hidaka central part, Ishikari, Rumoi offoshre and Shiribesi offshore). It is expected that the above Hidaka central part eq. (42.25°N , 142.5°E and M 7.25) will bring Muroran or Tomakomai cities a little big earthquake motions . In order to make rough estimation of such earthquake motion as maximum acceleration or maximum particle velocity on the ground surface by an earthquake ,we often use attenuation models, which show relationship among earthquake motion ,epicentral distance and magnitude(Hattori(1980),Tanaka et al.(1987)).

In the present report,an attenuation model was made by using strong motion records which were observed at the Construction Office of Muroran Harbor for 40 earthquakes (M:5.3-7.9) during the period 1968-1987.

$$\log A = 0.54M - 2.33\log(R+30) + 3.33 \quad (1)$$

(A:Maximum acceleration (cm/sec²
R:Epicentral distance (km)
M:Magnitude)

We can estimate the maximum acceleration to be 145 cm/sec² in Muroran by means of the above equation for the assumed Hidaka central part eq. On the other hand, the earthquakes which had brought Muroran big damage in the past is 1968 Tokachi-oki eq. and the maximum acceleration on the ground surface was 251 cm/sec². Taking into considerations the above-mentioned things,in the present report,we assumed 1968 Tokachi-oki eq. as a coming earthquake in the future. The source parameters of 1968 Tokachi-oki eq.,which are used as parameters for a coming eq. in the present paper, are as follows(Kanamori (1971),Kikuchi and Fukao(1985): length of fault 150 km,width of fault 100km,slip 4.1m, inclination of fault plane 20°, rise time 1 sec, rupture velocity 2.5km/sec, S wave velociyty on the wave path 3.5km/sec and starting point of rupture : center of the upper edge of the fault plane.

3-2. Lower underground structure

In the present report,the underground structure which is shallower than 1.0-1.5km is divided into lower and upper parts. The upper one is what is called soft ground and the lower one means the part of ground between the bottom of upper ground and the base rock , the S wave velocity of which comes to be 3km/sec.

This chapter is devoted to the description of the lower underground structure. The lower underground structure of Muroran area can be recognized at Horobetsu site ,which consists of four strata(Muroran(Pliocene), Shikanosawa, Takinokawa and Horobetsu(Miocene)) and base rock(Paleogene)(Wada et al.(1988))(Table 1(a)). The S wave velocity and density in each stratum have been estimated on the basis of bore hole data. In the present analysis , only the thickness of Muroran stratum was changed for each site. The lower underground structure of Tomakomai area is shown in Table 1(b).

Table 1. Lower underground structure (density(g/cm³),S wave velocity(m/sec) and thickness of layer(m))

Age		Layer	Density(g/cm³)	Assumed S wave velocity(m/s)	Thickness of layer(m)
Neogene	Pliocene	Muroran	2.2	1000	200~600
	Miocene	Shikanosawa	2.4	1400	290
		Takinokawa			
		Horobetsu	2.6	2000	320
Paleogene		Base	2.8	3000	∞

(a) Muroran

Age		Layer	Density (g/cm³)	S wave vel (m/s)	Thickness (m)
Later Diluvium		Nopporo	1.8	450	20
			1.9	520	100
Neo-gene	Pliocene	Mukawa	2.0	1400	1077
		Houbetsu			
	Miocene	Kasai			
		Hiratori+Keibu	2.0	1800	358
		Sinrou	2.2	2100	740
		Upper Takinoue	2.5	2200	1165
		Lower Takinoue			
Paleogene		Khoyosan+ Horonai (Base rock)	2.7	2600	∞

(b) Tomakomai

3-3. Upper underground structure (soft ground)

The upper underground structure means soft ground which consists of strata of Alluvium and Diluvium. The S wave velocity and density of soft ground were estimated on the basis of geological and geotechnical data by bore hole survey. The equations for estimating S wave velocity(V_s) and density(d) are as follows(Taniguchi(1989) and Maruyama(1986)):

$$V_s=64.964H^{0.228}N^{0.193}(1.000 \text{ for silt}, 1.134 \text{ for sand}, 1.221 \text{ for sandy gravel})(1.000 \text{ for Alluvium}, 1.221 \text{ for Diluvium}) \quad (2)$$

$$d=1.685N^{0.027}H^{-0.018}(1.000 \text{ for Alluvium}, 1.041 \text{ for Diluvium})(1.000 \text{ for clay}, 1.014 \text{ for silty sand}, 1.064 \text{ for fine sand}, 1.122 \text{ for gravel}) \quad (3)$$

The main areas of Muroran and Tomakomai cities were divided into lots of segments with a size of 500m*500m , to each of which one model of the upper underground structure was given. The number of segments , to each of which the model of underground structure was given are about 150 in Muroran area and about 100 in Tomakomai area ,respectively. The model of underground structure can not always be given to all segments because of lack of bore hole data.

4. EVALUATION OF MAXIMUM ACCELERATION ON THE GROUND SURFACE, SEISMIC INTENSITY DISTRIBUTION AND THE SEISMIC INTENSITY DUE TO PAST EARTHQUAKE

Maximum acceleration on the ground surface were obtained by Kobayasi and Midorikawa's method which calculated response spectrum and maximum acceleration by taking account of (1)source parameters of a coming earthquake and (2) upper and lower underground structure .

The idea of Kobayashi and Midorikawa is as follows: (1) The earthquake motion on the base rock, that is, seismic input is obtained by synthesizing seismic waves generated on a lot of fault elements into which fault plane are divided. (2)The maximum acceleration or maximum particle velocity on the ground surface are calculated by multiplying the earthquake motion on the base rock(seismic input) and amplification characteristics of the underground structure.

The size of Muroran city is around 15km in north and south and 12km in west and east , and epicentral distance of a coming earthquake is about 250km. On the other hand ,the main area of Tomakaomi city is a little wide ,but the epicentral distance is almost the same in every sites of the city. Therefore, the maximum seismic input ,that is, maximum acceleration on the base rock were around 20.5 cm/sec^2 for all segments of Muroran area, and 21.8 cm/sec^2 for every segments of

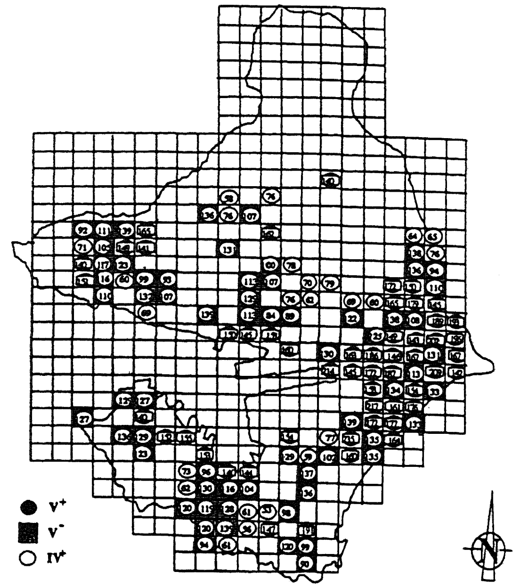


Fig. 3. Maximum accelerations(cm/sec^2) on the ground surface which were estimated for 500m*500m segment in Muroran city. The maximum accelerations are classified by the rank of intensity.

Tomakomai area. We can say, accordingly, that there are no difference among segments for seismic input on the base rock in Muroran area ,and also in Tomakomai area.

Nevertheless, there were much difference among the maximum acceleration on the ground surface as shown in Fig. 3. Therefore ,it can be said that the difference of maximum acceleration on the ground surface depend on only the differnce of underground structure. And moreover, it is expected that the maximum accelerations on the ground surface strongly depend on upper underground structure because the lower underground structure was treated as a common one for whole area excluding the thickness of uppermost stratum of lower part.

Fig. 3 shows the obtained maximum acceleration on the ground surface for Muroran area and the values are distributed from 53cm/sec^2 to 235cm/sec^2. Though the relation between the maximum acceleration on the ground surface and the seismic intensity is not always established, we assumed the following :IV^+ :45cm/sec^2-80cm/sec^2 ,V^-: 80cm/sec^2-140cm/sec^2 and V^+: 140cm/sec^2-250cm/sec^2 .

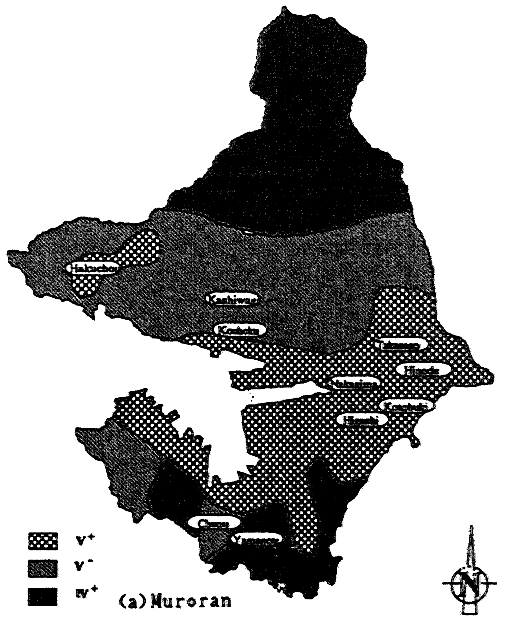
Figs. 4(a) and (b) are zoning maps of seismic intensity for Muroran and Tomakomai areas which were made on the above-mentioned classification, and Fig.5 is the seismic intensity distribution due to 1968 Tokachi-oki eq. in Muroran city(Department of Geophysics,Hokkaido University (1969)).

5. Results and Discussions

The following results were obtained :

(1) The maximum accelerations on the ground surface in Muroran City ,which were calculated for a future coming earthquake, are distributed from 53cm/sec^2 to 235cm/sec^2 Fig.4 shows the intensity distribution obtained on the values of maximum acceleration and the intensity classification shown in Fig.3. By means of comparing Fig.4 with Fig.5 and Fig.6 which shows the outline of geological features of Muroran City, the following are observed. That is, the seismic intensity distribution due to the coming earthquake is equivalent to that of 1968 Tokachi-oki eq. and almost all of sites, where the seismic intensity is high in Fig.4, correspond to the sites with Alluvium in Fig.6. Observing in detail, however,there are some sites where the above -mentioned correspondence between Fig.4 and Fig.6 are not always realized . We cannot explain these inconsistency excluding one part of Hakucho-dai area which was newly developed residential region. It may be due to such a rough zoning that only one value of maximum accelaration on the ground surface was obtained for one segment with the area of 500m * 500m. The more understanding must be made in the future.

(2) It can be said that the seismic input on the base rock are almost the same for whole segments of Muroran area .This is because big earthquakes will not occur near Muroran city and the size of Muroran city is fairly small. Therefore, even if the value of the maximum acceleration is different in every earthquake, the maximum acceleration



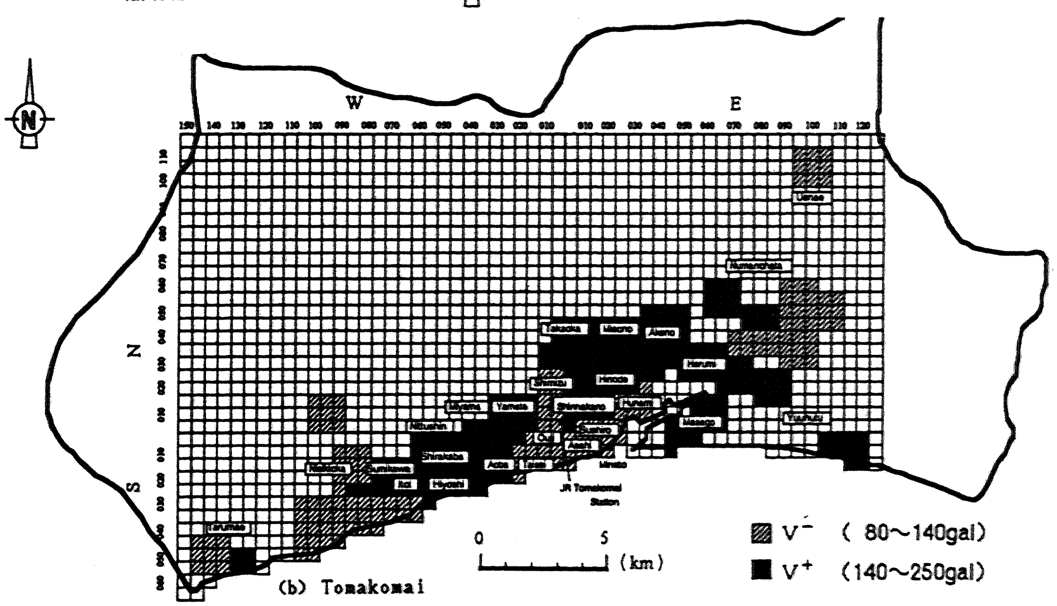


Fig. 4. Zoning of intensity which is expected for the future coming earthquake.

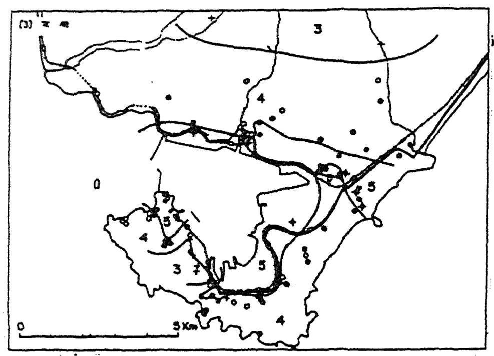


Fig. 5. Regional distribution of JMA intensity in Muroran area due to 1968 Tokachi-oki earthquake[Department of Geophysics, Faculty of Science, Hokkaido University(1969)].

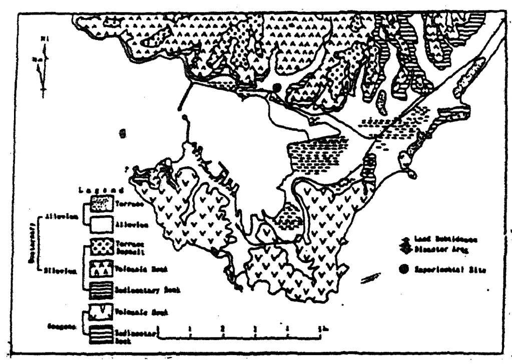


Fig. 6. Geological outline of Muroran area[Department of Geology and Mineralogy, Faculty of Science, Hokkaido University(1969)].

(seismic intensity) distribution must show the common pattern for earthquakes which will occur in the future. But for Tomakomai area, this does not always hold good.

(3) The above-mentioned inference can be recognized from comparison between Fig. 4 and 5 and can be confirmed also by the intensity distribution due to Hidaka sanmyaku hokubu eq. (Watanabe (1988)).

(4) The maximum acceleration on the ground surface strongly depends on upper underground structure. Therefore, it is inevitable for exact evaluation of maximum acceleration in whole area of Muroran or Tomakomai city to get the detail informations on upper underground structure
This is not limited to Muroran or Tomakomai area and should be said for all regions where mitigation and prevention of seismic disasters are necessary.

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