Estimating ground intensity for hypothetical east Aomori off earthquake using observed average S-wave velocity in Aomori prefecture

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ABSTRACT:

An occurrence possibility of magnitude 7 earthquake in east off Aomori prefecture is about 90% for next thirty years according to the national seismic hazard map for Japan published by the earthquake research committee, the headquarters for earthquake research promotion. The author estimates the seismic intensity of this kind earthquake around Aomori prefecture by combining empirical method. An amplification factor is estimated by an average S-wave velocity for top thirty meters. The average S-wave velocity is estimated by phase velocity of Rayleigh wave. Phase velocity of Rayleigh wave is deduced from microtremor exploration. As a result, the highest seismic intensity estimated by hypothetical fault model is about 5. This value is almost the same to the value of the 1968 Tokachi Oki earthquake that is a scenario earthquake in this region..

KEYWORDS: Seismic intensity in Japan, Average S-wave velocity, Microtremor exploration, Rayleigh wave, Phase velocity, Wavelength

1. INTRODUCTION

An occurrence possibility of magnitude 7 earthquake in east off Aomori prefecture is about 90% for next thirty years according to the national seismic hazard map for Japan published by the earthquake research committee, the headquarters for earthquake research promotion (Fujiwara et al., 2006). So far, We have experienced such earthquakes several times. The 1994 Sanriku-Haruka-Oki earthquake is a typical one. Its magnitude is 7.6. During the earthquake, we suffered both structural and human damage. So that, we will suffer damage by future M-7 earthquake with high possibility.

The earthquake research committee estimated ground motion for scenario earthquake in east off Aomori prefecture and open to the public via internet. The scenario earthquake is modeled by the 1968 Tokachi-Oki earthquake of magnitude 7.9. The highest seismic intensity is supposed to be around 6 by precise method and 5+ by simple method.

As recurrence interval of the scenario earthquake is about 97 years, occurrence possibility is not high so far. Though, magnitude 7 earthquake will occur in this thirty years with high possibility. Estimating ground motion for such kind earthquake is urgent issue. The author estimates the seismic intensity of such kind earthquake by combining empirical method.

2. OUTLINE OF ESTIMATING GROUND MOTION

Estimating procedure is often used in Japan such as Fujiwara et al.(2006) and outlined as follows. At first, ground motion indexes at the bedrock are estimated by empirical attenuation equations. Then amplification of surface layers is considered. Recently, amplification factor is evaluated from averaged S-wave velocities for top thirty meters (hereafter, AVS). However, information of AVS is generally poor. In such a case, geomorphologic classification and altitude of sites are used to evaluate AVS.

In this study, attenuation equation proposed by Si and Midorikawa (1999) is used to estimate a peak ground velocity at the surface of engineering bedrock. In their equation, earthquake type is a one of parameters. As the target event is interplate type earthquake, their equation is described in Eqn.2.1.

$$\log(HV) = 0.58\mathrm{M}_w + 0.0031H - \log X_{eq} - 0.002X_{eq} - 1.19 \quad (2.1)$$

In this equation, HV means horizontal peak velocity at engineering bedrock in (cm/s), M_w is a moment magnitude, H is hypocentral depth and X_{eq} is equivalent hypocentral distance.
Amplification of ground motion from engineering bedrock to ground surface is evaluated by a empirical relationship proposed by Midorikawa et al.(1994), described as Eqn. 2.2.

$$\log ARV = 1.83 - 0.66\log AVS \quad (2.2)$$

In this equation, ARV is the factor of peak velocity amplification, AVS is an average S-wave velocity for top thirty meters in (m/s).
We use a equation (2.3) proposed by Midorikawa et al.(1999) to convert a peak ground velocity to Japanese instrumental seismic intensity.

$$I = 1.02\log PGV + 2.58 \quad (2.3)$$

Where I is Japanese instrumental seismic intensity and PGV is peak ground velocity at the surface.

3. ESTIMATING AN AVERAGE S-WAVE VELOCITY

In this study, AVS is estimated by phase velocity of Rayleigh wave. Konno and Kataoka (2000) shows very close relationship between an average S-wave velocity for top layers and phase velocity of Rayleigh wave. Nagao and Konno (2002) compiles relationship between average S-wave velocities and phase velocities of Rayleigh wave. It is not easy to evaluate exact average S-wave velocity for top 30 meters, we use a phase velocity of Rayleigh wave with wavelength of 40 meters instead of exact AVS.
Microtremor exploration was made to extract phase velocity of Rayleigh wave around Aomori prefecture. Three vertical sensors were placed at apexes of equilateral triangle and one three components sensor was placed at the center of the equilateral triangle as shown in Figure 1. The length between center and apex is six meters. We estimated phase velocity of Rayleigh wave, using Spatial Correlation method proposed by Aki (1957).

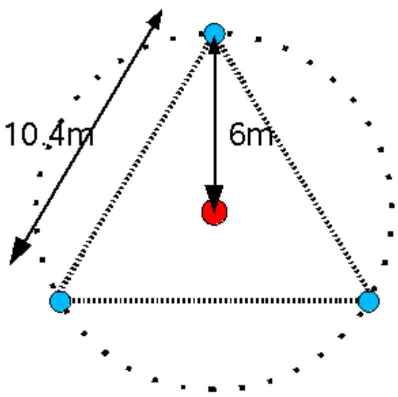

Figure 1 Array configuration. At the center of the equilateral triangle, one sensor with three components is placed. At each apex, vertical component sensor is placed.

Typical relation between wavelength and phase velocity is shown in Figure 2. Phase velocity becomes faster, as wavelength becomes longer. As array radius is six meters, there is a upper limit for estimating Rayleigh wave with longer wavelength. From our experience, wavelength of 40 meters is always lower than a limit. So that accuracy of phase velocity is enough high.

We have carried out this exploration at 42 sites in Aomori prefecture. Before our study, 47 PS profiles are open to the public by NIED as K-NET and KiK-net sites. The number becomes double. Figure 3 shows spacial distribution of the average S-wave velocity for top thirty meters.

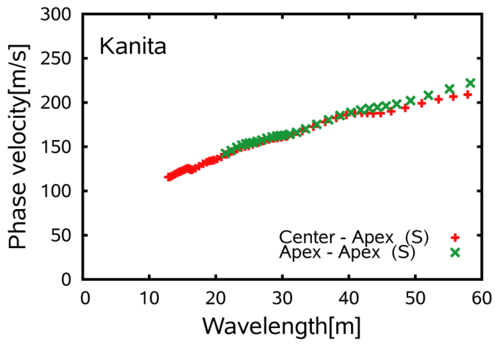

Figure 2 Typical dispersion curve obtained by microtremor exploration. Horizontal axis is wavelength and vertical axis is phase velocity.

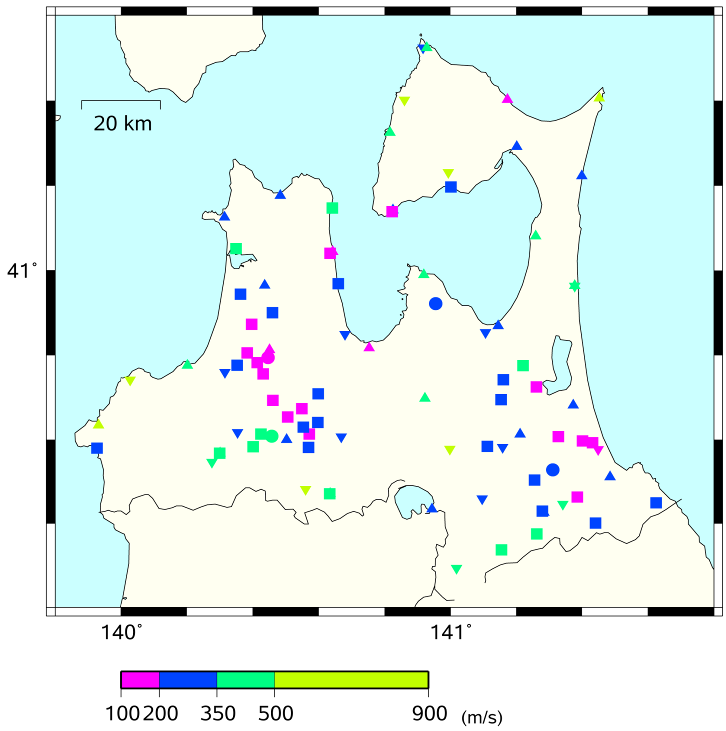

Figure 3 Map showing strong motion observation station and its average S-wave velocity for top thirty meters. A rectangular marks are stations operated by local government. Up- and down-ward triangles are K-NET station and KiK-net stations respectively. Color indicates the average velocity.

4. VERIFICATION OF THE ESTIMATION PROCEDURE

Seismic intensities during the 1994 Sanriku-Haruaoki earthquake are used to verify the estimating procedure. After the earthquake questionnaire were mailed to municipal office to estimate seismic intensity by researchers. Result is compiled by every local town.

Estimated seismic intensities are compared in Figure 4. In the Figure, horizontal axis is estimated value from this study and vertical axis is seismic intensity deduced from questionnaire study. Eighty percent of our result agrees to with questionnaire result in the range of error 0.5. From a practical point of view, this discrepancy is acceptable. Strictly to say, systematic bias can be seen. In lower intensity, this study is overestimation and in higher intensity, this study is underestimation. There are several reasons to cause this bias. First one is difference of area. In our study, seismic intensity is estimated at a certain point. Though questionnaire seismic intensity is obtained through spatial averaging process. The second one is that attenuation relation might be not adequate.

5. ESTIMATING SEISMIC INTENSITY FOR HYPOTHETICAL EVENT

For the hypothetical event, target fault model is build by referring the 1968 Tokachi Oki earthquake with magnitude of 7.9. Nagai et al. (2001) studied fault mechanism of the 1968 Tokachi Oki earthquake. They show two big asperities in the faults plane. Southern asperity correspond to the 1994 Sanriku Haruka Oki earthquake. As magnitude of our target is 7.6, northern half asperity pattern is used. A fault model is shown in Figure 5.

Estimated Japanese seismic intensities at stations around Aomori prefecture are plotted in Figure 6.The highest seismic intensity is about 5.3. In eastern part of Aomori prefecture, almost all stations will be suffered seismic intensity of 5.This value is almost the same to the value of the 1968 Tokachi Oki earthquake and future scenario event. Considering the configuration of fault and sites, it is quite natural that instrumental intensity of M-7 event is almost the same to M-8 event.

6. CONCLUSION

An occurrence possibility of magnitude 7 earthquake in east off Aomori prefecture is about 90% for next thirty years. This value is the second highest value in Japan. The author estimates the seismic intensity of this kind

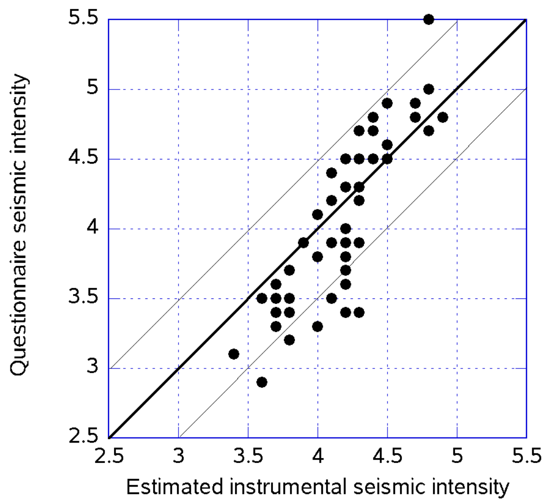

Figure 4 Estimated seismic intensity for 1994 Sanriku Haruka-Oki earthquake

earthquake around Aomori prefecture by combining empirical method.

As a result, the highest seismic intensity induced by a hypothetical fault model is about 5. This value is almost the same to the value of the 1968 Tokachi Oki earthquake that is a scenario earthquake in this region. Through verification study, there is a possibility that the procedure of this study might underestimate intensity near the fault. We should prepare for this hypothetical event as well as scenario earthquake.

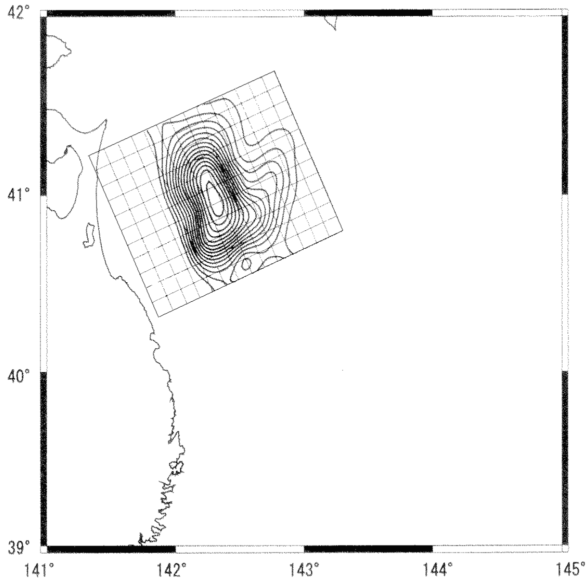

Figure 5 A Moment release model of hypothetical event. This model is modification of Nagai et al. (2001).

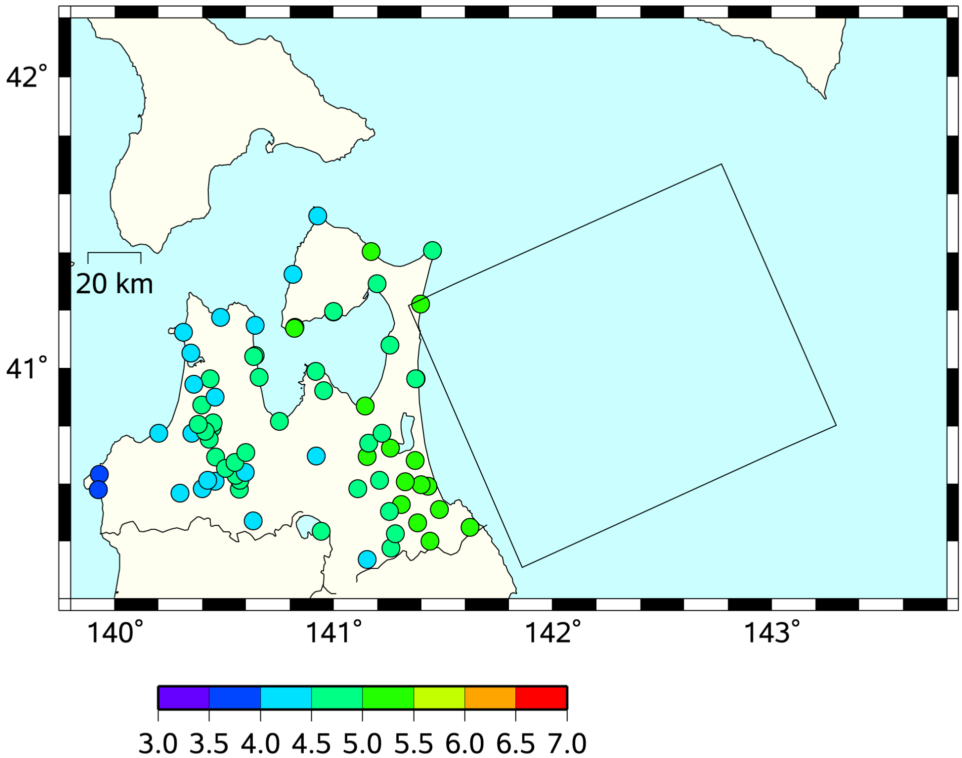

Figure 6 Map showing estimated Japanese seismic intensity for hypothetical event with magnitude of 7.6. Black rectangular is fault horizontal projection.

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