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Some Problems Related to Empirical Predictions of Strong Motion

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Abstract

The national seismic hazard mapping project of Japan started in 1999. The maps were published in March 2005. This paper describes two problems related to empirical predictions of strong motion that have been posed in the project. One is consideration of the effects of fault geometry in the empirical prediction such as the hanging wall effect. The effects are found significantly in strong motion records of the 2004 Mid-Niigata earthquake (M_w 6.6). Another is the effects of the deviation model of the attenuation relationship on the seismic hazard analysis. The amplitude dependent deviation model seems to provide more reasonable results for earthquakes with a high probability of occurrence. Further discussion of the problems will promise more reliable empirical strong motion predictions.

Key words: strong motion, empirical prediction, seismic hazard map, hanging wall effect, deviation of attenuation relationship, 2004 Mid-Niigata earthquake

1. Introduction

Following lessons learned from the Great Hanshin-Awaji earthquake disaster, the Headquarters for Earthquake Research Promotion was established to coordinate comprehensive earthquake research. In April 1999, the Headquarters established its fundamental mission statement on research over the next ten years, in which initiatives for developing national seismic hazard maps were proposed.

Following the proposal, the Earthquake Research Committee, which is one of the committees in the Headquarters, started the national seismic hazard mapping project of Japan to produce seismic hazard maps covering the whole of Japan (Fujiwara et al., 2003). The maps were published in March 2005 (Earthquake Research Committee, 2005a). In addition, the Japan seismic hazard information station (J-SHIS) is prepared to provide maps through the Internet (NIED, 2005).

In the mapping project, empirical methods as well as theoretical methods have been employed for strong motion prediction. This paper describes some problems related to empirical predictions of strong motion that have been posed in the project.

2. National Seismic Hazard Mapping Project

The Headquarters for Earthquake Research Promotion has promoted surveys of major active faults, long-term evaluations of the possibility of the occurrence of large earthquakes, and surveys of deep sedimentary basin structures. The national seismic hazard mapping project has been started to use the results for disaster mitigation.

In the project, to understand general seismic hazards throughout Japan, two types of map are produced. One is a deterministic ground shaking map with specified seismic source faults. This type of the map is also called a scenario earthquake ground shaking map. An example is shown in Fig. 1.

For the scenario map, the hybrid simulation method (e.g. Irikura and Kamae, 1999), which is a combination of the stochastic Green's function method and theoretical finite difference method, is mainly employed. The empirical method (e.g. Si and Midorikawa, 2000) is also used in mapping as a supplementary method.

The other is a probabilistic ground shaking map that shows the possibility of a certain area being attacked by strong shaking in a certain period by

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means of probability, as shown in Fig. 2. The reason for adopting two types of map is that these two maps have different advantages (e.g. McGuire, 2001), and should be selected according to the objectives.

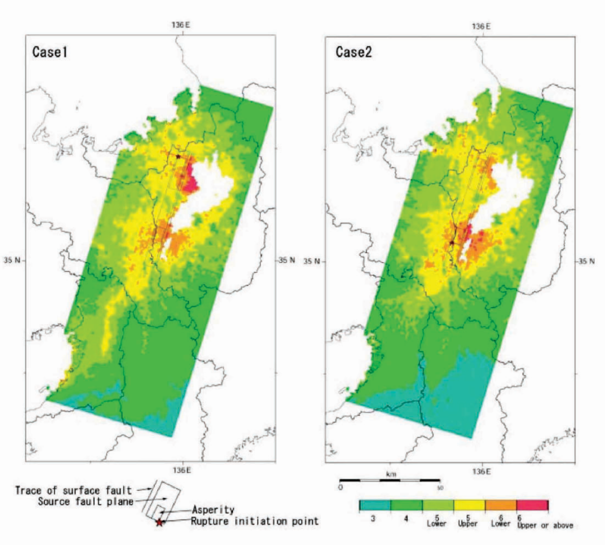

Fig. 1. Scenario shake maps for the Biwa-ko- seigan fault earthquake (Earthquake Research Committee, 2005a)

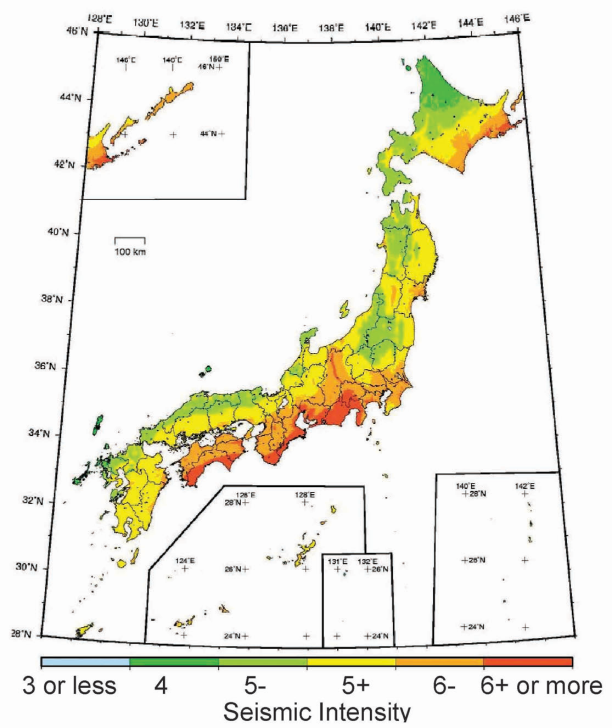

Fig. 2. Probabilistic hazard map (seismic intensity with 5% probability of exceedance in 50 years) (Earthquake Research Committee, 2005a)

Reflected in the probabilistic map are long-term evaluations of the possibility of the occurrence of large active fault and subduction earthquakes, which have been published by the Headquarters. Seismic hazard curves are computed with the probabilistic models of earthquake occurrence for each earthquake and the empirical attenuation relationship of ground motion.

3. Problem of Attenuation Relationship in Scenario Mapping

In scenario mapping, to confirm the validity of the results by the hybrid simulation method, the results are compared with those obtained by the empirical attenuation relationship. Fig. 3 shows a comparison of peak ground velocities computed by

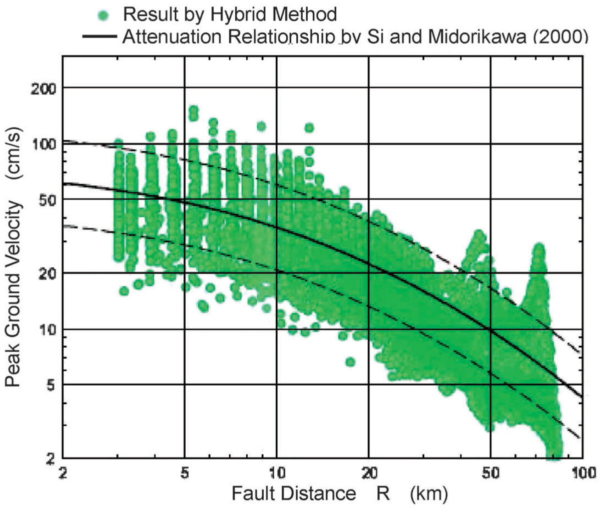

Fig. 3. Comparison of peak ground velocities by hybrid method with empirical attenuation curve (Earthquake Research Committee, 2005a)

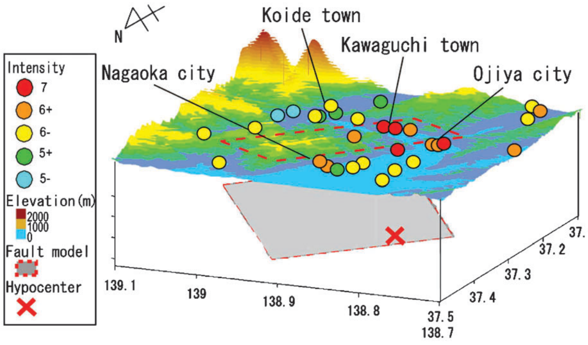

Fig. 4. Observed intensity distribution during the 2004 Mid-Niigata earthquake

the hybrid simulation method with the empirical attenuation curve. Both results agree well at intermediate distances, but the results obtained by the hybrid simulation method show a large scatter, and tend to be greater than the empirical curve in the near field.

This may be due to the effects of rupture directivity and fault geometry. The effects are also found in the strong motion records observed in the 2004 Mid-Niigata earthquake (M_w 6.6), which is due to a reverse and oblique fault. As shown in Fig. 4, the observed seismic intensities seem to be larger at the hanging wall side.

Figure 5 shows the attenuation of observed peak ground accelerations for the main shock. At distances of more than 30 km, good agreements between the observations and the attenuation curves can be seen. At distances of 10 to 20 km, however, several data are much higher than the curve. This trend is also found in the records for the largest aftershock (M_w 6.3).

Figure 6 shows the residuals of observations from the attenuation curve obtained by Si and Midorikawa (2000) for the main shock and the largest aftershock (Si and Midorikawa, 2005). The right and left sides of the figure are hanging wall and footwall sides, respectively. The mean of the residuals for each distance section is shown by a solid square.

At a distance of about 15 km at the hanging wall side, the mean residual shows a maximum of about 3. Although the local site effects are also one of the keys to the residuals, the microtremor measurement results (Miura and Midorikawa, 2006) suggest no systematic difference at the local site effects between the hanging wall and footwall sides.

Therefore, this could be evidence of the hanging wall effect on ground motion, which has been pointed out by Abrahamson and Somerville (1996).

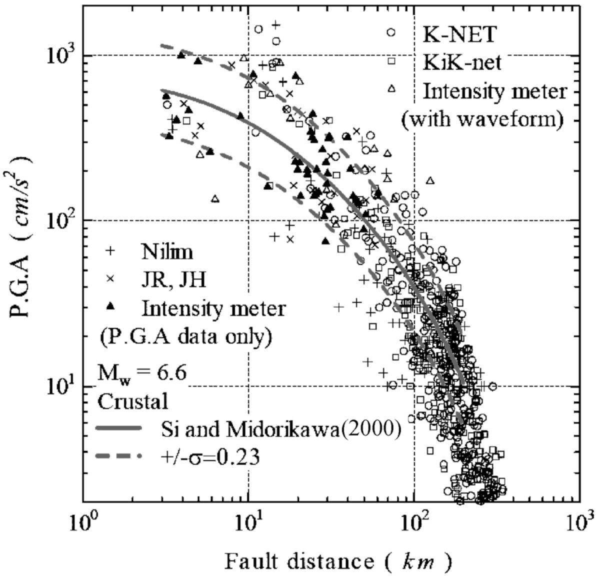

Fig. 5. Attenuation of peak ground accelerations during the 2004 Mid-Niigata earthquake

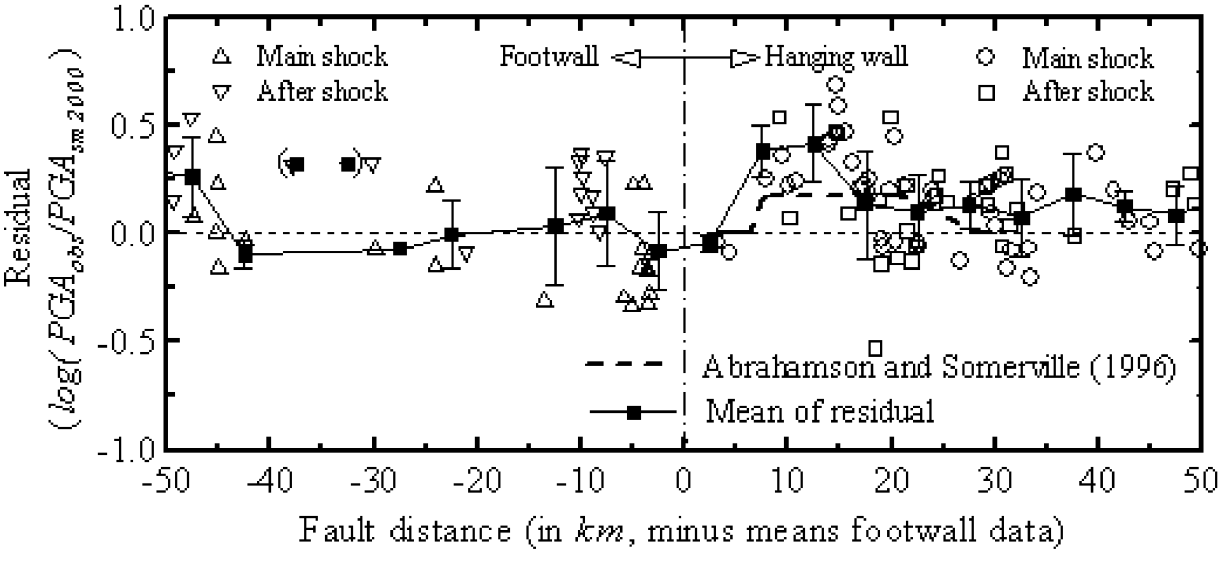

Fig. 6. Residuals of observations from attenuation curve by Si and Midorikawa (2000) for the main shock and the largest aftershock

The broken line in the figure shows the model for the hanging wall effect proposed by Abrahamson and Somerville (1996). The model seems smaller than the observations, and a revision of the model might be necessary using additional records.

4. Problem of Attenuation Relationship in Probabilistic Mapping

In the probabilistic seismic hazard analysis, the mean and deviation of the attenuation relationship are used to compute the hazard curve. It is well recognized that the expected ground motion intensity at a very low probability is controlled by the deviation of the attenuation relationship. For an earthquake with a high probability of occurrence, even at a relatively high probability, the high expected value is obtained due to the deviation.

In the mapping project, large subduction earthquakes along the Nankai trough such as the Tokai, Tonankai, and Nankai earthquakes are considered to have a high probability of occurrence. The expected intensity from the earthquakes is considerably high, and does not seem to be reasonable. To avoid this problem, the amplitude dependence of the deviation is introduced in the analysis, which gives a smaller deviation for larger amplitude level.

Amplitude dependence was first discussed by Donovan and Bornstein (1978), then statistically confirmed by Campbell and Bozorgnia (1994). It seems difficult to explain the reason for amplitude dependence clearly. Midorikawa and Ohtake (2004) show a clear amplitude dependence of deviation from the regression of recent Japanese records as shown in Fig. 7, and they suggest that this might be due to a multiplication of magnitude and distance dependences. In the project, the amplitude dependent deviation shown in Fig. 8 is adopted based on the analysis of records from the 2004 Tokachi-oki earthquake and the results obtained by Midorikawa and Ohtake (2004).

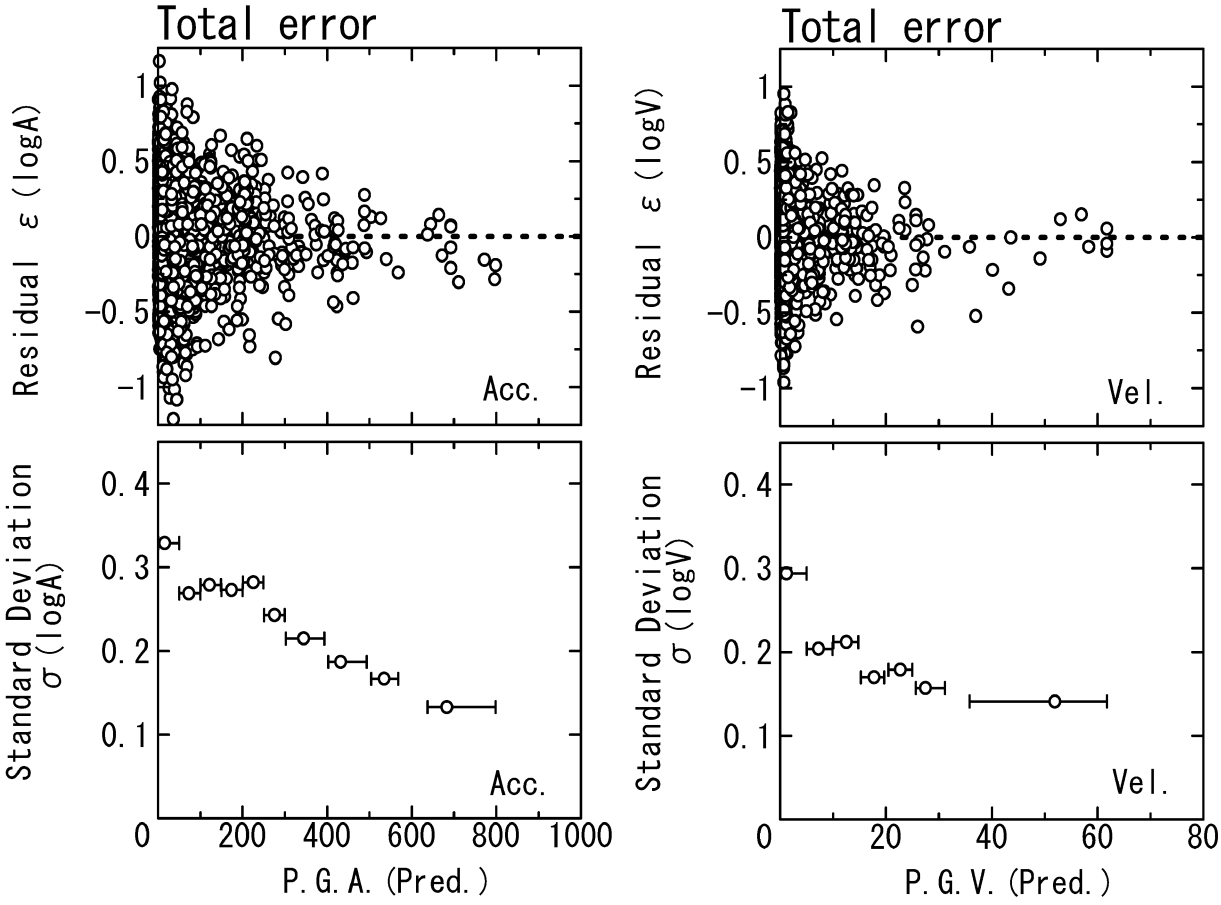

Fig. 7. Amplitude dependence of deviation of attenuation relationship (Midorikawa and Ohtake, 2004)

Figure 9 shows a comparison of seismic hazard maps with a 10% probability of exceedance in 50 years for the amplitude dependent and constant deviation models. In the maps, only the Tokai, Tonankai, and Nankai earthquakes are considered to emphasize the effects of the different deviation models. The amplitude dependent model shows a smaller expected intensity than the constant model, suggesting that selecting the deviation model is significant in the seismic hazard analysis.

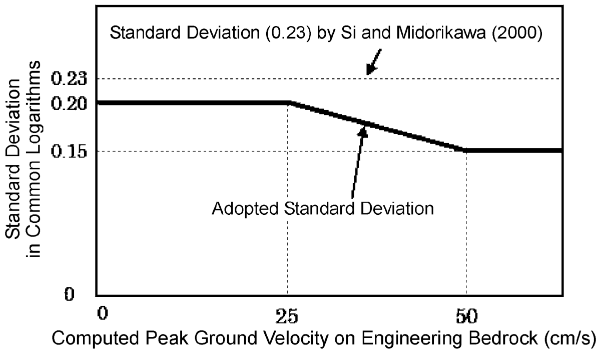

Fig. 8. Deviation model adopted in seismic hazard project (Earthquake Research Committee, 2005b)

5. Concluding Remarks

This paper describes two problems related to empirical predictions of strong motion that have been posed in the National Seismic Hazard Project of Japan. One is consideration of fault geometry in the attenuation relationship. The other is modeling the deviation in the attenuation relationship. Further discussion on the problems will promise more reliable empirical strong motion prediction.

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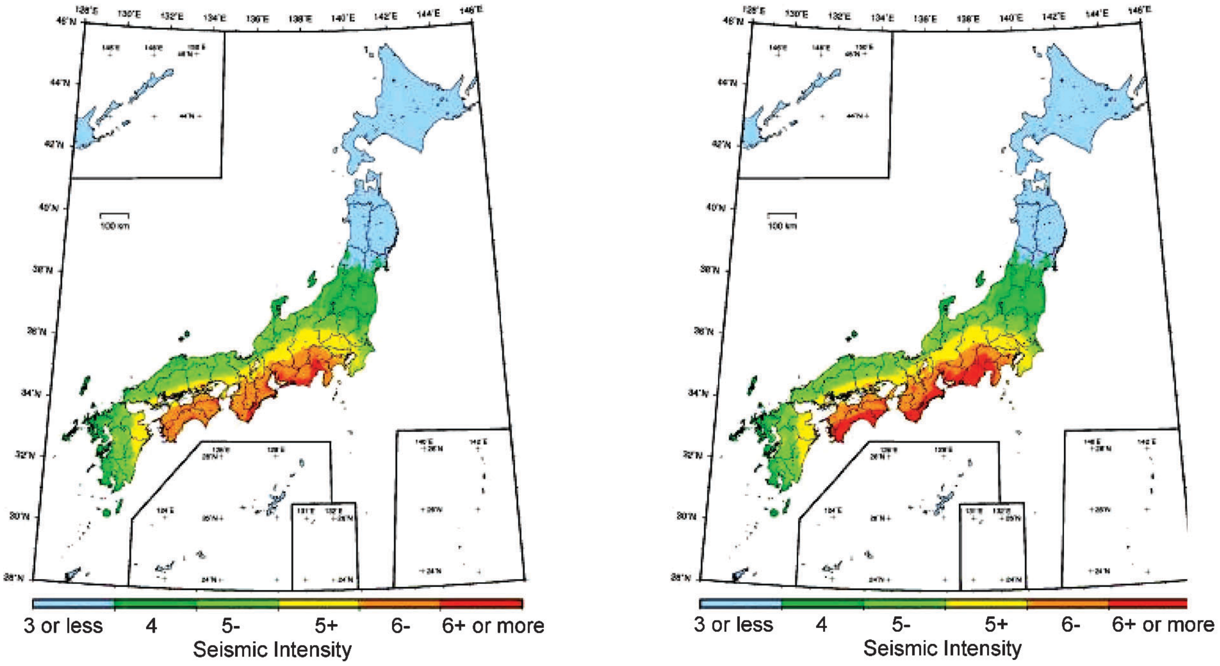

Fig. 9. Comparison of seismic hazard maps with a 10% probability of exceedance in 50 years for amplitude dependent deviation model (left) and for constant deviation model (right) (Earthquake Research Committee, 2005b)

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