Attenuation relationship for peak horizontal acceleration and velocity on the bedrock using strong ground motion records of 2007 Noto Hanto earthquake, Japan

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ABSTRACT :

In this study, we proposed the attenuation relationships for *PGA* and *PGV* based on records of main and after shock during the 2007 Noto Hanto earthquake. The amplification factors have not greatly changed between the main and the aftershock, it is considered that the correlation *PGV* to the amplification factors were good results

KEYWORDS: 2007 Noto Hanto earthquake, PGA, PGV, Attenuation relationship

1. Introduction

The Noto Hanto earthquake（M_{JMA}＝6.9）occurred in the northern part of Noto peninsula in Japan on March., 2007. Many structures such as wooden houses were severe damaged. Earthquake ground motion around the Noto peninsula was observed in the wide range, records of earthquake ground motion were obtained at many observation sites. For this earthquake, the maximum value of peak ground acceleration(*PGA*) is 1304cm/s^2 at the Monzen town site[1)], that of peak ground velocity(*PGV*) is 99cm/s at the Kyoshin-network(K-NET) site ISK005. Local government observation sites in Ishikawa prefecture, such as the Monzen town site, only have data of peak ground acceleration and JMA seismic intensity.

In this study, to investigate how a level of earthquake ground motion was the 2007 Noto Hanto earthquake compared with the general crustal earthquake. We proposed the attenuation relationships for *PGA* and *PGV* based on records of main and after shock during the 2007 Noto Hanto earthquake. In the analysis, we also evaluated amplification factors using the records of earthquake ground motion at JMA, K-NET and KiK-net observation sites. At JMA observation sites such as the Monzen town site, seismometers were temporarily installed after the 2007 Noto Hanto earthquake. As the proposed attenuation relationship was compared with that of the past study[2,3)], the amplification factors for *PGA* and *PGV* at each observation site were evaluated from the site coefficient in this study.

2. Used data of this study

Attenuation relationships of Japan meteorological agency (JMA), K-NET and KiK-net for *PGA* and *PGV* were evaluated from the records of earthquake ground motions. Locations of epicenters and observation sites in this study are shown in Figures 2.1 and 2.2. We used the 12 record earthquakes as shown in Table 2.1, JMA magnitude is 4.3 to 6.9. For observation sites, records were obtained from 5 earthquakes and over as shown in Table 2.1. The observation sites in this study were analyzed the records at 18 sites of JMA, 35 sites of the K-NET and 21 sites of the KiK-net, respevtively. JMA observation sites such as Monzen town site, seismometers were temporarily installed after the 2007 Noto Hanto earthquake. The temporal seismometer was installed at the surface ground of Monzen blanch office of Wajima city as well as the previous installed seismometer.

As shown in Figure 2.3, since peak period of spectral ratio of horizontal to vertical components (H/V) evaluated from microtremor records near the previous installed seismometer was agreement with those from the earthquake ground motion records of temporary one, it is suggested that the site effect of both observation sites is almost same.

Table 2.1 Summary of the earthquakes used in this study

Date	M_{JMA}	Latitude (°)	Longitude (°)	Depth (km)	Number
2007/3/25 9:41	6.9	37.22	136.69	11	68
2007/3/25 15:43	4.5	37.29	136.77	9	39
2007/3/25 18:11	5.3	37.30	136.84	13	72
2007/3/26 7:16	5.3	37.17	136.49	0	68
2007/3/26 14:46	4.8	37.17	136.55	9	65
2007/3/26 18:02	4.6	37.28	136.70	6	41
2007/3/28 8:08	4.9	37.22	136.71	13	66
2007/3/28 10:51	4.6	37.18	136.61	10	46
2007/3/28 13:05	4.7	37.28	136.68	7	53
2007/3/31 8:09	4.4	37.23	136.76	13	54
2007/4/6 15:18	4.3	37.27	136.79	12	32
2007/4/6 21:42	4.7	37.10	136.43	7	37

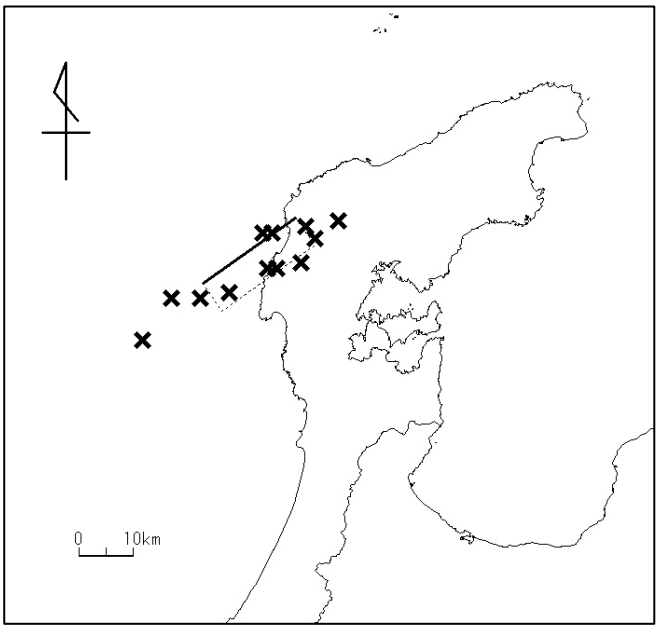


Figure 2.1 Locations of the earthquake. Solid line is the projective surface of the fault plane[2)]

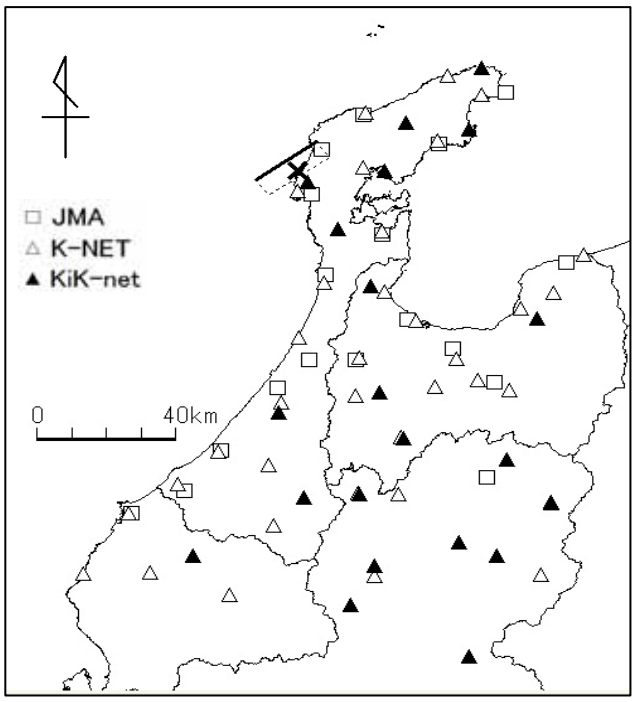


Figure 2.2 Locations of observation sites

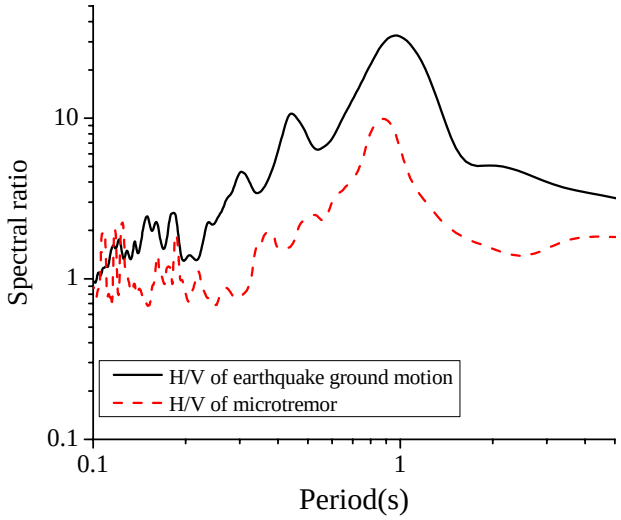


Figure 2.3 H/V spectrum of earthquake ground motion and microtremor at Monzen town site

3. Analytical method

In this study, assumption that indices of earthquake ground motion express as summation of condition of source effect, path effect and site effect, we determined parameters of the site effect by the two-stage regression analysis[2]. The used model of attenuation relationship is as follows.

$$\log A = S - \log(R + c_1 10^{C_2 M_{JMA}}) + kR + g \tag{3.1}$$

The coefficients of equation (3.1) were determined to minimize the integration of errors between the predicted and observed values of A, changing value of C_1. In the regression analysis, TYMH04 KiK-net site that is installed on the basement of surface layer with S-wave velocity 600m/s is selected as reference site, g of this site is equal to 0. Therefore, g at each observation sites obtained by the regression analysis is relative value for that of reference site of TYMH04. An site amplification factor is defined as 10^g. At the second step, S is expressed as a function in terms of M_{JMA} as follows.

$$S = aM_{\mathrm{JMA}} + b \tag{3.2}$$

Coefficients a, b are determined by the regression analysis.

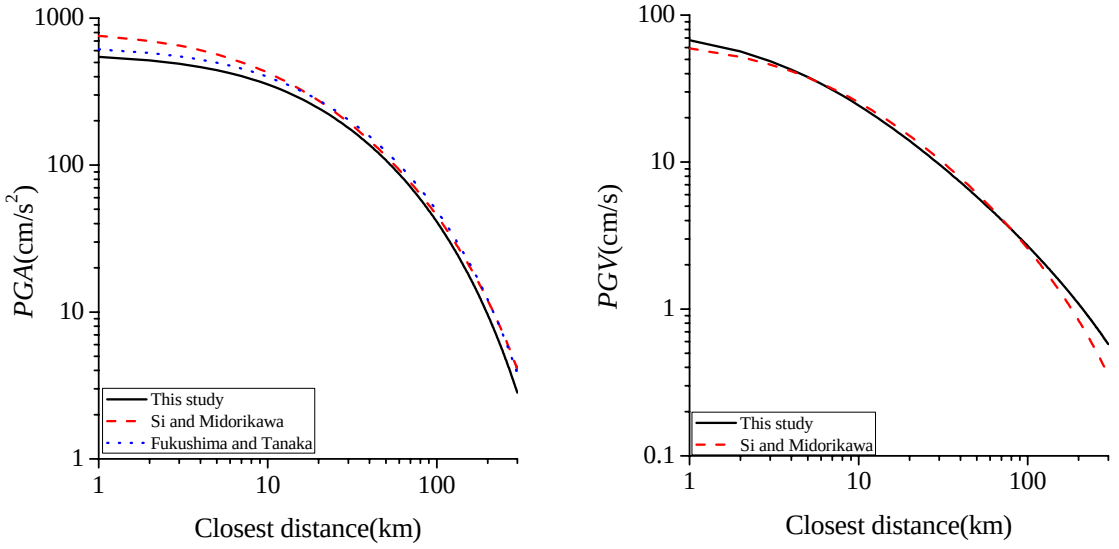
4. Attenuation curves for *PGA* and *PGV*

The regression coefficients were listed in Table 4.1. Coefficients a for *PGA* and *PGV* are large compared with those of the past studies[3,4], coefficients b are contrastively small. Coefficient C_1 for *PGA* is larger than those of S_i and Midorikawa(1999)[4], against *PGV* is small. Coefficient k for *PGA* is similar level to those of past studies[3,4], against *PGV* is also small. The attenuation curves for *PGA* and *PGV* obtained in this study are shown in Figure 4.1. The attenuation curve of *PGA* is an insignificantly small, however the slope of curve is almost same. The curve for *PGV* is generally agreement with those of Si and Midorikawa(1999)[4]. The attenuation curves and the observed values for *PGA* and *PGV* on the bedrock are shown in Figure 4.2. The observed values

on bedrock are evaluated by dividing the amplification factor into the one on surface. As shown in Figure 4.2, the observed values are roughly consistent to the attenuation curves obtained in this study.

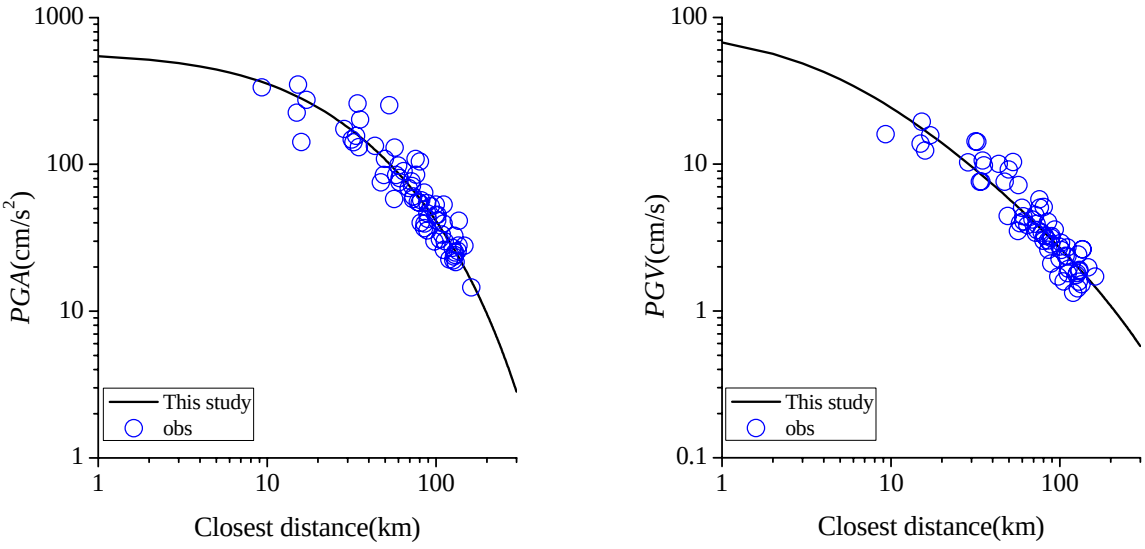
Table 4.1 Regression coefficients for *PGA* and *PGV*

	a	*b*	C_1	C_2	*k*
PGA	0.681	-0.609	0.0071	0.5	-0.0037
PGV	0.774	-2.701	0.0015	0.5	-0.0010



(a) *PGA* (b) *PGV*

Figure 4.1 Comparison of the attenuation curves in this study and in the past study[3,4)]



(a) *PGA* (b) *PGV*

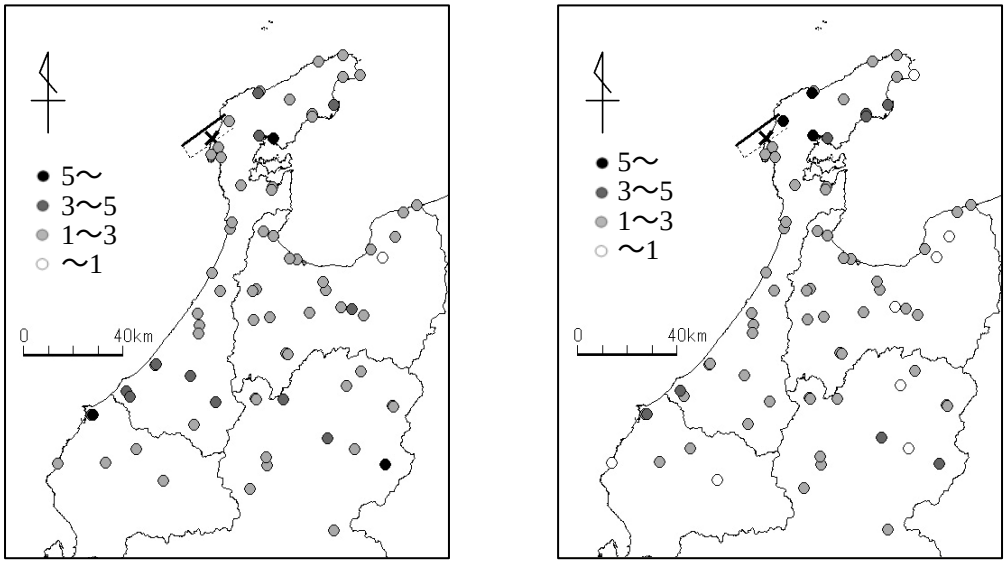
Figure 4.2 Comparison between the attenuation curves and the observed values of *PGA*, *PGV*

5. Site amplification factors for *PGA* and *PGV*

A distribution of site amplification factors for *PGA* and *PGV* are shown in Figure 5.1. As shown in Figure 5.2, observation sites with site amplification factors more than 5 are located at Fukui, Ishikawa and Gifu prefecture. On the other hand, observation sites with amplification factors more than 5 are only located at Noto peninsula in Ishikawa prefecture. *PGA*, *PGV* and the amplification factors of the observation sites located at the closest distance with less than 20km are shown in Figure 5.2. It is clear that the correlation *PGV* to the amplification factors is good. However the correspondence of *PGA* is not expected. Although the amplification factor for *PGA* at JMA Wajima site is large, *PGA* of this site is the smallest value. It is considered that the amplification factor for *PGA* at this site greatly decreased by nonlinear behavior of the surface ground. Since the amplification factors for *PGV* have not greatly changed between the main shock and the aftershock, it is considered that correlation *PGV* to the amplification factors were good results.

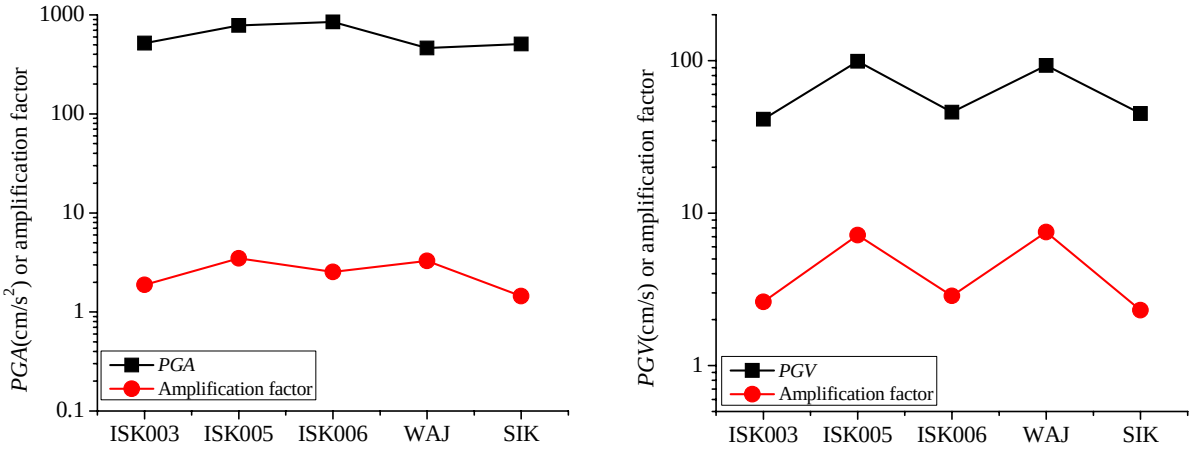
6. Conclusion

For the 2007 Noto Hanto earthquake, in order to evaluate peak horizontal acceleration (*PGA*) and velocity (*PGV*) at arbitrary sites, we proposed the attenuation relationships for *PGA* and *PGV* on the bedrock and the site amplification factors at each observation site were evaluated. The attenuation relationships and the site amplification factors were determined by two-stage regression analysis. Comparing the attenuation relationships obtained in this study to those of past studies, the attenuation curve is a little small compared with those of the past studies, however the slope of curve is almost same. The attenuation curve is generally agreement with that of the past study. A relationship between *PGA*, *PGV* and the amplification factors of observation sites located at the closest distance with less than 20km was examined. There are correlation between *PGV* and the amplification factors, however the correspondence of *PGA* and the amplification factors are not expected. It is considered that the amplification factor at a part of observation site decreased greatly by nonlinear behavior of the surface ground. Since the amplification factors have not greatly changed between the main shock and the aftershock, it is considered that the correlation *PGV* to the amplification factors were good results.



(a) *PGA* (b) *PGV*

Figure 5.1 Distribution of the site amplification factors for *PGA* and *PGV*



(a) *PGA* (b) *PGV*

Figure 5.2 Indices of earthquake ground motion and the site amplification factors of observation sites located at the closest distance with less than 20km. WAJ and SIK in Figure are denote JMA Wajima, Shika site, respectively

Acknowledgment

We used the earthquake motion records of JMA, K-NET and KiK-net developed by National Research Institute for Earthquake Science and Disaster Prevention. The authors would like to thank related organization.

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