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Microtremor H/V Spectrum Ratio and Site Amplification Factor in the Seismic Observation Stations for 2008 Iwate-Miyagi Nairiku Earthquake

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2008年岩手・宮城内陸地震の強震観測点における常時微動H/Vスペクトルとサイト増幅特性

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The great geo-disaster occurred in the 2008 Iwate-Miyagi Nairiku Earthquake. In this study, we carried out the microtremor measurement, and calculated microtremor H/V spectrum ratio in 17 seismic stations where the strong ground motion were recorded in the 2008 Iwate-Miyagi Nairiku Earthquake. Furthermore, we computed the horizontal and vertical site amplification factors in the seismic observation stations using the moderate earthquake motion records. The calculated H/V spectra and site amplification factors will contribute to the seismic motion estimation of the damaged areas and clarification of damage mechanisms in the future study.

Keywords: 2008 Iwate-Miyagi Nairiku Earthquake, seismic station, microtremor measurement, site amplification factor

1. Introduction

The great geo-disaster occurred in the 2008 Iwate-Miyagi Nairiku Earthquake. A lot of strong motions were recorded in the seismic observation stations by this earthquake. Particularly, the 4,022 gal (3-components PGA) in KiK-net Ichinoseki-nishi (IWTH25) was largest in the strong motion observation history. The ground shaking characteristics examination in the seismic observation stations is very important to estimate the seismic ground motion in the damaged areas in the future study.

Some investigation and studies which targeted strong motion observation stations in the 2008 Iwate-Miyagi Nairiku Earthquake were carried out (e.g. Takahashi *et al*., 2008; Yamada *et al*., 2009 and Sakai *et al*., 2010). However, these previous studies did not focus on the detailed ground shaking characteristics in the seismic stations. Furthermore, the site amplification factor in the vertical direction is not computed, though the site amplification factor in the horizontal direction is examined (Nozu *et al*., 2007 and Hata *et al*., 2009; 2010a; 2010b; 2010c).

In this study, we carried out the microtremor measurement, and calculated microtremor H/V spectrum ratio in 17 seismic stations where the strong ground motion were recorded in the 2008 Iwate-Miyagi Nairiku Earthquake. Furthermore, we computed not only the horizontal site amplification factor but also the vertical site amplification factors in the seismic observation stations using the moderate earthquake motion records. In other words, in this paper, the detailed ground shaking characteristics of the seismic observation stations is reported based on the microtremor H/V spectrum ratio and site amplification factor in the horizontal and vertical direction.

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2. Seismic observation station

Figure 1 shows the distribution of the target seismic observation station. These 17 seismic observation stations were including K-NET (Kinoshita, 1998), KiK-net (Aoi *et al*., 2000), JMA (Nishimae, 2004) and the dam sites. Here, the furthest station from the dam structure or embankment was adopted as the seismic observation station for the dam site. **Table 1** shows the list of the location, the epicentral distance, the JMA seismic intensity and PGA in the target seismic observation stations. This result suggests the effect of site response characteristics is remarkable, and the importance of the ground shaking characteristics evaluation in the seismic observation stations.

3. Microtremor measurement

3.1 Measurement conditions

In this study, the microtremor measurement was carried out in the targeted 17 seismic observation stations (**Figure 1** and **Table 1**). The conditions of the microtremor measurement in the seismic observation stations are shown in the **Photograph 1**. The specifications of the instrument for microtremor measurement are shown in the **Table 2** and the **Figure 2**. The measurement was done in 4 days from October 8, 2010 until October 11, except the microtremor measurement in the Ishibuchi dam at the down stream terrace on January 14, 2010. The measurement direction was 3 directions of NS, EW and UD components. Here, the mean of the horizontal 2 components were adopted in the calculation of the H/V spectrum ratio. The measurement time was 11 minutes (≒ 163.84 sec × 4 sections), the sampling frequency was 100Hz.

3.2 Calculation of H/V spectrum ratio

How to calculate a microtremor H/V spectrum ratio is mentioned in the following. First, the high-pass filter of 0.1Hz is adopted, and, 3 time sections of the 163.84 sec each were extracted considering noise. Next, Fourier amplitude spectrum of the each 3 time sections was calculated with a Parzen window (band width of 0.05Hz). Finally, a microtremor H/V spectrum ratio was calculated at a seismic observation station as the average spectrum ratio of 3 time sections. Here, the frequency range to evaluate microtremor H/V spectrum ratio is from 0.2Hz to 10Hz considering the performance of the instrument for microtremor measurement.

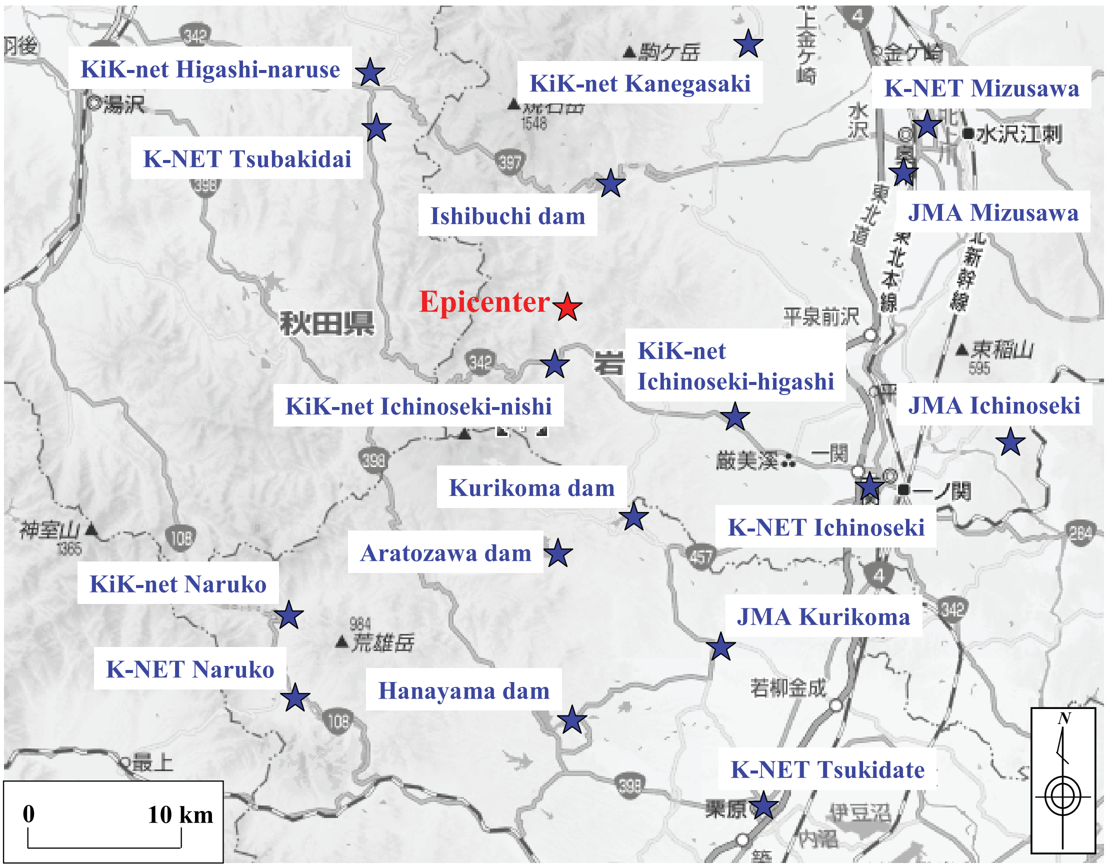


Figure 1 The distribution of the target seismic observation stations.

Table 1 The list of the various factors in the target seismic observation stations.

Observation station name	East longitude	North latitude	Epicentral distance (km)	JMA instrumental seismic intensity	3-components PGA (gal)
KiK-net Ichinoski-nishi	140.87	39.01	2.7	6.4	4022.1
Ishibuchi dam (Down stream terrace)	140.90	39.11	9.6	6.4	2544.0
KiK-net Ichinoski-higashi	141.01	38.97	12.8	6.1	1372.1
Aratozawa dam (Right abutment bedrock)	140.92	38.91	13.9	6.0	1344.9
Kurikoma dam (Down stream bedrock)	140.86	38.88	16.3	5.5	508.3
K-NET Tsubakidai	140.72	39.15	19.2	5.3	437.9
KiK-net Higashi-naruse	140.72	39.17	21.3	6.4	2599.9
KiK-net Kanegasaki	141.02	39.20	21.9	5.5	538.5
K-NET Ichinoseki	141.12	38.93	23.0	5.1	307.8
JMA Kurikoma	140.99	38.82	24.9	5.9	699.1
JMA Mizusawa	141.14	39.13	25.0	5.1	388.1
K-NET Mizusawa	141.15	39.15	26.9	5.1	243.2
KiK-net Naruko	140.66	38.86	27.3	5.0	288.8
Hanayama dam (Right abutment bedrock)	140.87	38.78	27.6	5.4	510.4
JMA Ichinoseki	141.22	38.95	30.6	4.6	400.0
K-NET Naruko	140.65	38.80	32.2	5.5	676.3
K-NET Tsukidate	141.02	38.73	35.4	5.7	812.3

Table 2 The list of the various factors of the adopted the instrument for microtremor measurement.

Manufactures／Model	Buttan service Co., Ltd. ／ GEONET1-2S3D	
Element section	Input component number	1, 2, 3 components (Horizontal 2; Vertical 1)
	Natural period of pendulum	2 seconds (based on the C-R adjustment)
	Sensitivity	1 V/cm/sec
	Measurable frequency	0.5～18 Hz (-3dB)
	Resistance coil	4,000 Ω
A/D conversion section	Conversion method	Delta-sigma over sampling mrthod
	Sampling frequency (Data rate)	50, 100, 200 Hz
	Dynamic range (AD resolution)	24 bit
	Effective resolution	More than 19 bit
	AD input voltage	±2.5V
	Digital filter	Sampling frequency × 0.216 (-3dB)
Amplification section （Preamplifier section）	Amplification degree	0, 40 dB
	Filter	20, 100Hz (High cut filter)
Data output	Output type	Connection by the USB or radio
	Effective transfer rate	115.2 kbit/sec
	Start bit	1 bit
	Stop bit	2 bit
	Data length	8 bit
	Parity bit	None
	Flow control	None
Others	Power source	DC12V (Usable car battery)
	Cabinet case material	Aluminum
	Measurements／Weight	W120 × D120 × H140 ／ 1.8kg
	GPS geophone	Acquisition of time and location

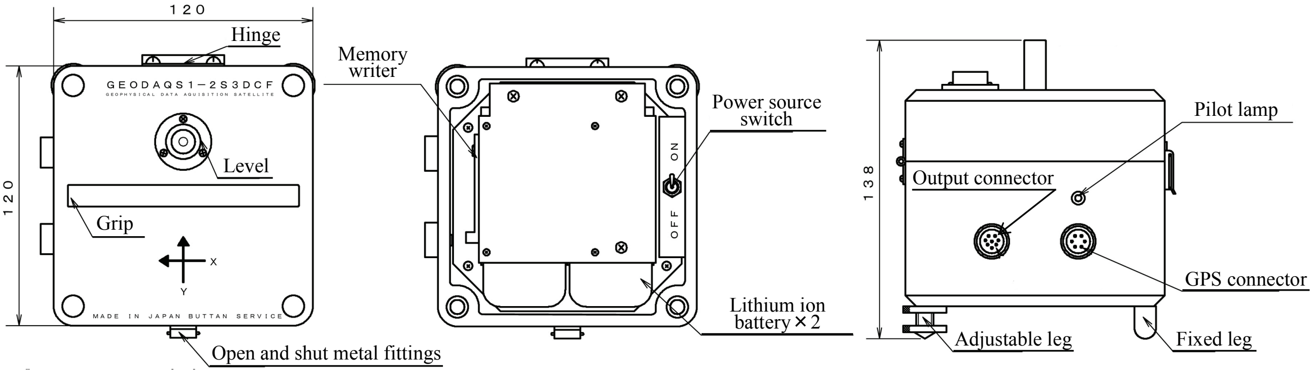


Figure 2 The upper view (left), the lower view (center) and the side view (right) of the instrument for microtremor measurement.


KiK-net Ichinoseki-nishi


KiK-net Ichinoseki-higashi


Aratozawa dam
(Right abutment bedrock)


Kurikoma dam
(Down stream bedrock)


K-NET Tsubakidai


KiK-net Naruko


KiK-net Kanegasaki


K-NET Ichinoseki


JMA Kurikoma


JMA Mizusawa


K-NET Mizusawa


KiK-net Naruko


Hanayama dam
(Right abutment bedrock)


JMA Ichinoseki


K-NET Naruko


K-NET Tsukidate

Photograph 1 The execution conditions of the microtremor measurement in the seismic stations.

4. Site amplification factor

4.1 The method for the factors in horizontal direction

In this section, the calculation of a site amplification factor in the horizontal direction in the targeted 17 seismic observation stations is mentioned. The site amplification factors for the K-NET and KiK-net stations were already reported based on the spectral inversion (Nozu *et al*., 2007). However, the site amplification factor in the seismic observation stations of the JMA and the dam site were not reported yet. In this study, the spectral ratio method is applied for these sites (e.g., The Japan Port and Harbor Assoc., 2007).

First, Fourier amplitude spectrum with a Parzen window (band width of 0.05Hz) is computed. In this method, the fact that some earthquake motions are observed in the reference station and the target station at the same time is focused. **Table 3** shows the combination of the target station and the reference station. Here, the target observation stations are observation stations in the JMA or in the dam site. Then, the reference stations are chosen from K-NET or KiK-net stations around the each target station.

Secondly, for each combination of target and reference, the spectral ratio of the Fourier amplitude between the reference station and the target station is calculated. The effects of geometrical spreading and anelastic attenuation are considered as the path effect (Boore, 1983, Satoh and Tatsumi, 2002) to shrink the Fourier spectra. Thus, the spectral ratio of the Fourier amplitude is corrected considering the path effect.

Thirdly, the mean of the corrected spectral ratio (the target station / the reference station) is obtained by earthquake observation records. Here, the moderate earthquake motion record before the main shock was used for the JMA sites calibration, and the aftershock motion records were used for the dam sites calibration. That is because there is no main shock records in the dam sites.

Finally, the site amplification factor of the target site is obtained by the multiplication of the spectral ratio and the site amplification factor of the reference site.

4.2 The method for the factors in vertical direction

In this section, the method to obtain a site amplification factor in the vertical direction is mentioned. The same method was used for all 17 seismic observation stations.

First, the spectral ratio of the vertical Fourier amplitude to the horizontal Fourier amplitude is calculated for each observation station. Here, a Parzen window (band width of 0.05Hz) is applied to the Fourier amplitudes.

Next, the mean of the spectral ratio (the vertical direction / the horizontal direction) is obtained by earthquake observation records. As same as the method for horizontal direction, the moderate earthquake motion record before the main shock was used for the K-NET, KiK-net and JMA sites calibration, and the aftershock motion records were used for the dam sites calibration.

Finally, the site amplification factor in the vertical direction is obtained by the multiplication of the spectral ratio and the site amplification in the horizontal direction. Note the difference between the method for horizontal direction and for the vertical direction is the definition of spectral ratio. For horizontal direction estimate, the ratio of target site to reference site was used. For vertical direction estimate, the ratio of vertical component to horizontal component was used.

4.3 Results

Figure 3 shows the calculation results of the site amplification factor in the horizontal and vertical direction based on the above-mentioned method. Furthermore, **Figure 3** shows the microtremor H/V spectum ratio observed at the sites (**3.2** sections). In **Figure 3**, the site amplification factor in the vertical direction is almost similar to the site amplification factor in the horizontal direction. Furthermore, the characteristics of both spectra (peak frequency, spectrum shape and so on) and that of the microtremor H/V spectrum ratio are also similar. It suggests that the ground shaking characteristics in microtremor and seismic motion considered in this study share common characteristics.

Table 3 The combination of the target station and the reference station.

Target station	Reference station
Ishibuchi dam (Down stream terrace)	KiK-net Kanegasaki
Aratozawa dam (Right abutment bedrock)	KiK-net Ichinoseki-higashi
Kurikoma dam (Down stream bedrock)	KiK-net Ichinoseki-higashi
JMA Kurikoma	K-NET Tsukidate
JMA Mizusawa	K-NET Mizusawa
Hanayama-dam (Right abutment bedrock)	K-NET Tsukidate
JMA Ichinoseki	K-NET Ichinoseki

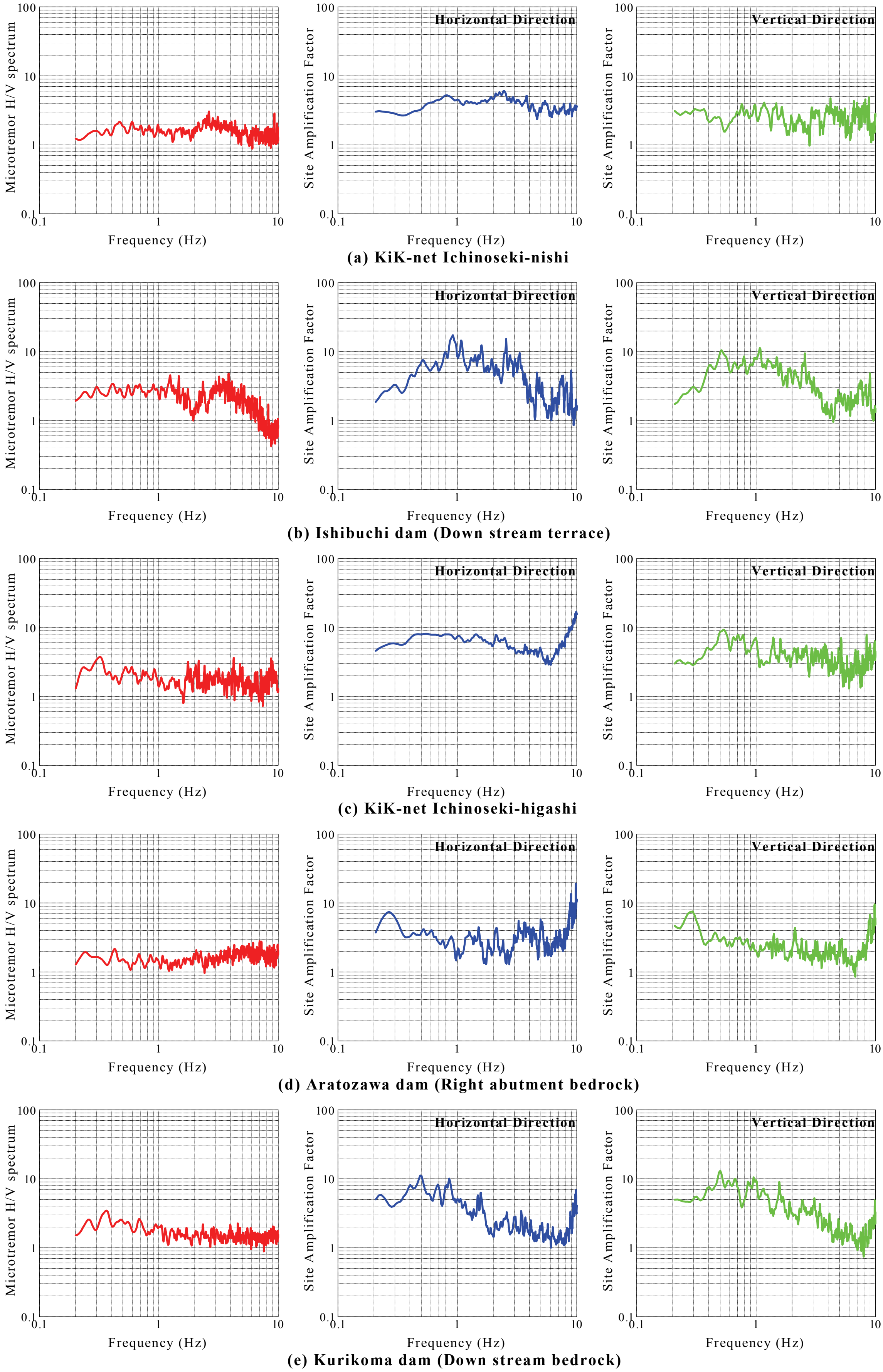
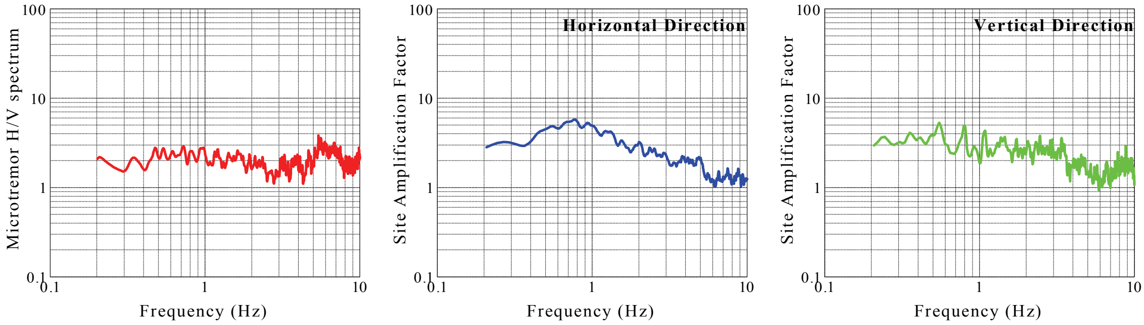
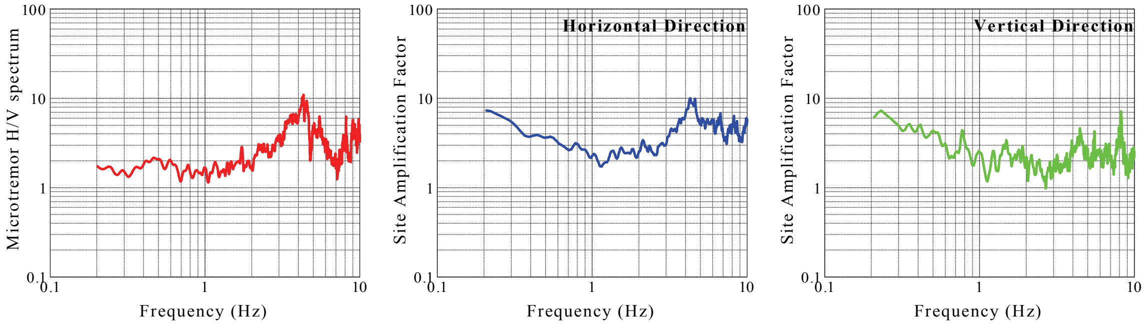


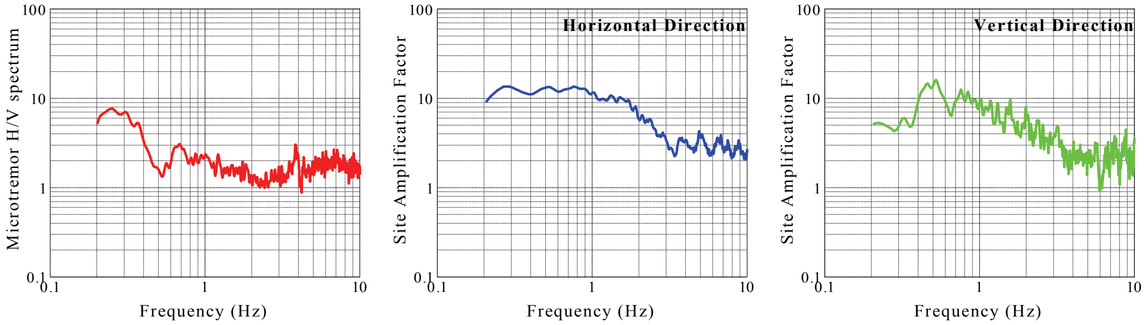
Figure 3 H/V spectrum, horizontal site amplification factor and vertical site amplification factor in the seismic stations.



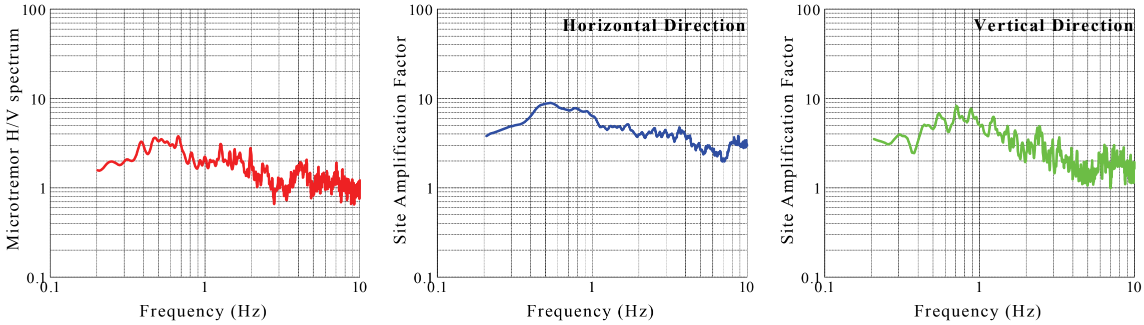
(f) K-NET Tsubakidai



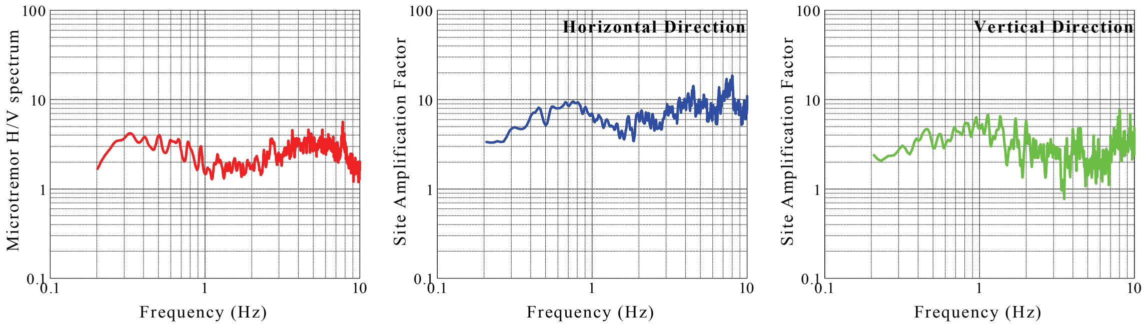
(g) KiK-net Higashi-naruse



(h) KiK-net Kanegasaki



(i) K-NET Ichinoseki



(j) JMA Kurikoma

Figure 3 H/V spectrum, horizontal site amplification factor and vertical site amplification factor in the seismic stations. (cont.)

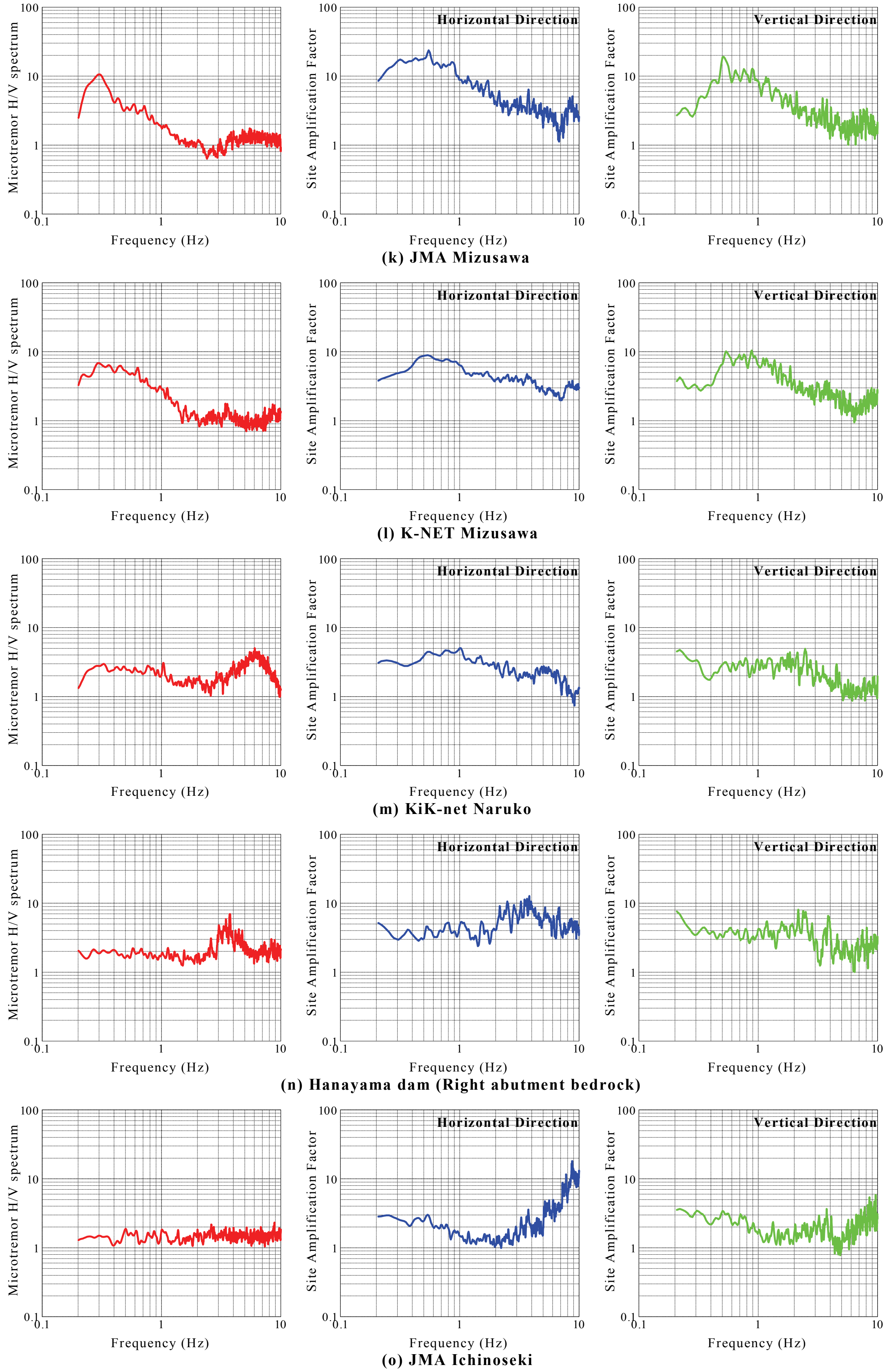


Figure 3 H/V spectrum, horizontal site amplification factor and vertical site amplification factor in the seismic stations. (cont.)

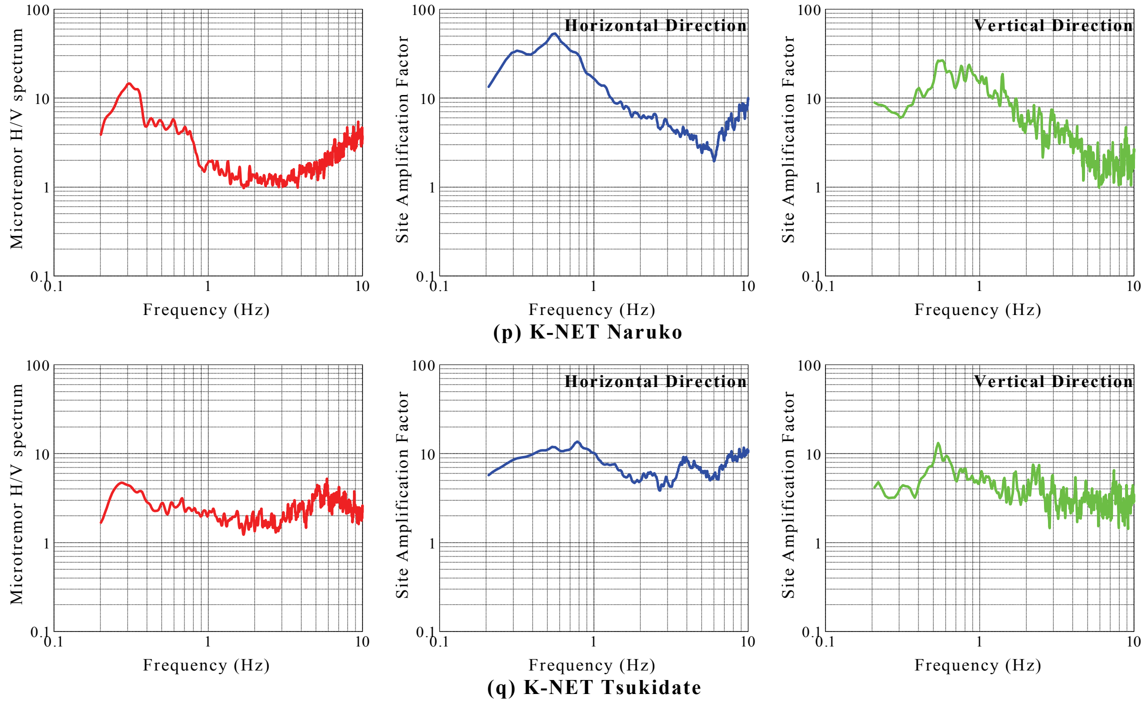


Figure 3 H/V spectrum, horizontal site amplification factor and vertical site amplification factor in the seismic stations. (cont.)

5. Conclusions

In this study, we carried out the microtremor measurement, and obtain microtremor H/V spectrum ratio in 17 seismic stations where the strong ground motion were recorded in the 2008 Iwate-Miyagi Nairiku Earthquake. The horizontal and vertical site amplification factors in these stations are also evaluated.

These results will contribute to clarify the detail ground shaking for the damaged area in the 2008 Iwate-Miyagi Nairiku Earthquake.

Data and resources

K-NET and KiK-net data can be obtained from the National Institute for Earth science and Disaster prevention (NIED) at http://www.kyoshin.bosai.go.jp/kyoshin/ (last accessed October 2010). Seismic observation data of JMA were collected from the Japan Meteorological Business Support Center by CD-ROM. Seismic observation data of Aratozawa dam and Hanayama dam were provided from integration office for Kurihara regional dams at Miyagi prefecture. Then, seismic observation data of Kurikoma dam was provided from administration office for Kurikoma dam at Miyagi prefecture.

Acknowledgments

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References

Aoi, S., K. Obara, S. Hori, K. Kasahara and Y. Okada (2000): New strong-motion observation network: KiK-net, *EOS, Transactions, American Geophysical Union*, 329.

Boore, D.M. (1983): Stochastic simulation of high-frequency ground motions based on seismological models of the radiated spectra, *Bulletin of the Seismological Society of America* (*BSSA*), Vol.73, pp.1,865-1,894.

Hata, Y., Ohsumi, T. and Nozu, A. (2009): Seismic motion estimation in the Nuruyu Hot Spring for 2008 Iwate-Miyagi Nairiku Earthquake based on empirical site amplification and phase effect (in Japanese), *Proc. of Japan Society of Civil Engineers 2009 annual meeting*, I-331, pp.661-662.

Hata, Y., Nozu, A. and Nakamura, S. (2010a): Seismic motion estimation in the damaged areas by 2008 Iwate-Miyagi Nairiku Earthquake (in Japanese), *Disaster report on the 2008 Iwate-Miyagi Nairiku Earthquake*, JGS, pp.24-38.

Hata, Y., Nakamura, S. and Nozu, A. (2010b): Seismic motion estimation in the damaged sites of the Ichihasama river area for 2008 Iwate-Miyagi Nairiku Earthquake based on empirical site amplification and phase effect (in Japanese), *Proc. of Japan*

Society of Civil Engineers 2010 annual meeting, I-343, pp.685-686.

Hata, Y., Nakamura, S., Nozu, A., Yamada, M. and Hada, K. (2010c): Seismic motion estimation in the Matsurube bridge and Ichinonohara for 2008 Iwate-Miyagi Nairiku Earthquake based on empirical site amplification and phase effect (in Japanese), *Proc. of Japan Society of Civil Engineers 2010 annual meeting*, I-344, pp.687-688.

Kinoshita, S. (1998): Kyoshin-net (K-NET), *Seismological Research Letters*, Vol.69, pp.309-332.

Nishimae, Y. (2004): Observation of seismic intensity and strong ground motion by Japan Meteorological Agency and local governments in Japan, *Jour. of Japan Association for Earthquake Engineering*, Vol.4, No.3, pp.75-78.

Nozu, A., Nagao, T. and Yamada, M. (2007): Site amplification factors for strong-motion sites in Japan based on spectral inversion technique and their use for strong-motion evaluation (in Japanese with English abstract), *Jour. of Japan Association for Earthquake Engineering*, Vol.7, No.3, pp.215-234.

Sakai, Y., Atsushi, A., Arai, K. and Suzuki, T. (2010): Damage investigation of surroundings of the seismic stations in the 2008 Iwate-Miyagi Nairiku Earthquake and correspondence of damage to buildings with strong ground motions (in Japanese with English abstract), *Jour. of Japan Association for Earthquake Engineering*, Vol.10, No.4, pp.14-53.

Satoh, T. and Y. Tatsumi (2002). Source, path, and site effects for crustal and subduction earthquakes inferred from strong motion records in Japan (in Japanese with English abstract), *Jour. of Struct. Constr. Eng.*, AIJ, No.556, pp.15-24.

Takahashi, Y., Tanino, M. and Motosaka, M. (2008): Microtremor H/V spectrum ratio in the damaged areas by 2008 Iwate-Miyagi Nairiku Earthquake (in Japanese), *Proc. of the 6th annual meeting of Japan Association for Earthquake Engineering*, pp.320-321.

The Japan Port and Harbor Association (2007): Technical standards, and commentaries for port and harbor facilities (in Japanese).

Yamada, M., Fukushima, Y. and Suetomi, I. (2009): Building damage during the 2008 Iwate-Miyagi Nairiku Earthquake (in Japanese with English abstract), *Annuals of Disaster Prevention Research Institute*, *Kyoto University*, No.52B, pp.241-247.

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