NON-LINEAR SITE RESPONSE CHARACTERISTICS OF K-NET ISK005 STATION AND RELATION TO THE EARTHQUAKE DISASTER DURING THE 2007 NOTO-HANTO EARTHQUAKE, CENTRAL JAPAN

Tomotaka Iwata[1], Kimiyuki Asano[2], Masayuki Kuriyama[3] and Asako Iwaki[3]

[1] *Professor, Disaster Prevention Research Institute, Kyoto University, Uji, Kyoto, Japan*
[2] *Assistant Professor, Disaster Prevention Research Institute, Kyoto University, Uji, Kyoto, Japan*
[3] *Graduate student, Disaster Prevention Research Institute, Kyoto University, Uji, Kyoto, Japan*
Email: iwata@egmdpri01.dpri.kyoto-u.ac.jp

ABSTRACT :

On March 25, 2007, the 2007 Noto-Hanto earthquake of M_J6.9 occurred. We analyzed the strong ground motion records at the Anamizu (K-NET, ISK005) station, where recorded JMA seismic intensity of 6+, to get the ground motion characteristics at the station. Comparing the H/V spectral ratios of the mainshock records and those of records for before events and for aftershocks, non-linear site response behavior during the mainshock ground motions was observed. As the H/V characteristics were already recovered at the coda wave part of the mainshock records, non-linear site response was restricted only the strong shaking part.

We also conducted aftershock and microtremor observations by the temporally-installed stations to understand extension of the area whose subsurface layer characteristics are similar with that at the ISK005 station. Large amplifications of S-wave portion of aftershock records at the ISK005 and sites were observed by comparing those at the ANC, where is regards as a rock station. As the site specific ratio, amplification of approximately 10 at the frequency range of 1-1.5Hz among aftershocks. Single station microtremor H/V ratio also show the similar predominant frequency at Anamizu downtown sites and the low-velocity subsurface layer seems to extend the disaster area during the mainshock.

KEYWORDS: Non-linear site response, the 2007 Noto-Hanto earthquake, microtremor observation, aftershock observation

1. INTRODUCTION

On March 25, 2007, the 2007 Noto-Hanto earthquake of M_J6.9 occurred. JMA seismic intensity of 6+ were observed at Wajima, and Nanao cities and Anamizu town near the source area. Strong motion record at Anamizu town (K-NET Anamizu, ISK005) hass larger values that was expected from the empirical attenuation relation (e.g. Iwata et al., 2008). Figure 1 shows corrected observed peak ground velocities at K-NET and KiK-net stations. The site amplification factors are corrected to get the PGVs on the engineering bedrock by the empirical relationship between Vs30 and the amplification factors of PGV (Midorikawa et al., 1994). After the correction, the PGV values at OSK005 is still larger than one-standard-deviation of the empirical attenuation relationship of PGV by Si and Midorikawa (1999). There are many collapsed wooden houses near the station and it is very important to investigate such ground motion characteristics for understanding large seismic disaster in this area. At first, we compare ground motion characteristics of the events before the mainshock, the mainshock, and the aftershocks and show the change of those characteristics with events. In the next, we conduct temporal microtremor measurements and aftershock observations to see the extension of subsurface structure that generates amplification of ground motions. From the aftershock observation, strong ground motion amplification is observed at the center of the downtown Anamizu including K-NET site. The amplification by subsurface structure is discussed. Single microtremor observations are conducted more than 150 sites in Anamizu town with approximately 0.2km span, that cover most of the downtown area of Anamizu town. Detail subsurface structure is estimated by this microtremor observations and the relationship between the subsurface structure and earthquake damage area is discussed.

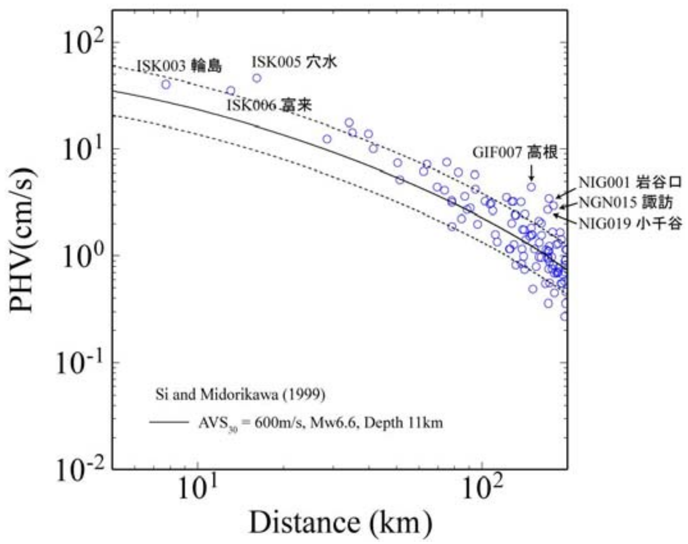

Figure 1 Peak horizontal velocity distribution. Solid line shows the empirical relation by Si and Midorikawa (1999).

2. H/V SPECTRAL RATIO OF OBSERVED GROUND MOTIONS

We took the spectral ratio of horizontal (vectorial summation of two horizontal components) and vertical components of the ground motions. H/V spectral ratio is called as the receiver function that would characterize ground motion characteristics at that site. Nine event records for the mainshock and 22 aftershock records are analyzed together with the mainshock record. H/V spectral ratio is taken at the S-wave portion for the events without the mainshock. For the mainshock records, we take the running H/V spectral ratio from the S-wave onset to the S-coda part. Figure 2 shows the H/V spectral ratio. H/V spectral ratios before and after the mainshock show the peak frequency of 1.2Hz (0.8s in the period). That during the mainshock shows the peak frequency of approximately 1Hz or less during the strong shaking. Another important point is that the peak frequency is recovering to 1.2Hz in the S-wave coda part. The H/V peak level values are also changed. The peak values are approximately 20-30 for the events before and after the mainshock, whereas that is about 10 during the mainshock. This phenomenon is clearly showing that the non-linear soil response was occurred during the mainshock.

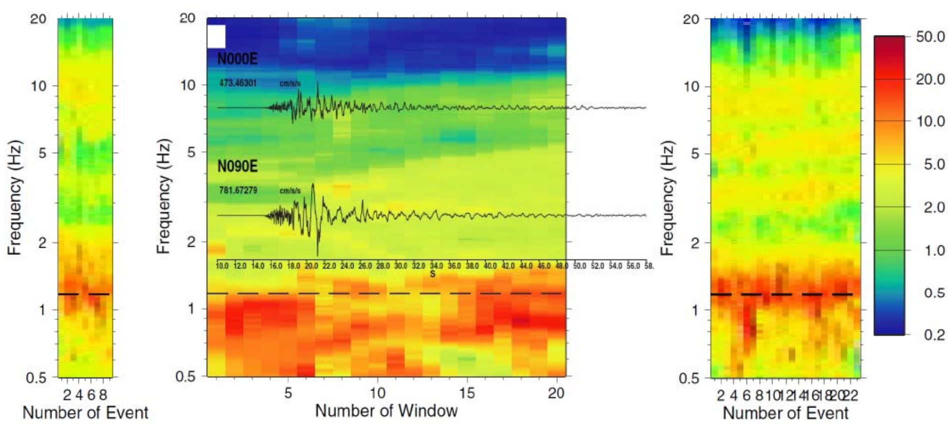

Figure 2 Temporal variation of H/V spectral ratios of earthquake ground motion data at ISK005. Left and right panels show H/V for before and after the mainshock. Center panel shows temporal change during the shaking of the mainshock.

From subsurface structure information at ISK005, K-NET, a 10m thickness of peat layer and a 5m thickness of silt and soil layer are observed. A rock layer starts from 15m depth. S-wave velocity of the peat layer is 60m/s and that of silt and soil layer is 130m/s. Resonant frequency of this subsurface velocity structure is estimated as 1.2Hz and this coincides to the peak frequency of weak motion H/V spectral ratio obtained in Chapter 2. Therefore, the ground motion characteristics at ISK005 are strongly controlled by this subsurface velocity structure that has very low S-wave velocity layer of 10 to 15m thickness.

3. AFTERSHOCK OBSERVATION

We conducted aftershock observation in Anamizu town. Figure 3 shows temporal stations on the topography map. Anamizu town has a small sedimentary basin whose size is approximately 2km wide. We installed four stations, West end of the small basin, CHU, ISK005 site, KNET, Anamizu downtown, HOS, and East end of the basin TWN. Station HOS is the site of a temple whose main shrine was partially collapsed. Station TWN is seems to be a rock site. Examples of observed aftershock records of four stations are shown in Figure 4. EW-component of ground velocities are shown. At a glance, large amplifications are observed at the KNET and HOS stations. The ground motion level at CHU is between that at TWN and those at KNET and HOS. Spectral ratios to the ground motion at TWN are also shown in Figure 4. We took the average for five events. Large amplifications at KNET and HOS are observed in the frequency range of 1-2Hz. That frequency range coincides to H/V peak frequency at ISK005 stations. Those characteristics indicate that thin subsurface low-velocity structure strongly affect this observation characteristics at KNET and HOS.

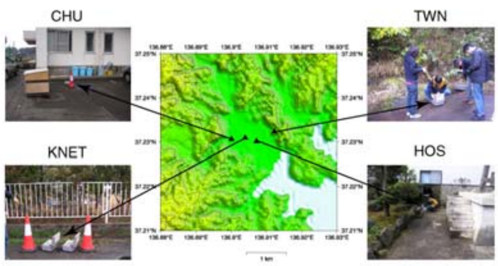

Figure 3 Temporal aftershock observation station distributions

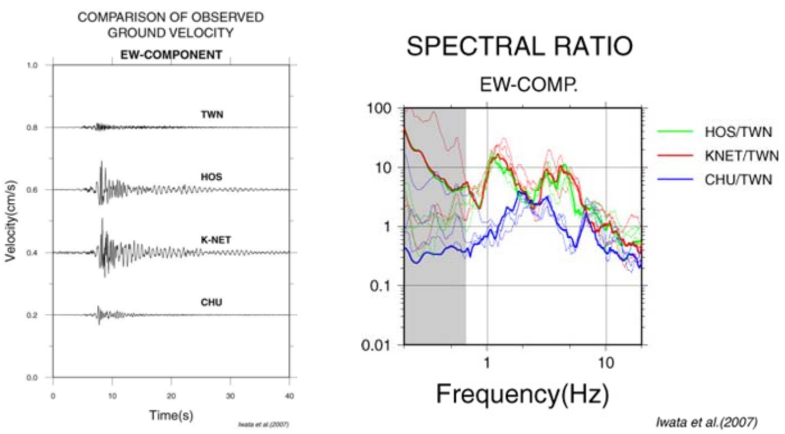

Figure 4 [Left] Example of comparison of observed ground velocities (EW component) at the four temporal observation stations. [Right] Spectral ratios to the S-wave part at TWN as the reference site. Solid lines show the average values. Shaded area shows low SN ratio.

4. MICROTREMOR OBSERVATION

As shown in the previous chapters, we show that 1) the ground motion characteristics observed at ISK005 are related to the subsurface velocity structure whose S-wave velocity is very low, this velocity structure shows the predominant frequency of approximately 1Hz, and 2) predominant frequency of approximately 1Hz at ISK005 and earthquake disaster area is observed from aftershock observation. This predominant frequency is shifted to lower frequency (0.8Hz) during the strong shaking because of non-linear behavior of this subsurface low-velocity layer. To see the extension of this velocity layer in Anamizu town, we conducted microtremor observation. Totally we set 147 temporal microtremor observations to cover Anamizu small basin area. Station aperture is approximately 0.2km. At each site, three-component microtremor observation was conducted more than 15min. For the analysis, we calculated the H/V (vectorial summation of amplitude spectra of two horizontal components to vertical component) spectral ratio of 10 segments whose time length of 20.48s, smoothing followed by Konno and Ohmachi (1998), and took the average.

Figure 5 shows station distribution and the observed H/V spectral ratio along East-West cross section in the center of Anamizu town. In this figure, Clear H/V peak is observed except A7, where is the rock site. From East to West, the peak H/V frequency is shifting from low to high frequency. We picked up the peak frequency of H/V spectral ratio for each station and the peak period of H/V is shown in Figure 6. Along the small rivers, the peak period of H/V becomes longer toward to the river mouth area. It seems to be reasonable that this tendency would be related to the subsurface low S-wave velocity layer. Large disaster area is corresponding to the region whose peak period of H/V is 0.5-1.0s. Following to the occurrence of non-linear site response at ISK005 station as shown in Chapter2, the resonant period of ground motions in the area of peak period of H/V of 0.5-1.0s would be shifted to longer one because of the non-linear response of this subsurface layer, and that would affects much wooden houses. Near the river mouse area, whose peak period is more than 1.0s, the ground motion during the mainshock has longer period characteristics that would not affect much the houses.

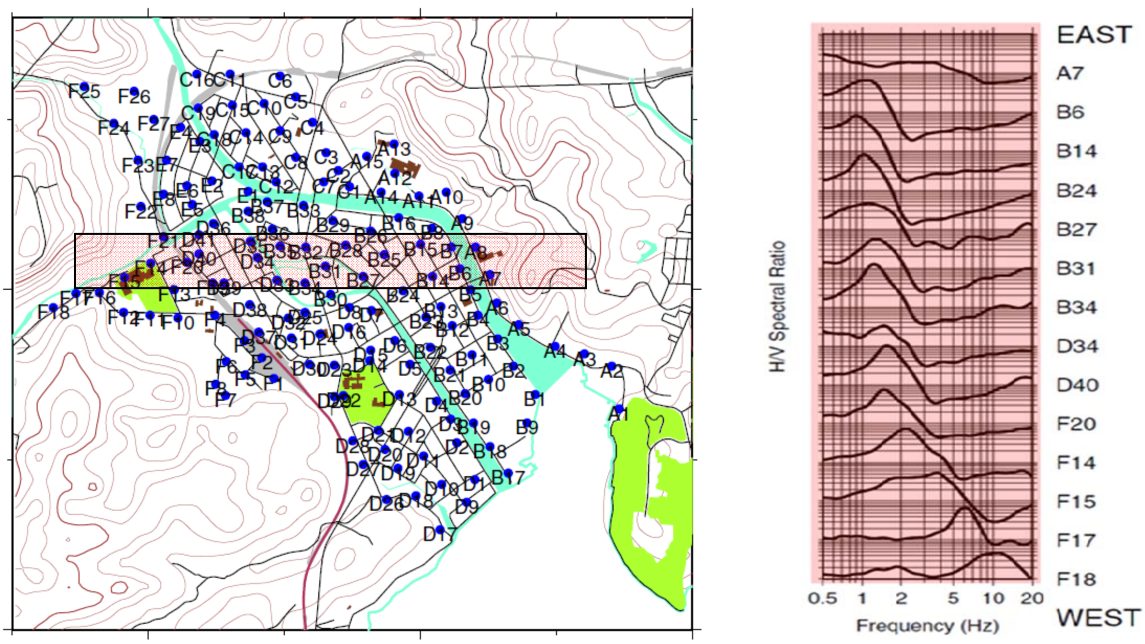

Figure 5 [Left] Temporal station distribution of the microtremor array observation. [Right] Examples of H/V spectral ratio along the EW cross section shown in the red color box in the left side map.

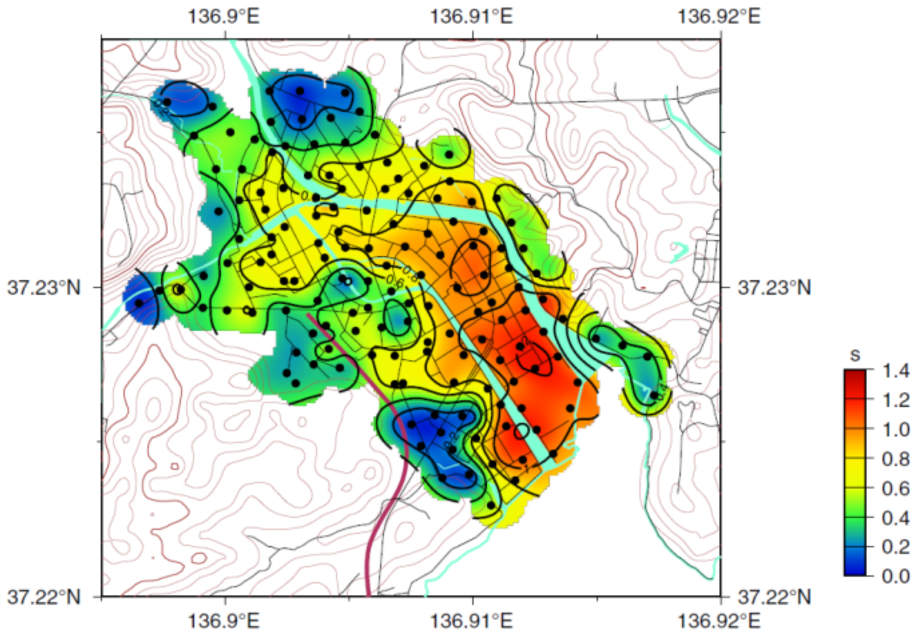

Figure 6 Peak period distribution of microtremor H/V spectral ratio.

5. CONCLUSIONS

We analyzed the strong ground motion records at the Anamizu (K-NET, ISK005) station, where recorded JMA seismic intensity of 6+ during the 2007 Noto-Hanto earthquake, to get the ground motion characteristics at the station. Comparing the H/V spectral ratios of the mainshock records and those of records for before events and for aftershocks, non-linear site response behavior during the mainshock ground motions was observed. As the H/V characteristics were already recovered at the coda wave part of the mainshock records, non-linear site response was restricted only the strong shaking part. From the aftershock and microtremor observations by the temporally-installed stations to understand extension of the area whose subsurface layer characteristics are similar with that at the ISK005 station. Large amplifications of S-wave portion of aftershock records at the ISK005 and sites were observed by comparing those at the ANC, where is regards as a rock station. As the site specific ratio, amplification of approximately 10 at the frequency range of 1-1.5Hz among aftershocks. Single station microtremor H/V ratio also show the similar predominant frequency at Anamizu downtown sites and the low-velocity subsurface layer seems to extend the disaster area during the mainshock.

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