Ground motion simulation in Anamizu town during the 2007 Noto-Hanto Earthquake

Shimizu, R.[1]**, Maeda, T.**[2] **and Saito, G.**[1]

[1] *Graduate student, Dept. of Architecture , Waseda University, Tokyo. Japan*
[2] *Professor, Dept. of Architecture, Waseda University, Tokyo. Japan*
Email: curare-ryo@fuji.waseda.jp

ABSTRACT :

We attempted to illustrate the building damage in the central region of Anamizu town by characteristics of earthquake ground motion and subsurface structure. We conducted the microtremor observation and calculated H/V spectra, the peak frequency of which is about 1Hz in the southeastern area and 1.5~3.0Hz in the western area. Then we estimated the subsurface structure in the central region of Anamizu town simulating the peak frequency of H/V spectrum, and found non-uniformity of the depth of subsurface structures ,which is ranging from almost 0m to around 20m. And we estimated the earthquake ground motion in the central region of Anamizu town using equivalent linear analysis. Based on these estimations, we presumed that (1) the amplitude of a little over 1Hz of the estimated earthquake ground motion coincides with the building damage level, and, (2) earthquake ground motion might be affected by the 2- or 3-dimesional topographical effect.

KEYWORDS: Noto Hanto earthquake, building damage, subsurface structure , microtremor, H/V spectrum, equivalent linear analysis

1. INTRODUCTION

Noto Hanto earthquake (M6.9) occurred on March 25, 2007. Many buildings suffered damage in the central region of Anamizu town that was about 20km away from the epicenter. The Epicenter, the location of observation points, and Japanese seismic intensity during the main shock are shown in Fig. 1. Distribution of the building damage in the central region of Anamizu town is shown in Fig.2.

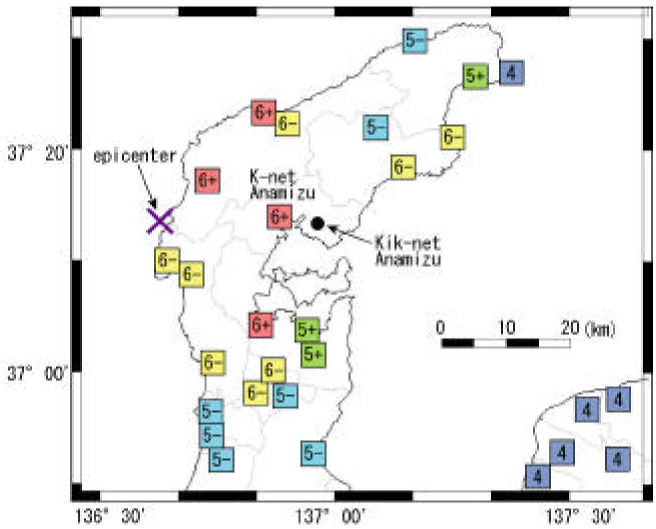

Fig.1 The Epicenter, the location of observation points, and Japanese seismic intensity during the main shock (reference of Japan meteorological agency web site)

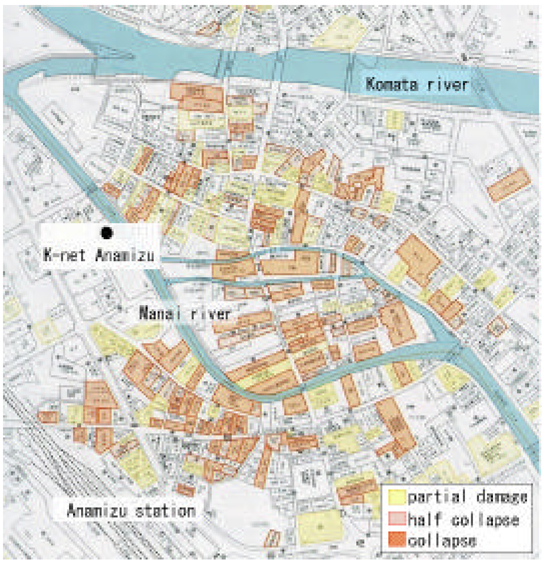

Fig.2 Distribution of the building damage in the central region of Anamizu town (overwritten on reference of Nikkei Architecture)

The damage was watched around K-NET Anamizu observation point , and particularly severe in the basin of Manai river, where many buildings were collapsed completely. It is thought that the thick soft ground amplified earthquake ground motion at slightly long period.

In view of such situation, we estimate the subsurface structure in the central region of Anamizu town from microtremor recording. Then we estimate the earthquake ground motion by the equivalent linear analysis. Based on these results we are clarifying the relation between subsurface structure and the building damage.

2. CHARACTERISTICS OF EARTHQUAKE GROUND MOTION

Maximum acceleration of about 800gal was recorded in EW component, which consists more ingredients of around 0.7Hz than NS component (shown in Fig.3). Comparing the Fourier spectrum amplitudes of EW component of several earthquakes, the main shock have a predominant frequency of around 0.7~1.0Hz, meanwhile, earthquakes of medium or small maximum acceleration have that of around 1.5Hz as shown in Fig.4. This difference suggests that the ground behaved nonlinearly during a main shock.

PS logging data and SH wave amplification characteristics of K-NET Anamizu are shown in Fig5 and Fig.6 respectively. The depth of upper boundary of layer, of which S wave velocity is more than 290m/s, is 16m. and the very soft ground of S wave velocity 60m/s is distributed from 2m to 11m in depth. The first predominant frequency of SH wave is 1.5Hz, which may correspond to the Fourier spectrum of small earthquake ground motion (shown in Fig.4). In addition, the S wave of less than 1Hz is not amplified by these subsurface structure for small or medium earthquake ground motion.

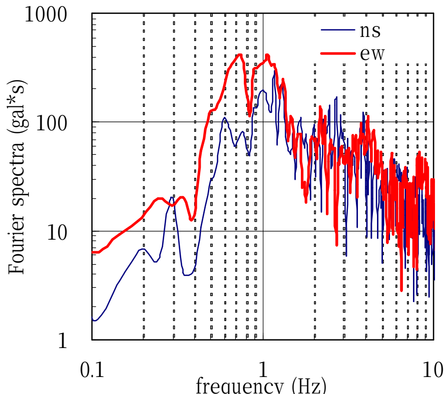

Fig.3 Fourier spectra of earthquake ground motion during a main shock.

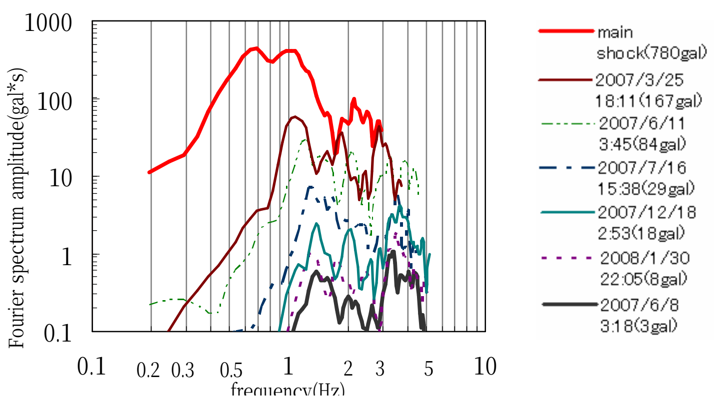

Fig.4 The Fourier spectra amplitudes of EW component of medium size or small size earthquakes and main shock

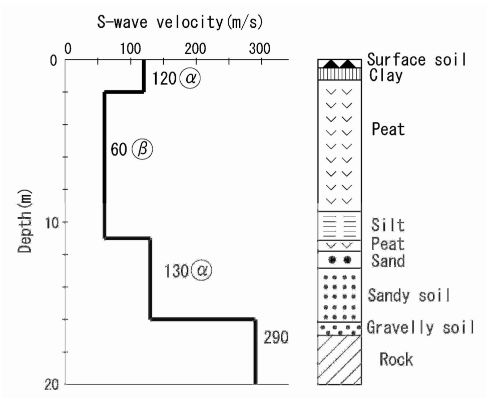

Fig.5 PS logging data of K-NET Anamizu

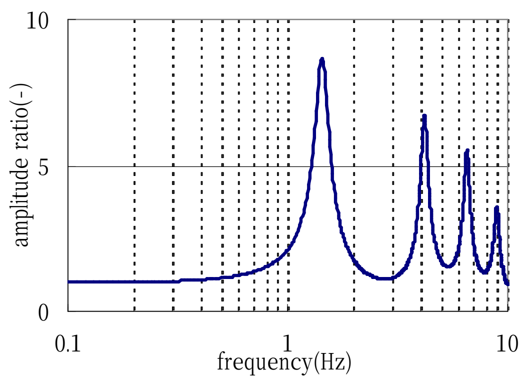

Fig.6 Theoretical SH wave amplification characteristics of K-NET Anamizu

3. MICROTREMOR OBSERVATION

To estimate the subsurface structure of the central region of Anamizu town, we conducted single microtremor observation and microtremor array observation from August 3 to 4, 2007. We observed microtremor using a portable three component seismometer (shown in Fig.7, AKASHI GPL, sampling frequency:100Hz) or the record system which includes three servo accelerometer (shown in Fig.7, RION LS-10C, sampling frequency: 256Hz)and data logger (DA-20 RION). All measurement time is 15 minutes.

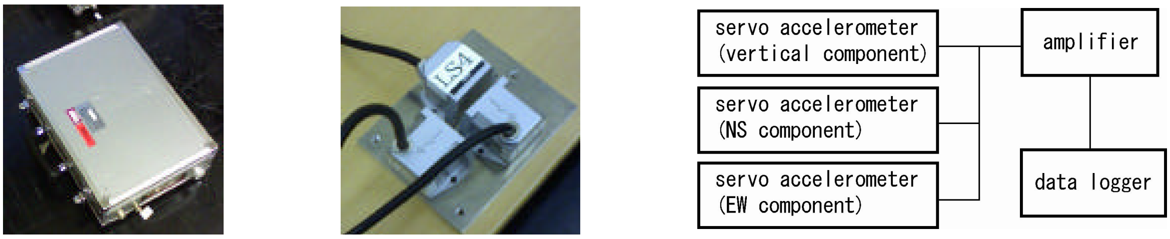

Fig.7 Left: appearance of three component portable seismometer (AKASHI GPL), center: servo accelerometer (RION LS-10C), and right: configuration of the recording system.

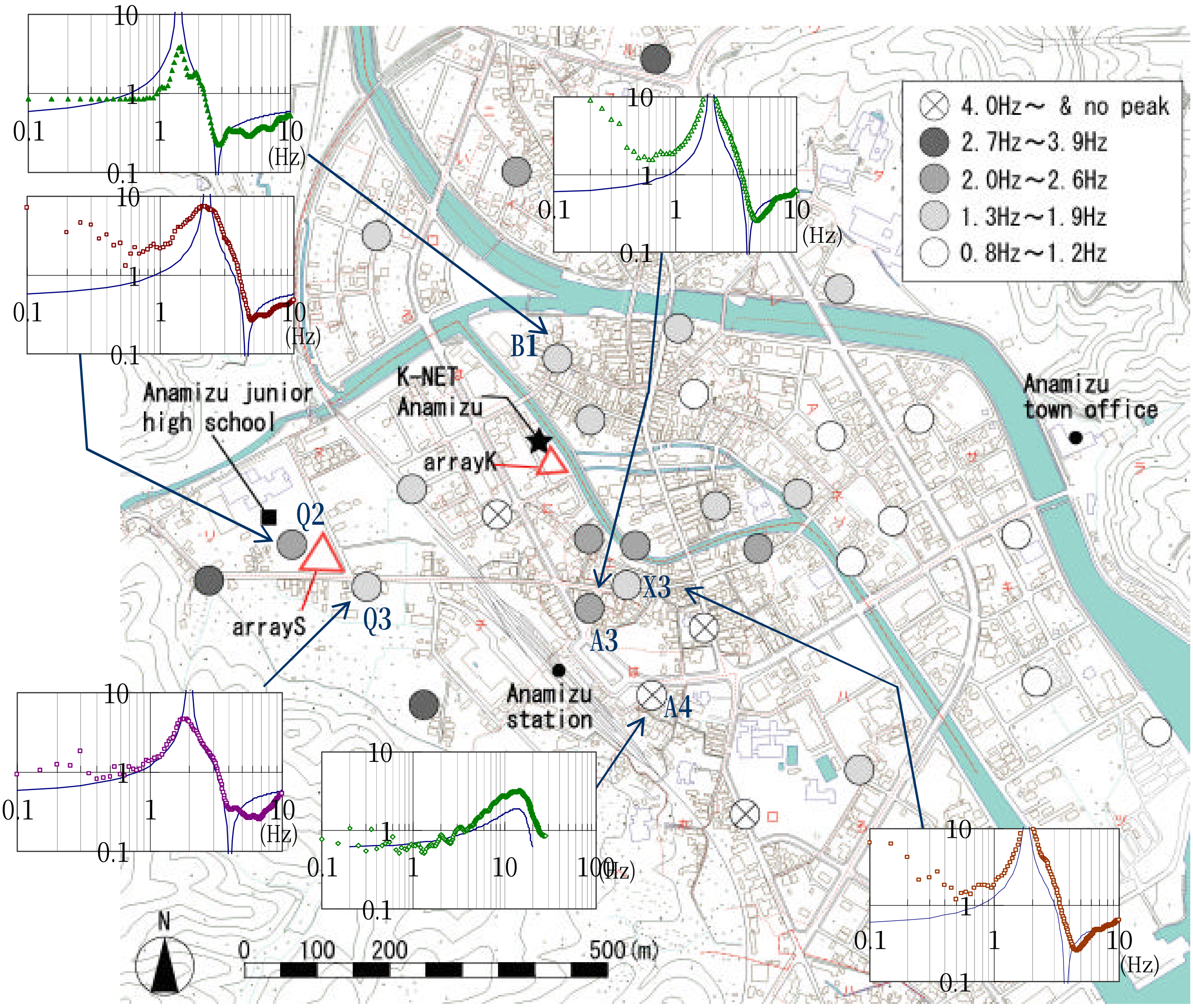

Fig.8 Distribution of peak frequencies of H/V spectrum of single observation points and location of array observation points. Observational and theoretical H/V spectrum of some points are also shown.

We conducted microtremor array observation adjacent to K-NET Anamizu observation point (array-K) and at Anamizu junior high school (array-S) shown in Fig.8. Array radius is 48(array-S only), 24, 12, 6 and 3m.

We also conducted single point three component microtremor observation. Peak frequencies of H/V spectrum of observation points are shown in Fig.8. Peak frequency of H/V spectrum which is calculated using coda wave of small size Earthquake in K-NET Anamizu is also shown. Peak frequency is about 1Hz in the southeastern area and 1.5~3.0Hz in the western area including K-NET Anamizu and Anamizu junior high school in the figure. Peak frequency is invisible at some observation points such as A4.

4. ESTIMATION OF THE SUBSURFACE STRUCTURE OF THE CENTRAL REGION

4.1 Subsurface Structure at Array Observation Points

We calculated phase velocity by the SPAC method (Aki (1957)) using the microtremor vertical component record of 15 minutes. The phase velocity of array-K and theoretical Rayleigh wave phase velocity (Luco and Apsel (1983)) based on PS logging data of K-NET Anamizu (shown in Fig.5), mostly coincide with each other as shown in Fig.9.

Phase velocity of array-S is shown in Fig.10. The phase velocity of array-S is much faster than that of array-K in a range of 2~4Hz and that of more than 5Hz of array-S is slightly slower than that of array-K. We conducted inversion of the subsurface ground structure at array-S, using PS logging data of K-net Anamizu as a initial value, and targeting at both H/V spectrum and phase velocity. The result of inversion is shown in Fig.10.

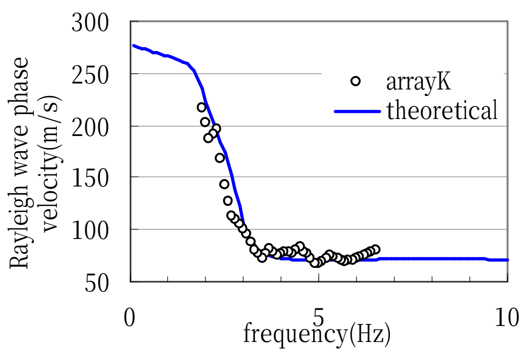

Fig.9 Left: the phase velocity of array-K and theoretical Rayleigh wave phase velocity dispersion curve.

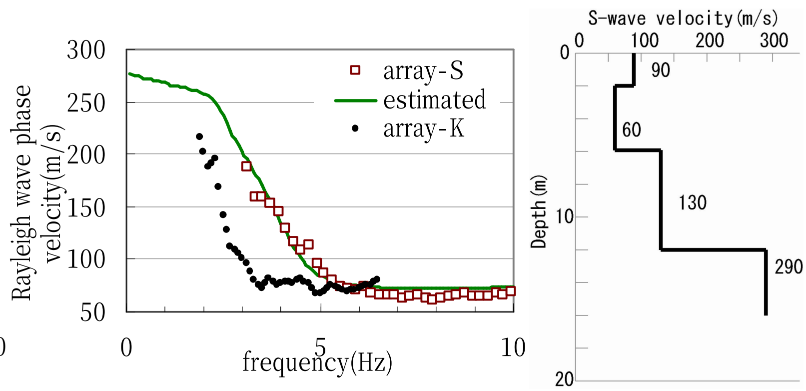

Fig.10 Left: the phase velocity of array-S and estimated Rayleigh wave phase velocity dispersion curve. right: estimated subsurface ground structure of array-S.

4.2 Subsurface Structure at Single Microtremor Observation Points

We estimated the subsurface structure of observation points in the western area by simulating the peak frequency of H/V spectrum with Rayleigh wave fundamental mode, referencing the soil profile of surface-wave method by Hayashi et al.(2007) and the above-mentioned subsurface ground structure at array-K and array-S.

The distribution of total depth of soft ground layers that the S wave velocity is less than 290m/s is shown in Fig.11 and Fig.12. In those figures, horizontal distribution of the depth between the observation points is linearly interpolated. It is concluded that the subsurface structure is not uniform in depth there. The depth of soft ground layers is about 20m in the northeastern part where the damage is severe, and is about 10m in X part where the damage is the severest. And the depth is very shallow in some areas as shown in Fig.12.

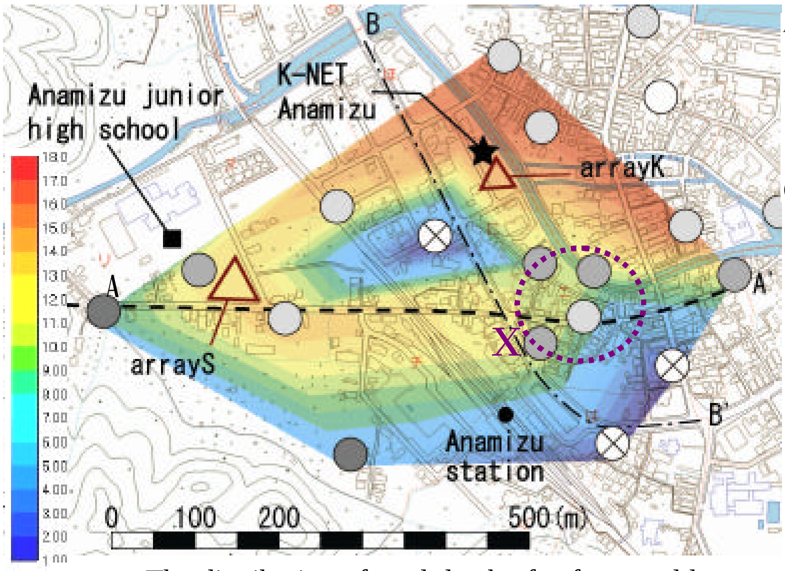

Fig.11 The distribution of total depth of soft ground layers that the S wave velocity is less than 290m/s.

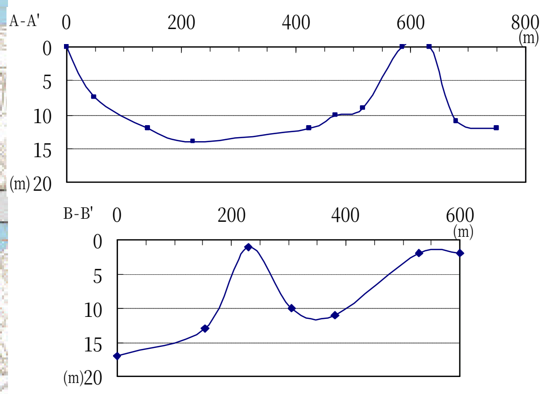

Fig.12 Cross section pattern diagram of total depth of soft ground layers that the S wave velocity is less than 290m/s. upper: section A-A' and lower: section B-B' (represented in fig.11) .

5. ESTIMATION OF THE EARTHQUAKE MOTION DURING THE MAIN SHOCK

To discuss the relation between the building damage and subsurface structure, we estimated the earthquake ground motion in the central region of Anamizu town. We conducted the equivalent linear analysis, using the subsurface structure of K-net (Fig.5) and 1-dimesional deep ground structure (Fig.13) that was estimated by inversion of receiver function by Yamanaka et al. (2007). We estimated G-γ and h- γ curves (Fig.14) referencing the transition of peak frequency of Fourier spectrum during the main shock and peak frequency of earthquakes before the main shock at K-net Anamizu, and also referencing the weak nonlinear characteristics of peat soil by Noto and Kajiya (1987).

We assumed that the top and the third-top layers have nonlinear characteristics of silt and the second-top layer has that of peat (shown as α and β in Fig.5 respectively). We used the EW component record of the main shock of K-net Anamizu as an input, and estimated the incident wave at 2,300m/s layer's surface as an output in this analysis.

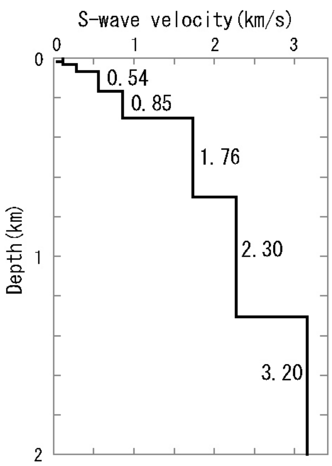

Fig.13 The 1-dimesional deep ground structure

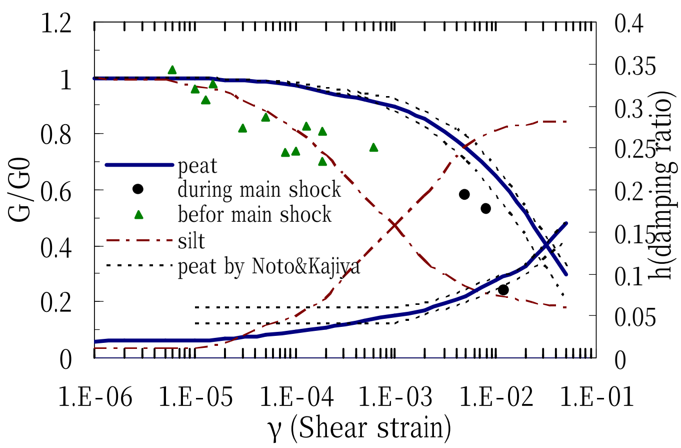

Fig.14 Estimated (G/G0)-γ and h- γ curves

The estimated deep earthquake incident wave is shown in Fig.15 (time history) and Fig.16(Fourier spectrum). The hypogeneous earthquake wave record of Kik-net Anamizu (partially missing data. location is indicated in Fig.1) is also shown for reference. Both waves coincide with each other in a range from about 0.5Hz to 2.5Hz in Fourier spectrum. Main pulses are analogous with each other, except for the predominance of more than 4Hz in estimated wave.

We estimated the surface earthquake ground motion at single micro-tremor observation points by the equivalent linear analysis, assuming the non-uniformity only in depth, and using above-mentioned deep ground structure model and subsurface structure, which is estimated by simulating H/V spectrum. For joining deep ground structure and subsurface structure, the depth of upper boundary of layer of S wave velocity 540m/s is fixed as 30m except for points where the hard soil seemed to be cropped out.

The distribution of maximum velocities of estimated surface ground motion and that of maximum strain levels (EW component) are shown in Fig.17 and Fig.18, respectively. The maximum velocity and strain level around X area (the severest damage area) are slightly smaller than those of K-net Anamizu, that is to say, the maximum velocity nor strain level does not correspond to the building damage level.

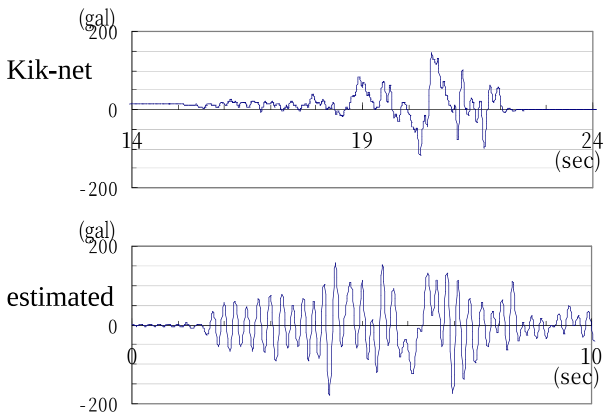

Fig.15 Time history of estimated deep earthquake incident wave and the hypogeneous earthquake wave of Kik-net Anamizu

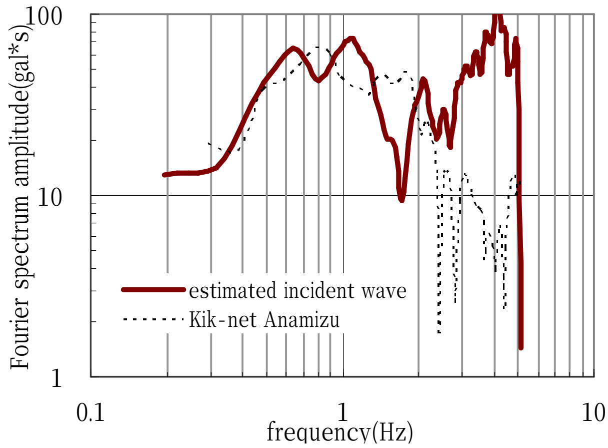

Fig.16 Fourier spectrum of estimated deep earthquake incident wave (doubled size) and the hypogeneous earthquake wave of Kik-net Anamizu

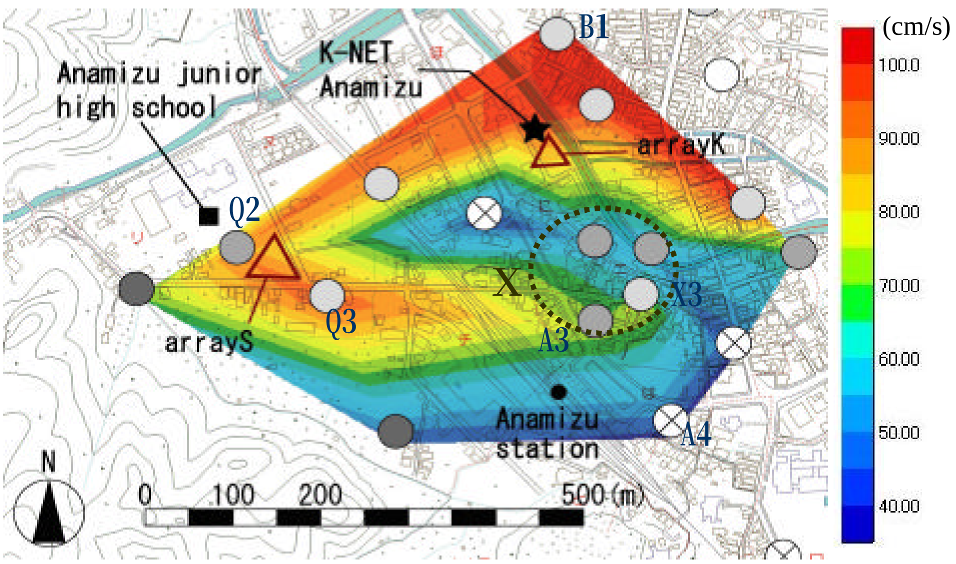

Fig.17 The distribution of maximum velocity(cm/s)

Fourier spectra of some observation points are shown in Fig.19. Comparing these spectra, the amplitude in a little over 1Hz is large at A3 and X3 where the building damage is the severest. On the other hand, the amplitudes in around 0.7Hz are large at B1, B2, Q2 and K-net Anamizu, and the amplitude in low frequency is relatively small at A4 where the hard soil seemed to be cropped out .

It is thought that the peak of the earthquake ground motion of a little over 1Hz resonated the peculiar period of the house which increased during the main shock ,and it increased the building damage. This estimation is in accordance with the report by Sakai(2007) that the building damage correlates with the earthquake ground motion of around 1Hz during Noto hanto earthquake, despite the strong correlation with that of around 0.7Hz during other large earthquakes.

In addition, it is also thought that earthquake ground motion was affected by the 2- or 3-dimesional topographical effect in the region because of non-uniformity of the subsurface structure in depth as shown in Fig.11.

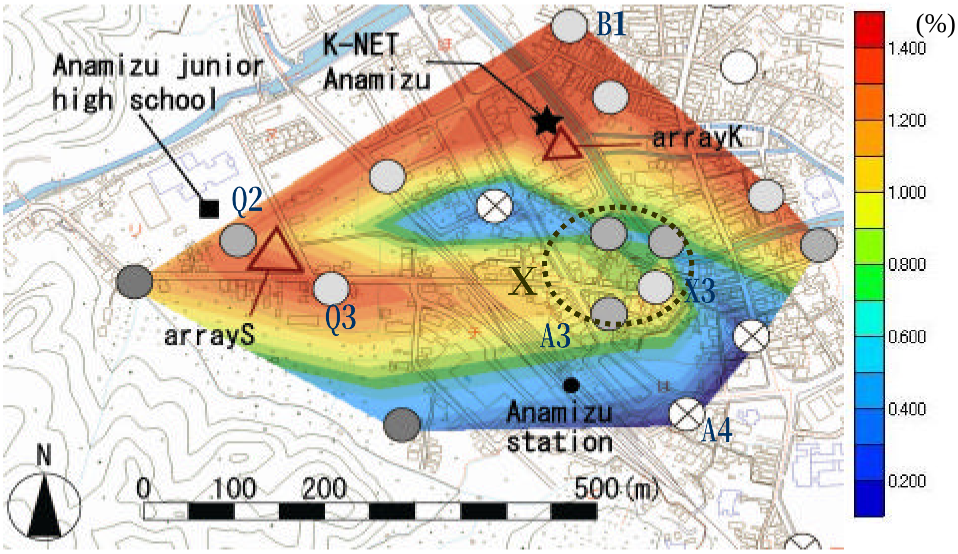

Fig.18 The distribution of maximum strain level(%)

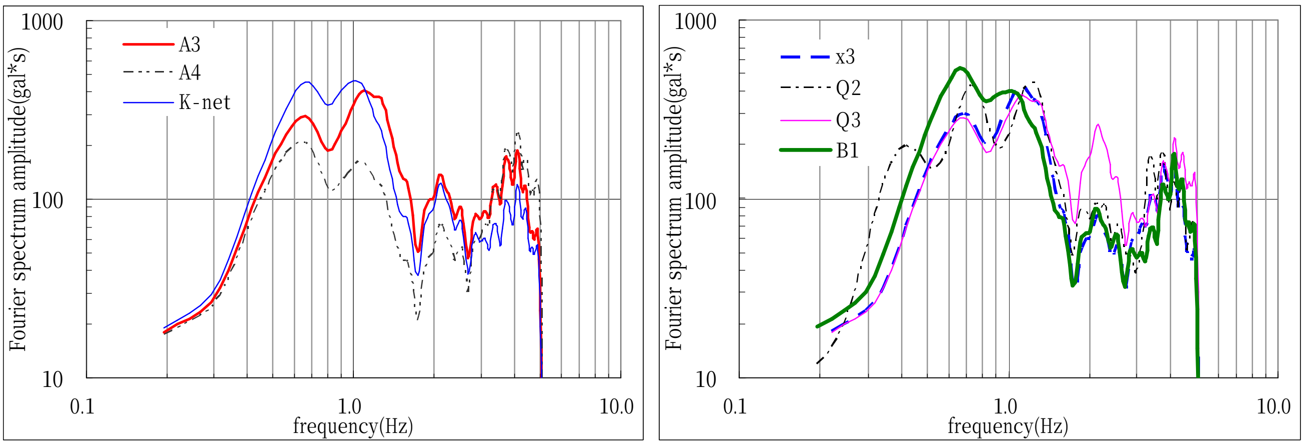

Fig.19 Estimated Fourier spectrum of single microtremor observation points

6. CONCLUSION

In this study, we attempted to illustrate the building damage in the central region of Anamizu town in terms of characteristics of earthquake ground motion and subsurface structure. First, we estimated the subsurface structure of the central region of Anamizu town from single microtremor and microtremor array recordings, and found non-uniformity of the depth of subsurface ground layers ,which is ranging from almost 0m to about 20m.

Next, we estimated earthquake incident wave EW component at 2,300m/s layer's surface from the ground motion record of K-net Anamizu by the equivalent linear analysis referencing the previous reports about estimated 1-dimesional deep ground structure and nonlinear characteristics of subsurface ground. As a result, we presumed that (1) the amplitude of a little over 1Hz of the estimated earthquake ground motion coincides with the building damage level, and, (2) earthquake ground motion might be affected by the 2- or 3-dimesional topographical effect in the region.

In the future, we are going to carry on a higher-density microtremor observation and study closely about earthquake ground motions referencing further information such as borehole logging data and the change of the river course that flows through the central region of Anamizu town.

We give an address of thanks to Waseda University Grant For Special Research Projects and National Research Institute for Earth Science and Disaster Prevention for providing seismic wave data of K-net and Kik-net.

REFERENCES

Japan meteorological agency web site, http://www.seisvol.kishou.go.jp/eq/kyoshin/jishin/070325_noto/index.html(In Japanese)

Multiple authors. (2007). Tracking of Noto hanto earthquake, Nikkei Architecture.849,28-29. (In Japanese)

Hayashi, K., Tamura, M., Hirade, T., Adhikari, K., Maita, M. and Yamamoto, A. (2007). Site investigation by surface-wave method and micro-tremor array measurements at central Anamizu, Ishikawa prefecture. Proceedings of the 117th SEGJ Conference, 37-40. (In Japanese)

Yamanaka, H., Motoki, K. and Fukumoto, S. (2007). Local site effects in damaged areas during the 2007 noto hanto earthquake. The 35th Symposium of Earthquake Ground Motion, 23-30. (In Japanese)

Sakai, Y. (2007). Relationship between structural damage and ground motions in the 2007 Noto-hanto earthquake. The 35th Symposium of Earthquake Ground Motion, 31-40. (In Japanese)

Noto, S. and Kajiya, Y. (1987). An experimental study on dynamic properties of peat soils(2nd report). Monthly Report of Civil Engineering Research Institute for Cold Region 406, 14-24. (In Japanese)

Tokimatsu, K., Suzuki, H. and Midorikawa, S. (2007). Nonlinear soil behavior observed in strong motion records at K-net Anamizu and JMA Wajima in the 2007 Noto-hanto earthquake. Summary of Technical Papers of Annual Meeting of the Architectural Institute of Japan 2007 B-2, 183-184.(In Japanese)

Aki, K. (1957). Space and time spectra of stationary stochastic waves, with special reference to microtremors, Bull. Earth. Res. Inst., 35, 415-456.

Luco, J. E. and R.J. Apsel (1983) On the Green's functions for a layered half-space, Part 1, Bull Seism. Soc. Am, 73:4, 909-929.