SECOND EUROPEAN CONFERENCE ON EARTHQUAKE ENGINEERING AND SEISMOLOGY, ISTANBUL AUG. 25-29, 2014

MICROTREMOR FIELD TESTING TO ESTIMATE LOCAL SITE RESPONSE OF BASIN STRUCTURE INCLUDING ALLUVIAL FAN

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ABSTRACT

Field testing of microtremor measurements conducted in basin structure including alluvial fan area is reported for seismic vulnerability assessment. Predominant frequency distribution is presented on the map. Predominant frequency shifts longer from alluvial fan area of eastern part to alluvial plain area of western part of the basin. Alluvial soft ground is distributed in western and northern part of the basin and its characteristics appear in the results of microtremor measurements. Ground motions of main shock of the 2011 Tohoku earthquake are analyzed. Amplitude ratio of between two sites in the basin is discussed. Outstanding amplification cannot be observed because two sites are relatively close. More intensive field testing and strong motion observation are required for more precise estimation.

INTRODUCTION

Ground motion on basin structure varies in response to site characteristics, and local site response becomes quite complicated in case of soft ground with thick alluvial subsurface layers. One-dimensional wave propagation characteristics are changeable with variable depth of soft subsurface layer. Moreover, in case that surface wave propagation dominates reflected from basin edge, amplitude of ground motion in long period range may become larger than expected. Those phenomena make it difficult for structural design of building and seismic vulnerability assessment of cities and villages on basin structure.

Microtremor field testing is often adopted to briefly estimate local site response. Recently geological data are getting acclimated by subsurface exploration. Data derived from those surveys directly and indirectly brings a lot of useful information to researches and engineers. However, geological survey costs a lot and it is difficult to understand dynamic characteristics of ground in effectively wide area. On the other hand, microtremor field testing is effective technique to briefly understand dynamic characteristics of ground. Results are applied to estimation of seismic load for structural design and seismic vulnerability assessment in urban area.

In this study, results of microtremor field testing on basin structure including alluvial fun are reported as preliminary investigation. Yamagata basin located in North-east district of Japan is estimated where alluvial fan area exists in east part and thick soft subsurface layer is accumulated in west part of the basin. One of important objectives is to research where the boundary of alluvial fan and soft ground with respect to structural and geotechnical engineering. Based on the observed records of microtremor field testing, H/V spectral ratios at 11 sites in Yamagata basin are estimated. Thickness of soft subsurface layer is estimated by fluctuation of predominant estimated frequencies from microtremor field testing using one-dimensional wave propagation theory. Results of this study are preliminary, however, piling up observed data and combination with earthquake observation and

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numerical simulation will lead to more precise assessment of seismic vulnerability of the basin structure.

OUTLINE OF YAMAGATA BASIN

Local site response of basin structure including alluvial fan is examined by microtremor field testing in this study. The site for this study is Yamagata basin located on Tohoku district (Northeast part of Japan) that is about 60km west from Sendai city damaged by 2011 Tohoku earthquake. Location of Yamagata basin is shown in Figure 1.Yamagata basin has the Tertiary layer with fold structure in North-South direction and the Quaternary deposits thickly accumulated. Sedimentation of alluvial fan is thickly and widely accumulated in the eastern part of the basin as shown in Figure 2. The alluvial fan area is considered hard ground due to previous investigation such as boring data. Toward west, ground condition changes to alluvial plain, and soft soil layer is considered thicker than around the boundary of alluvial fan area of eastern part of the basin. While the earthquake observation site (K-NET Yamagata) is on the alluvial fan area, the downtown of Yamagata city is located on the centre of the Yamagata basin where is affected by the soft soil ground consisting of the Quaternary deposits. Therefore, local site responses of the centre and western part of Yamagata basin are different from the basin edge area including the earthquake observation site. That means it is difficult to estimate seismic vulnerability of downtown Yamagata based on the earthquake records of K-NET Yamagata.

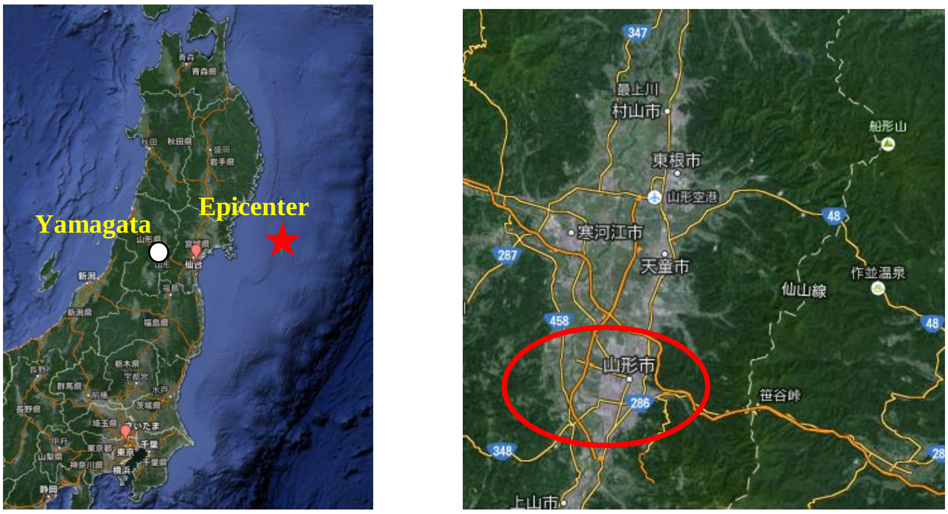

Figure 1. Location of Yamagata basin (@Google)

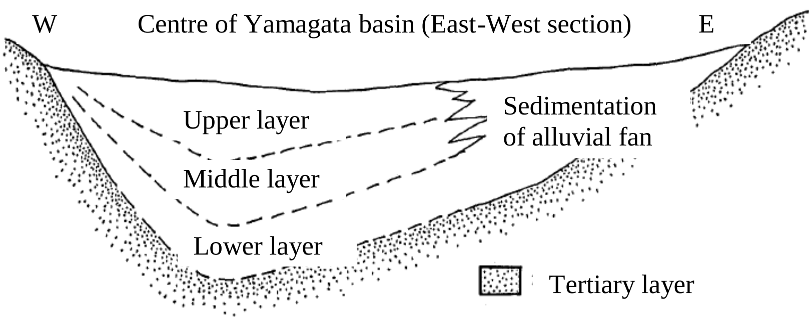

Figure 2. Deep ground structure of Yamagata basin (Yamanoi, 1986)

MICROTREMOR MEASUREMENTS

Field testing of microtremor measurements is conducted to estimate local site response of Yamagata basin. Results will lead to the estimation of seismic vulnerability assessment of the downtown of Yamagata city (about 250,000 of population) located on the centre of Yamagata basin.

Microtremor measurements are conducted along with the observation lines. Some observation lines to cross the Yamagata basin in East-West direction from alluvial fan area to alluvial plain area are prepared for microtrmeor measurements, so that local site response of observation sites on some sections of Yamagata basin is discussed. Distribution of field testing sites is illustrated in Figure 3. Field testing sites are categorized into three groups such as Area A, B and C. Sites on hard ground of alluvial fan belong to Area A including the transition area (eg. KGT) from alluvial fan to alluvial plain accumulating soft subsurface layers. Soft ground area split into two groups such as Area B for west and C for north part of the basin.

Microtremor measurements were continuously carried out in 10 minutes with sampling frequency of 100Hz. Small time window of 40.96 seconds for data analysis is applied to the entire duration of observed records and moving from the beginning to the end by step of which width is equal to the half of the window. Transfer functions are derived for every small section divided by the window and the results are averaged all through the duration.

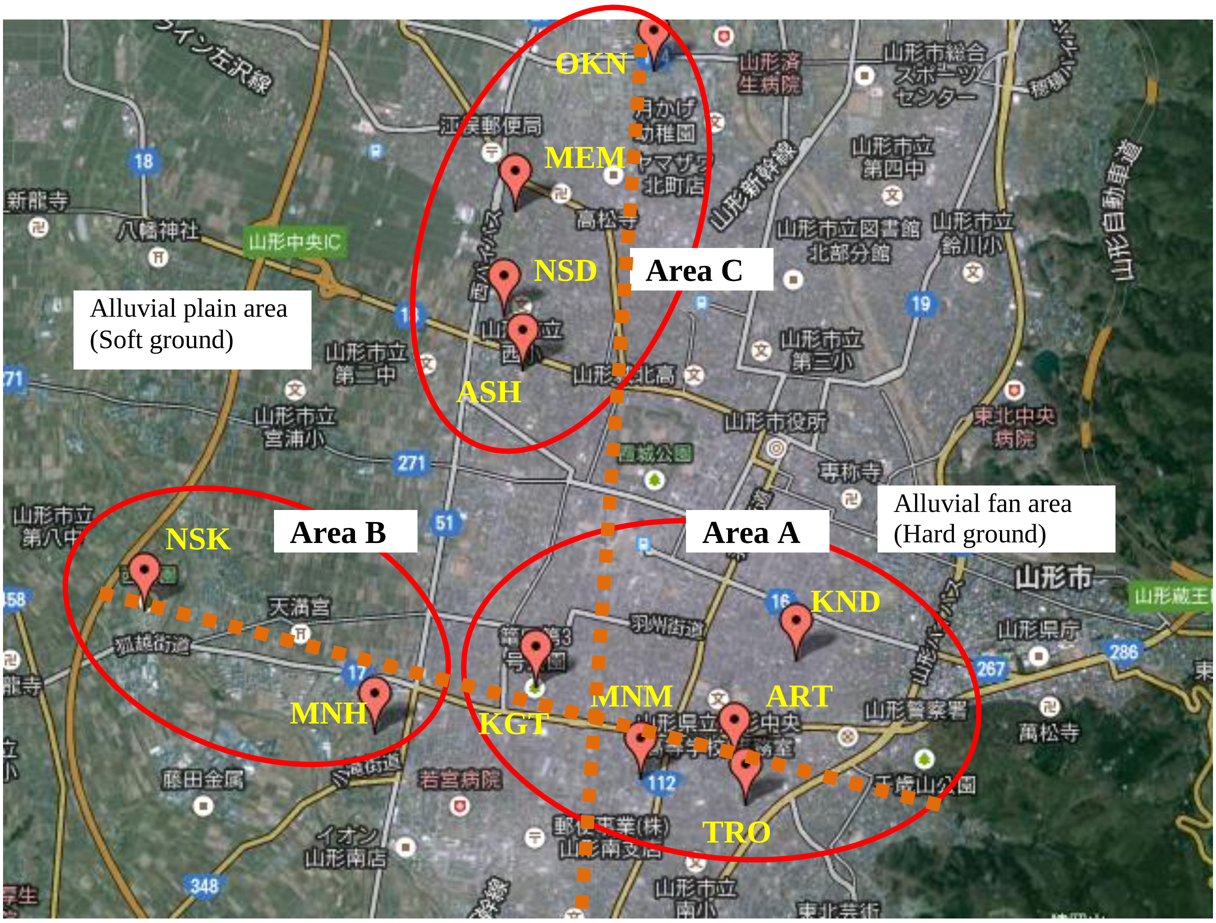

Figure 3. Distribution of the field testing sites of microtremor measurements (Image@2014 Cnes/Spot Image, Digital Globe, Landsat, Map@2014 Google, ZENRIN)

Results of microtremor measurements are mainly studied by the comparison of H/V spectra in Figure 4 to 6. H/V spectral ratios of hard ground in alluvial fan are shown in Figure 4. Spectral peaks are found around 1.34Hz and 2Hz in KGT. Spectral peaks in 1.0 to 1.5Hz can be found in ARD and TRO. In the site of MNM, small peak can be seen about 1.3Hz, but largest peak appears in about 2.2Hz. Those sites can be assumed to be on the transition area from alluvial fan to alluvial plain of relatively soft ground. Distinctive peak cannot be observed in KND. According to standard penetration test in the neighbourhood of this site, the site of KND is considered hard ground with filling soft soil of 1 to 2m. H/V spectral ratio of KND is correspondent with ground condition from standard penetration test. Peak in low frequency range about 0.2 to 0.3Hz is also found in all the results of Figure 4.

H/V spectral ratios of Area B (soft ground in western part) are shown in Figure 5. Peak in low frequency range is predominant, however, clear peak about 0.6Hz can be observed. H/V spectral ratios of Area C that is also soft ground in northern part are shown in Figure 6. Spectral peak around or less than 1Hz can be observed in ASH, NSD, OKN and MEM. Peak in low frequency around 0.2Hz is also found. It should be noted that low frequency range less than 0.2Hz should be paid attention because of resolution of sensors.

Summary of the results from field testing of microtremor measurements is listed in Table 1. Frequency indicating spectral peak in H/V spectral ratio is estimated predominant frequency of subsurface soft layer. Peaks in lower frequency than estimated predominant frequencies are also summarized in Table 1 as characteristics of deep ground structure.

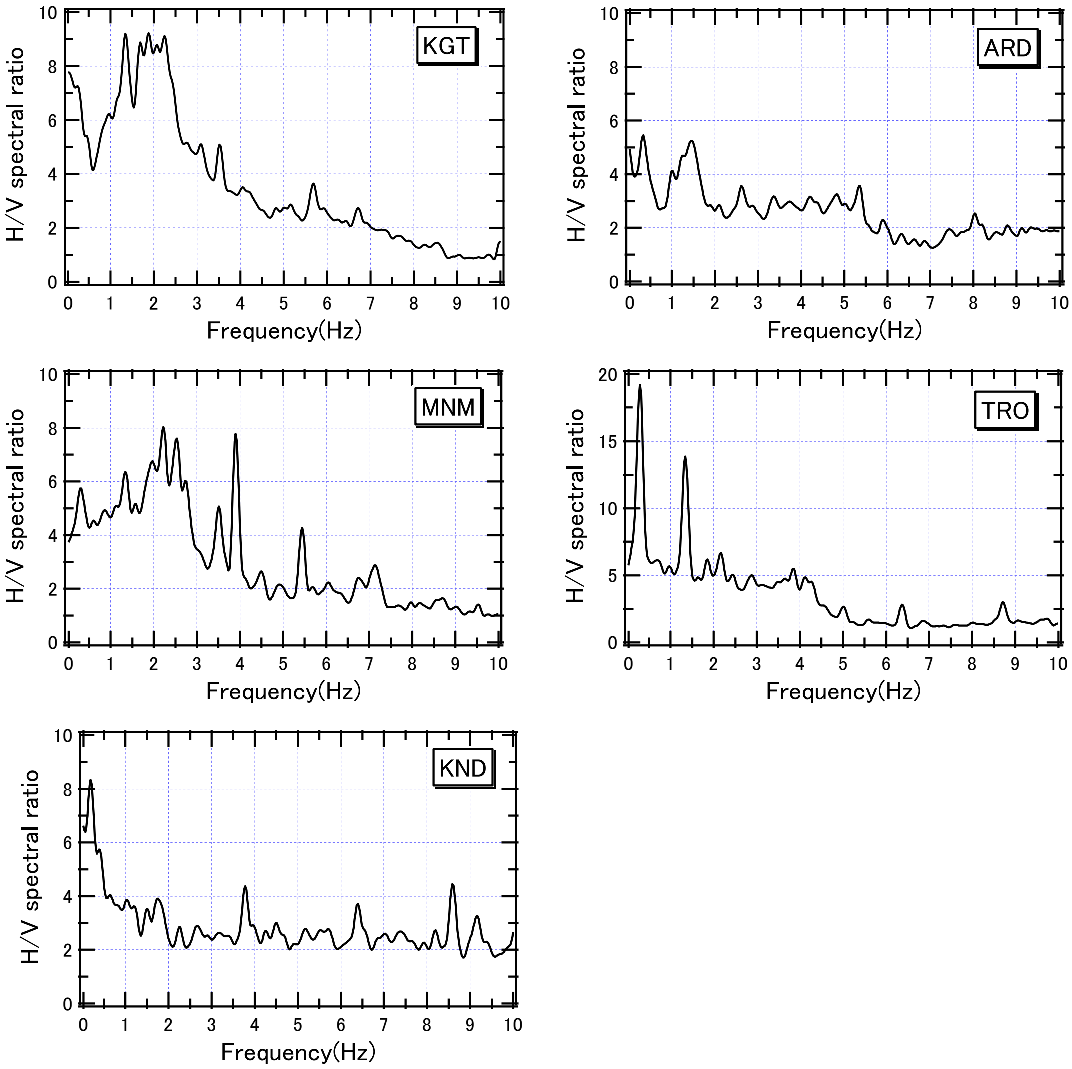

Figure 4. H/V spectral ratios of hard ground and transition area (Area A: east)

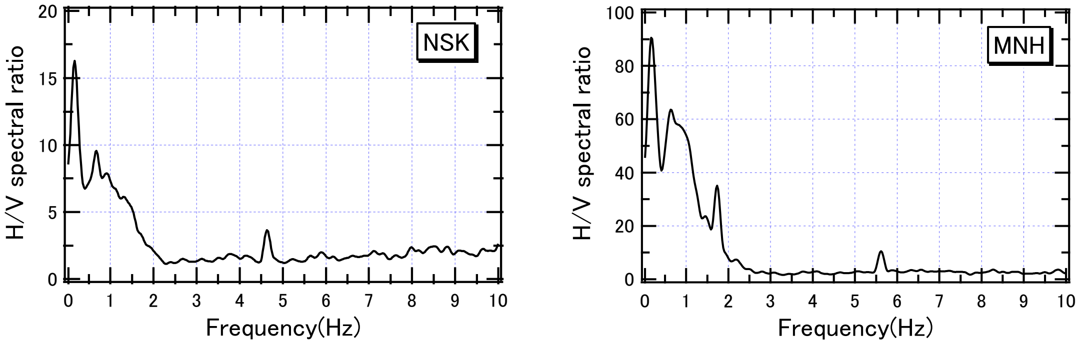

Figure 5. H/V spectral ratios of soft ground area (Area B: west)

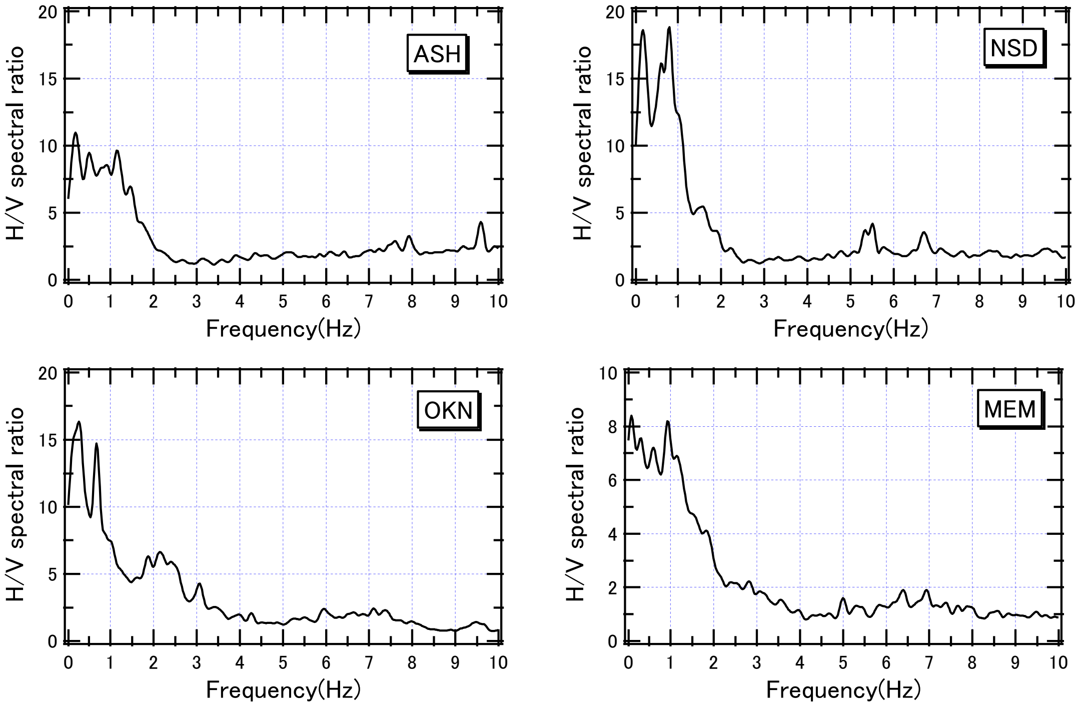

Figure 6. H/V spectral ratios of soft ground area (Area C: north)

Table 1. Estimated predominant frequency of each site (unit: Hz)

	NSK	MNH	KGT	ASH	NSD	MEM	OKN	ARD	MNM	KND	TRO
Subsurface	0.68	0.64	1.34, 1.88	1.15	0.81	0.90	0.61	1.46	2.22	—	1.34
Deep grd.str.	0.17	0.17	—	0.20	0.20	0.10	0.15	0.34	0.29	0.20	0.29

DISTRIBUTION OF PREDOMINANT FREQUENCY

H/V spectra clearly show the difference of local site response of alluvial fan area of the eastern part of the basin and alluvial plain area of western part of the basin. Specific peak of H/V spectra are not found in the results of alluvial fan sites. That means alluvial fan area is considered hard ground from the engineering view point. On the other hand, clear peaks are observed from 0.6 to 2.2 Hz in the sites of alluvial plain area. Results indicate that local site response of alluvial plain area of western part of Yamagata basin is affected by subsurface soft soil layers, and local site response is amplified. Figure 7 shows the distribution of results of microtremor measurements and estimated boundary between alluvial fan area and alluvial plain area. Distribution of predominant frequencies estimated in the previous section indicates that ground condition shifts hard to soft from eastern part of alluvial area to western part of alluvial plain area. Form of Yamagata basin is longer in NS direction than in EW direction. It can be seen that soft ground is distributed in northern part of basin.

Based on the distribution of predominant frequencies, boundary between alluvial fan area and alluvial plain area is estimated with respect to the engineering point of view. Geological fluctuation of the boundary on the map should be considered, however, boundary is estimated as tentative straight band in this study for engineering use. Area surrounded by red circle in Figure 7 is considered complicated by penetration of drowned valley. Therefore it is difficult to estimate boundary. Piling up field testing data will lead to more precise estimation of the boundary.

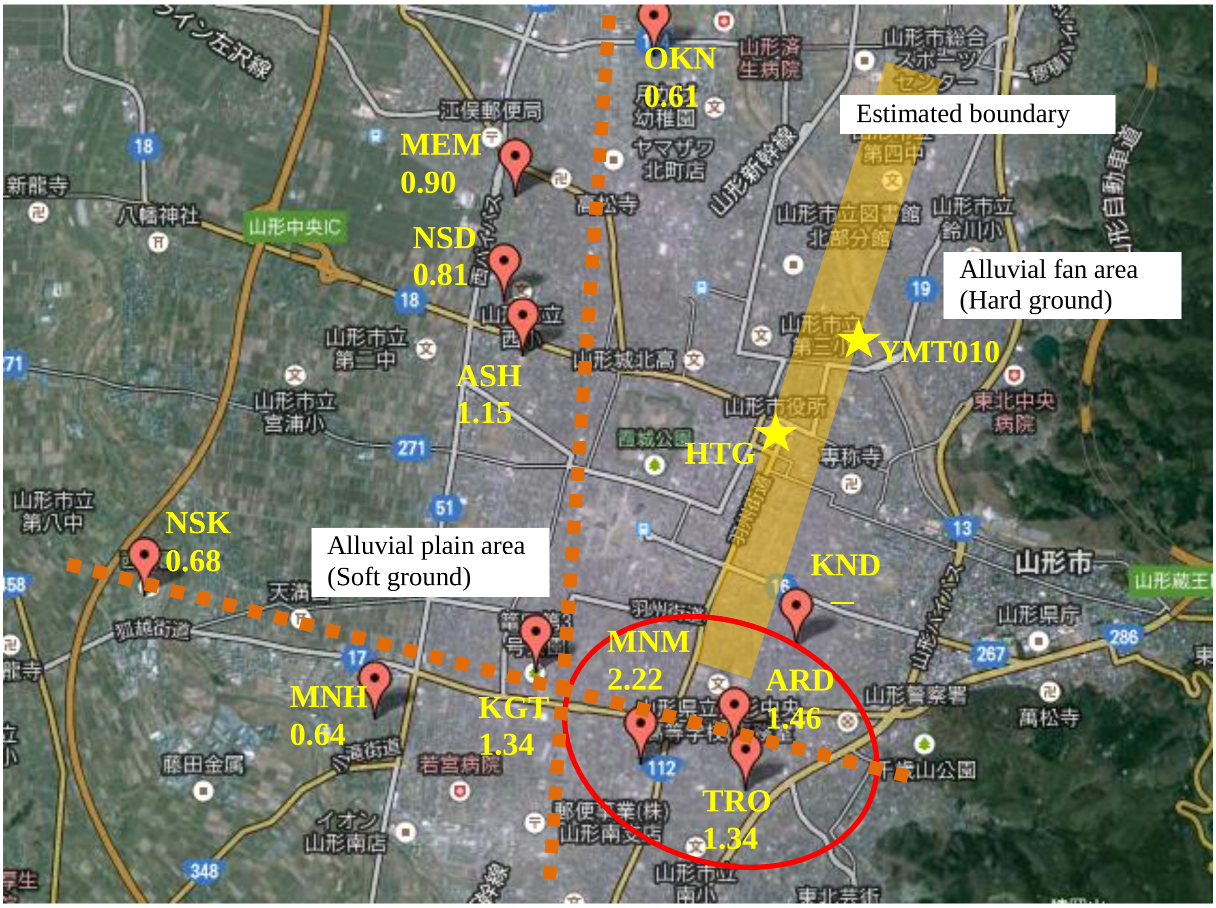

Figure 7. Distribution of the results of microtremor measurements and estimated boundary between alluvial fan area and alluvial plan area (Image@2014 Cnes/Spot Image, Digital Globe, Landsat, Map@2014 Google, ZENRIN)

GROUND MOTIONS OF THE 2011 TOHOKU EARTHQUAKE

Ground motions of main shock of the 2011 Tohoku earthquake were recorded in some sites in and around Yamagata basin. Two star marks in Figure 7 are earthquake observation sites. The site of HTG is the observation site governed by Yamagata Prefecture and YMT010 is K-NET observation site. Figure 8 and 9 are ground motions observed in Yamagata basin. The site of the YMT010 is known to be located at hard ground. Although ground condition of HTG is not clearly understood, it may be on the transition zone from alluvial fan to alluvial plain. Fourier spectra of HTG and YMT010 are shown in Figure 10. It is difficult to estimate distinctive predominant frequency, but multi peaks are observed in less than 4Hz. The effect of subsurface ground should be discussed considering source and path effect in more detail. Figure 11 shows amplitude ratio of HTG to YMT010. Spectral peaks can be observed at around 4Hz and in higher frequency range. In the frequency range of 1 to 3Hz that is important to structural design of buildings, amplitude ratio tends to be less than 1. It is difficult to find out the difference of ground motion characteristics between HTG and YMT010. Field testing and strong motion observation data should be more accumulated in the future for more precise estimation of seismic vulnerability assessment.

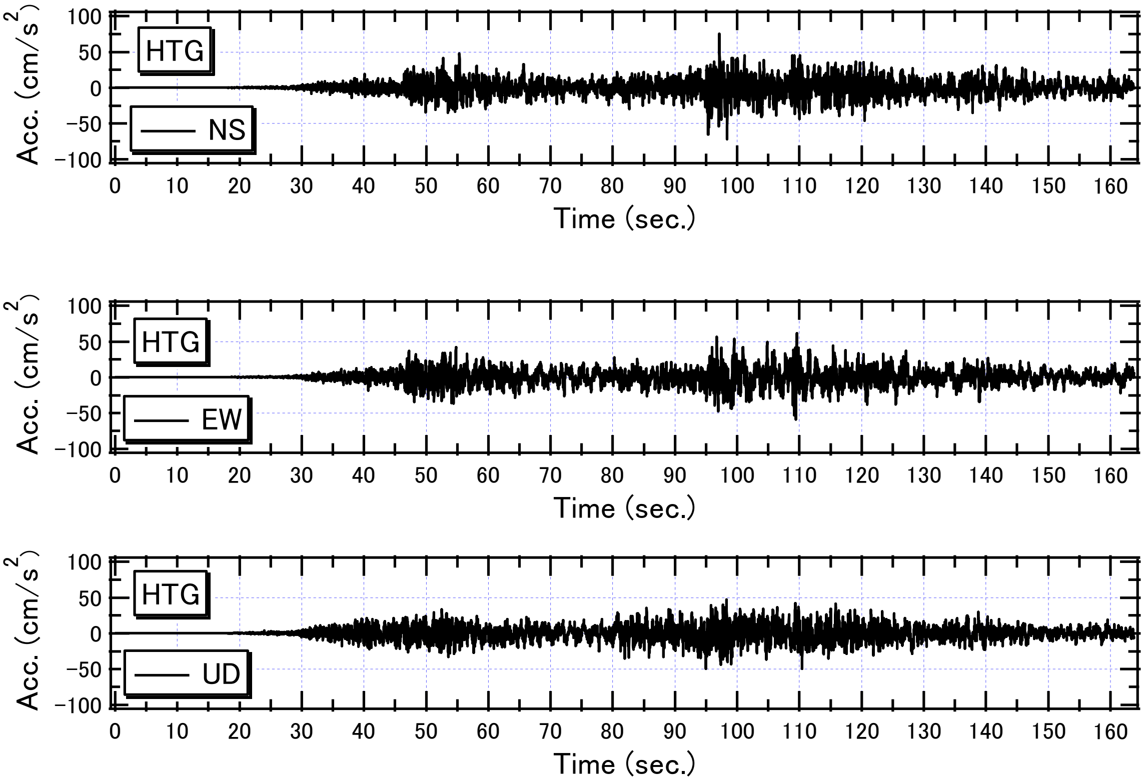

Figure 8. Observed record of HTG for the 2011 Tohoku earthquake (Main shock)

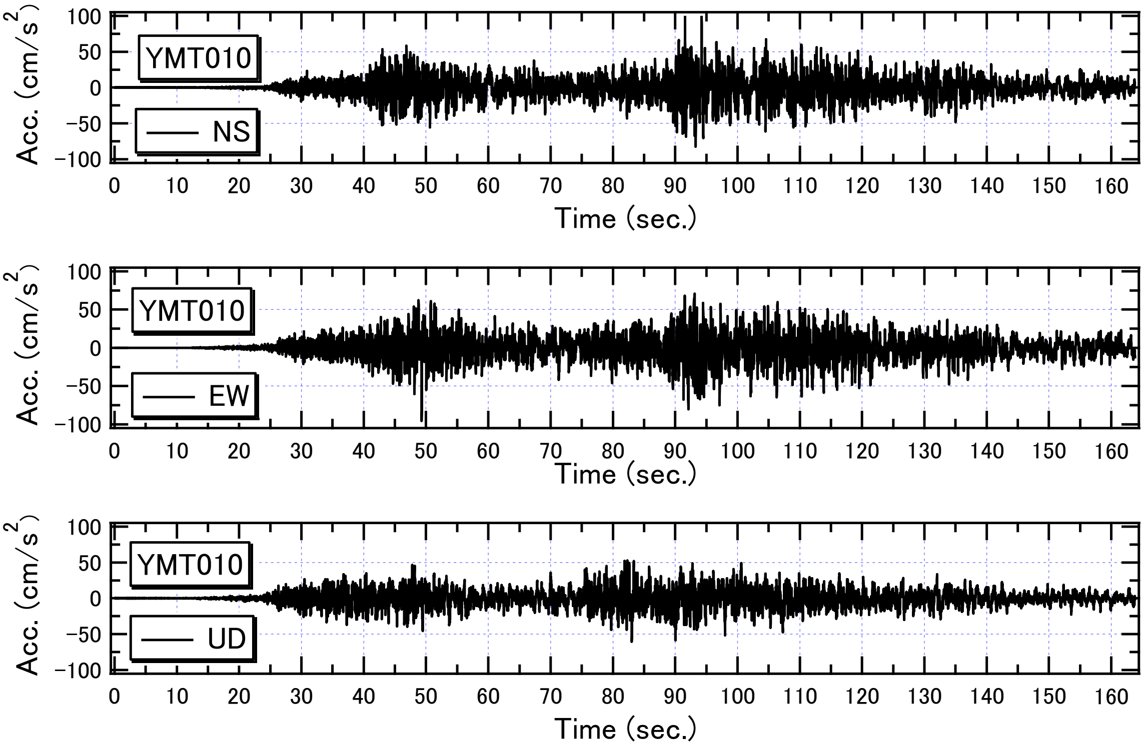

Figure 9. Observed record of YMT010 for the 2011 Tohoku earthquake (Main shock)

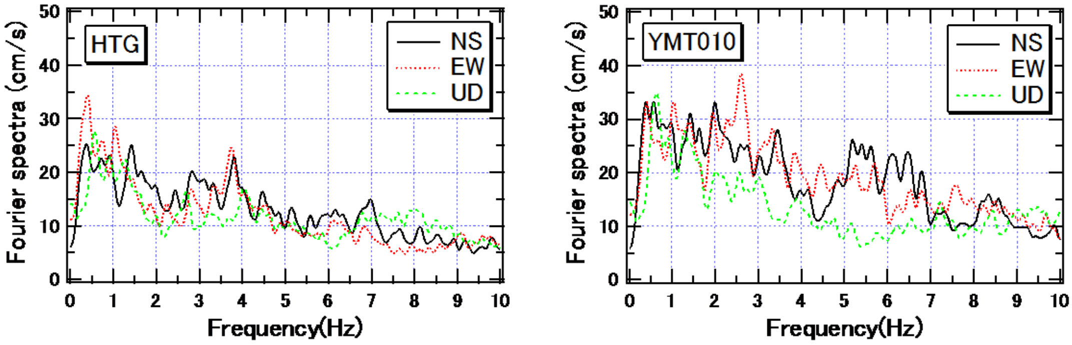

Figure 9. Fourier spectra of HTG and YMT010 for the 2011 Tohoku Earthquake (Main shock)

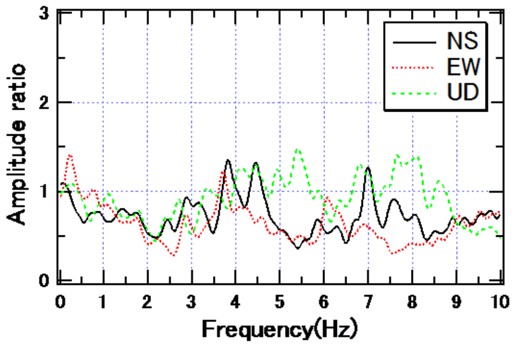

Figure 10. Amplitude ratio between HTG and YMT010 for the 2011 Tohoku Earthquake (Main shock)

CONCLUSIONS

Attempt of field testing of microtremor measurements for seismic vulnerability of Yamagata basin is reported as preliminary investigation. One of the characteristics is that the basin has hard ground consisting of alluvial fan in its eastern part, and alluvial soft ground accumulating thick soft subsurface layer in its western part. Microtrmor measurements are conducted in 11 sites in Yamagata basin. Predominant frequency and frequency in lower range indicating the effect of deep ground structure are discussed based on the field testing results. Distribution of predominant frequency is presented and boundary between alluvial fan and alluvial plain is estimated.

Ground motions of the 2011 Tohoku earthquake observed in Yamagata basin are illustrated and examined spectral characteristics between HTG and YMT010. Outstanding spectral amplification cannot be observed in 1 to 3Hz, but slight amplification appears at about 4Hz. It is difficult to estimate the difference of local site response of two sites, because distance between HTG and YMT010 is close.

Field testing and strong motion observation data should be more accumulated for more precise assessment of seismic vulnerability of Yamagata basin.

REFERENCES

Yamanoi T (1986) Formation of Yamagata basin and transition of natural environment, Science report of Faculty of Science, Yamagata University (in Japanese)

ACKNOWKEDGMENTS

The earthquake records were observed by K-NET (NIED) and Yamagata Prefecture. The author is grateful to all the involved parties.