16TH EUROPEAN CONFERENCE ON EARTHQUAKE ENGINEERING THESSALONIKI 18 - 21 JUNE 2018

CREATION OF A NEW HAZARD MAP REFLECTING THE LOCAL GROUND CHARACTERISTICS

Tsutomu OCHIAI[1], Tstsushi INUBUSHI[2], Takahisa ENOMOTO[3], Navarro MANUEL[4]

ABSTRACT

The authors have continuously conducted high-density microtremor observation in Kanagawa prefecture since the 1990's. In this report, we organized and integrated these results and constructed a ground information database. We also tried to create a hazard map focusing on the predominant period and amplification factor of the H/V spectral ratio by analyzing from the new viewpoint using the database created. From the hazard map, Kanagawa prefecture as a whole has a high degree of danger in limited areas such as Sagami plain south and Tokyo Bay coastal areas (mainly in Yokohama and Kawasaki), which is generally consistent with the past examination.

Keywords: Microtremor observation; H/V spectral ratio; Ground vibration characteristics; Hazard map, Kanagawa prefecture

1. INTRODUCTION

Although earthquake damage prediction is generally performed at the prefectural level, in recent years expectations have been rising detailed earthquake damage prediction can be achieved also at the municipal level. Based on numerous earthquake damage surveys conducted to date, it has been pointed out that variance in building damage is due to differences in the surface soil structure. Therefore, for generating detailed damage prediction detailed data on ground vibration characteristics of the surface layer is necessary. While several methods such as boring surveys and earthquake observation records have been in use for mapping ground vibration characteristics of surface layers, permanent observation of microtremors has been identified as an effective method for grasping detailed ground vibration characteristics across wide areas. Many studies have confirmed that the dominant period of the H/V spectrum coincides well with the dominant period of the ground (Nakamura 1989, Bard 1999). On the other hand, many positive and negative studies are continuing on the constant use the amplication rate of microtremors (Lermo et al. 1994, etc). Recently, researches such as a meshod of calculating the H/V spectrum ratio theoretically by diffuse-wave field (Matsushima et al. 2014).

From a theoretical approach, it has been said that microtermors are predominated by the surface wave component and that especially where relatively soft sedimentary layers in the surface soil structure are present, the dominant period and amplification factor of the ground can be estimated by way of the H/V spectral ratio based on the characteristics of the Rayleigh wave (Architectural Institute of Japan 2005, Koji Tokimatsu et al. 1995, etc.). For this reason, analysis that uses the microtremor induced H/V spectral ratio is considered effective for estimating disaster risk during earthquakes.

The authors have been carrying out high-density microtremor observation continuously in Kanagawa prefecture since the 1990s (Tsutomu Ochiai et al. 2003, Naohiro Ueno et al. 2010, etc.). In this research, we organized and integrated these results and constructed a ground information database. Furthermore, evaluation indices focusing on the dominant period and amplification factor of the H/V spectral ratio are presented and based on their use an attempt was made to create a hazard map.

[1]Senior Staff, Kozo Keikaku Engineering Inc., Tokyo, Japan, tsutomu-ochiai@kke.co.jp
[2]Research associate, Kanagawa University, Kanagawa, Japan, inubushi@kanagawa-u.ac.jp
[3]Professor, Kanagawa University, Kanagawa, Japan,enomoto01@kanagawa-u.ac.jp
[4]Professor, Almeria University, Almeria, Spain, mnavarro@ual.es

2. TOPOGRAPHY AND GEOLOGY OF KANAGAWA PREFECTURE

Fig. 1 shows the micro topographical map of Kanagawa Prefecture. The prefecture's topography is roughly divided into the following three types (The Japanese Geotechnical Sciety, 2010, Tsutomu Ochiai et al. 2010, Disaster Prevention Frontier Website).

Western region: Topography featuring rugged, mountainous undulations characterized by Hakone Volcano
Central region: Topography consisting of flat terraces and lowlands spreading on both sides of the Sagami River
Eastern region: Topography consisting of hilly land characterized by the Tama Hills and the Miura Peninsula

Note that about one third of the terrain off the western border of the prefecture is mountainous and therefore excluded from the observation area.

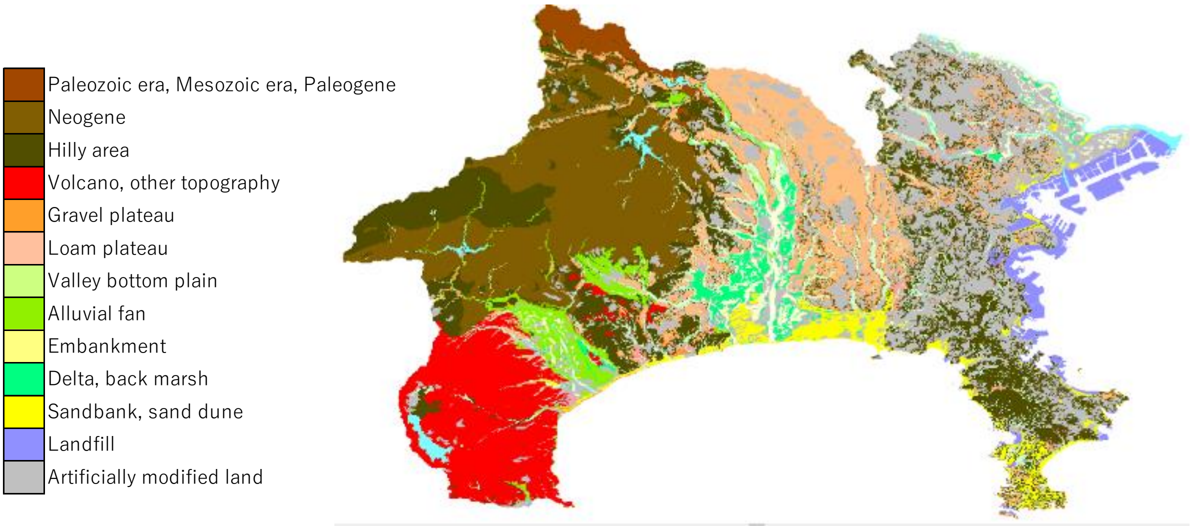


Figure 1. Kanagawa prefecture micro topography classification map

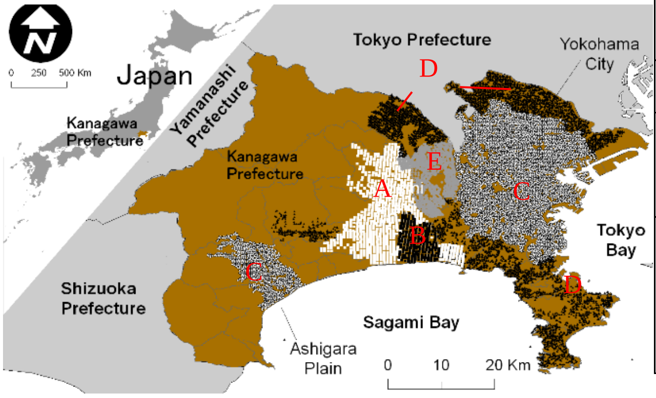
3. CONSTRUCTION OF THE GROUND INFORMATION DATABASE

3.1 Integration of microtremor observation data

High-density microtremor observation has been continuously implemented since the 1990s referencing the maps of towns and villages in Kanagawa prefecture with observation points near the center of a standard 250×250m mesh (one-quarter area mesh)(Statisitics Bureau of the Ministry of Internal Affairs and Communications).
Observation records the waveform data of three components in total, two components in horizontal direction (EW, NS components) and one component in vertical direction (UD component). The recording is set to a sampling frequency of 100 Hz and an observation time of 180 seconds. At the same time, position information (latitude and longitude) and observation conditions are also recorded on the map and by GPS. Table 1 shows observation areas and the number of observation points. The observation points throughout Kanagawa Prefecture and the observation equipment used at that time, respectively color coded, are shown in Fig. 2 (a). Observation equipment is shown in Fig2. (b). Until 1999 we used QST_111 and QST_112 (Tokyo Sokushin) or UP-225S (Shindo Giken). From 2000 onward we used VSE-15D servo velocimeters (Tokyo Sokushin) and from 2016 JU410 accelerographs (Hakusan Corporation). Haddle tests carried out from time to time among this observation equipment have verified the absence of barely any variance between instruments in the cycle range (0.1 to 2.0 seconds) targeted by this research.

Table 1. List of observation points

Observation Areas	No. of observation points	Observation Areas	No. of observation points
Yokohama City	6146	Zama City	254
Yokosuka City	583	Yamato City	376
Kamakura City	345	Ayase City	217
Miura City	327	Kawasaki City	1553
Hadano City	587	Sagamihara City	865
Zushi City Hayama Cho	278	Sagami Plain	958
Fujisawa City	502	Ashigara Plain	1117
		Total	14108



(a) Observation points

Observation equipment	A	B	C	D	E
Recorder	DR-F2aTEAC	UPS-T3	SPC-35	SPC-51	JU410
Amplifier	AL-120-F Tokyo Sokushin	Shindo Giken	Tokyo Sokushin	Tokyo Sokushin	Hakusan Corporation
Sensor	QST_111 QST_112 Tokyo Sokushin	UP-225S Shindo Giken	VSE-15D Tokyo Sokushin	VSE-15D Tokyo Sokushin	

(b) List of observation equipment

Figure 2. Observation points and List of observation equipment

3.2 Observation data analysis method and analysis results

From the observed waveform data of the three components NS, EW, UD, we extracted for each component several relatively low-noise, stable 20.48 second intervals and calculated the Fourier spectrum. The H/V spectral ratio is calculated by dividing the two-dimensional horizontal component obtained by geometrically averaging the spectra of the horizontal two components by the upper and lower components in each calculated interval. Finally, regarding the old observed waveform, the average H/V spectral ratio of all the extracted intervals is obtained.

Since this study targets the surface ground, the dominant period and amplification factor are calculated from particularly prominent peak points of the H/V spectral ratio in the cycle range around 0.1 to 2.0 seconds. In order to read clear peaks of the H/V spectral ratio, in principle, clear peak points with a spectral ratio of 2.0 or more were calculated as dominant periods. However, when a clear peak point is not found, it is calculated with multiple peak points as candidates with reference to peripheral dominant periods as well as boring data and surrounding geographical features.

3.3 Construction of the ground information database

The database of ground vibration characteristics was constructed for lowlands, plateaus, and hilly areas in Kanagawa Prefecture, where the formation of the terrain is complex. As information to be converted into the data base it was decided to use the 11 items shown in Fig. 3. The data is currently organized by GIS on PC but will in future be organized by Web-GIS. Assuming data use by third parties, it is planned to create a system that enables viewing these data and the H/V spectral map display, etc., by selection on the area map (Fig. 4).

1. Observation point code of each observation point
2. Municipality name
3. Latitude/longitude of the observation points
4. Elevation of the observation points
5. Dominant period calculated from the H/V spectral ratio
6. Amplification factor calculated from the H/V spectral ratio
7. Shape of the H/V spectral ratio
8. Micro topography evaluated from the micro topographical map
9. Amplification factor evaluated from the amplification factor chart

10.Hazard calculated from the microtremor H/V spectral ratio

11Other (H/V spectral ratio, PDF of transient wave form)

Figure 4. Data base items

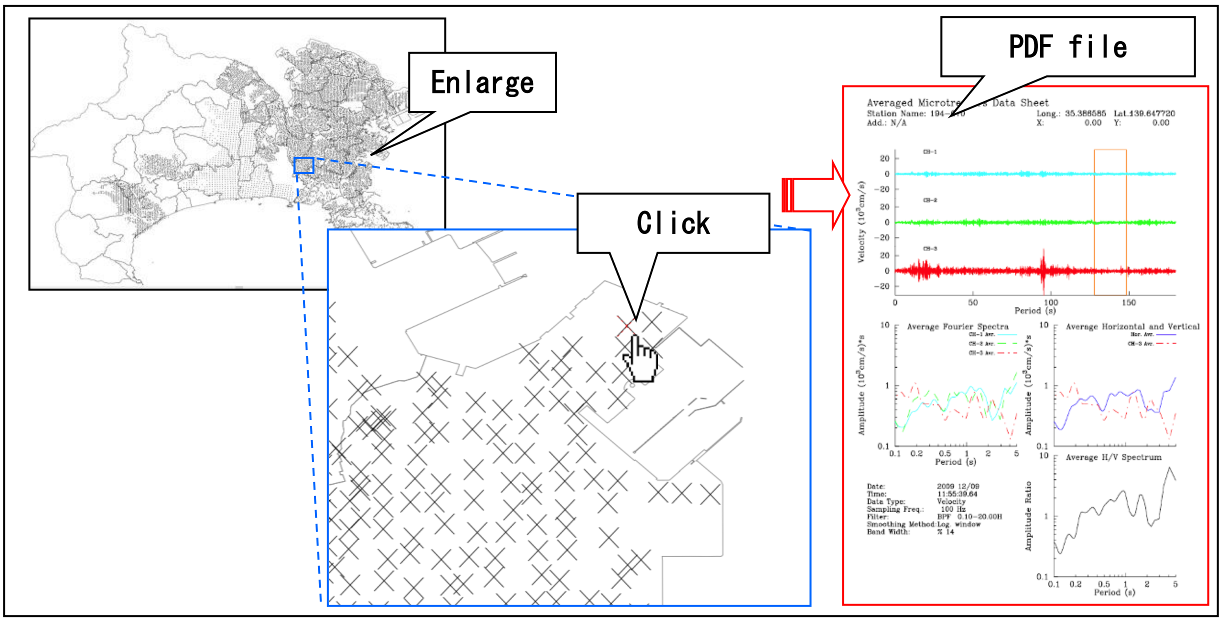


Figure 4. Illustration of the practical application of the data base

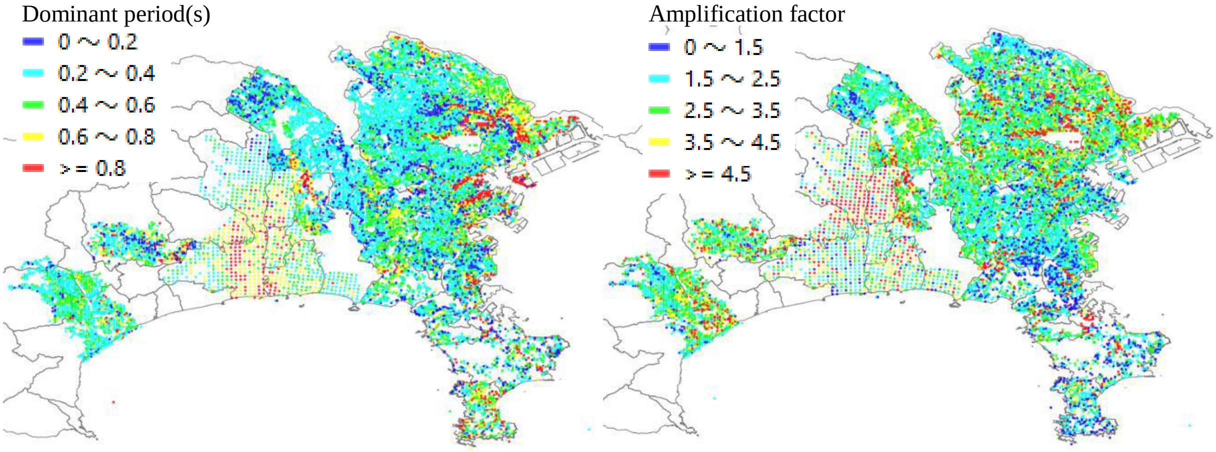
4. HAZARD MAP PRODUCTION

4.1 Comparison of microtremors' predominant period/amplification factor and micro topographical map

For the ground in Kanagawa prefecture, based on existing topographical and geological maps from past research, a 50 m mesh micro-topographical map and an amplification ratio map of the surface ground were created and used (Disaster Prevension Frontire Website, Cabinet Office 2005). This was compared with the dominant period (Fig. 5 (a)) and amplification factor data (Fig. 5 (b)) obtained from the H/V spectral ratio of microtremors.

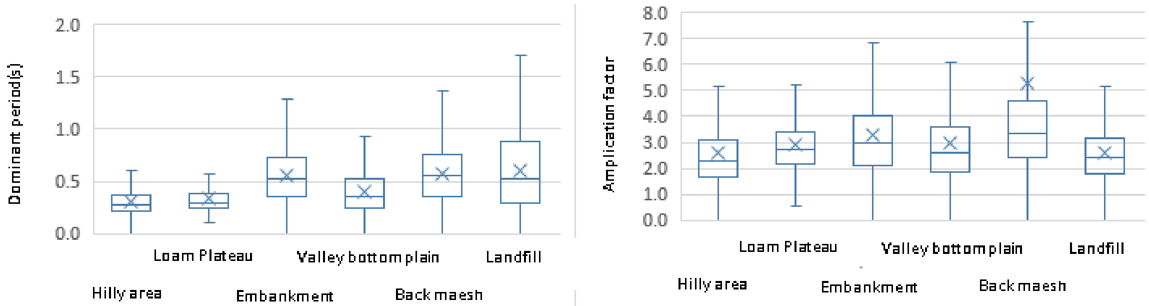
From the dominant period distribution, it is apparent that in the Sagami Plain the dominant period is relatively long in the lowland mainly around the Sagami River. Furthermore, the dominant period is long also along the coastal area of the Miura Peninsula and the Kawasaki Yokohama coastal area. It is long also along the Tsurumi River, albeit localized. This is thought to be due to the prolongation of the dominant period caused by the accumulation of a soft layer in the river basin. On the other hand, although the trend in the amplification factor is less pronounced compared with the dominant period distribution, amplification on the whole is high along the river and in the coastal area and low in the inland loam plateaus etc. (In the Sagami Plain, where the upstream amplification factor is higher than near the estuary, further analysis will be necessary in the future.)

The micro topographical classification and the distribution of dominant period and amplification factor due to microtremor are shown in Fig. 6. Although variation is significant, compared with hilly areas and loam plateaus the dominant period tends to be longer in natural embankments, back marshes, and landfill sites. Althproh relatively speaking the amplification factor tends to be inverse to the dominant period only in landfill sites, there is overall consistency with the correlation of the dominant periods. Incidentally, the correlation was found less clear compared with the dominant periods.
The results of similar studies on the amplification factor obtained from the micro topographical classification and the dominant period and amplification factor due to microtremor are shown in Fig. 7. Respectively, it can be seen that if the amplification factor due to the micro topography is large, microtremors' dominant periods and amplification factor tend to be large also.



(a) dominant period distribution (b) Amplification factor distribution

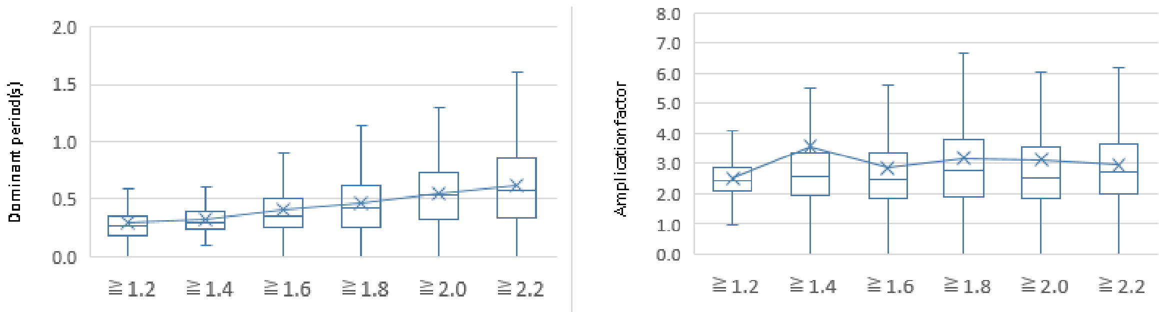
Figure 5. Microtremor Observation result



(a) Micro topography classicitaction and microtremor dominant period

(b) Micro topography classicitaction and microtremor amplication factor

Figure 6. Micro topography classification and Microtremor Observation result



(a) Micro topography amplication factor and microtremor dominant period

(b) Micro topography amplication factor and microtremor amplication factor

Figure 7. Micro topography amplication factor and Microtremor Observation result

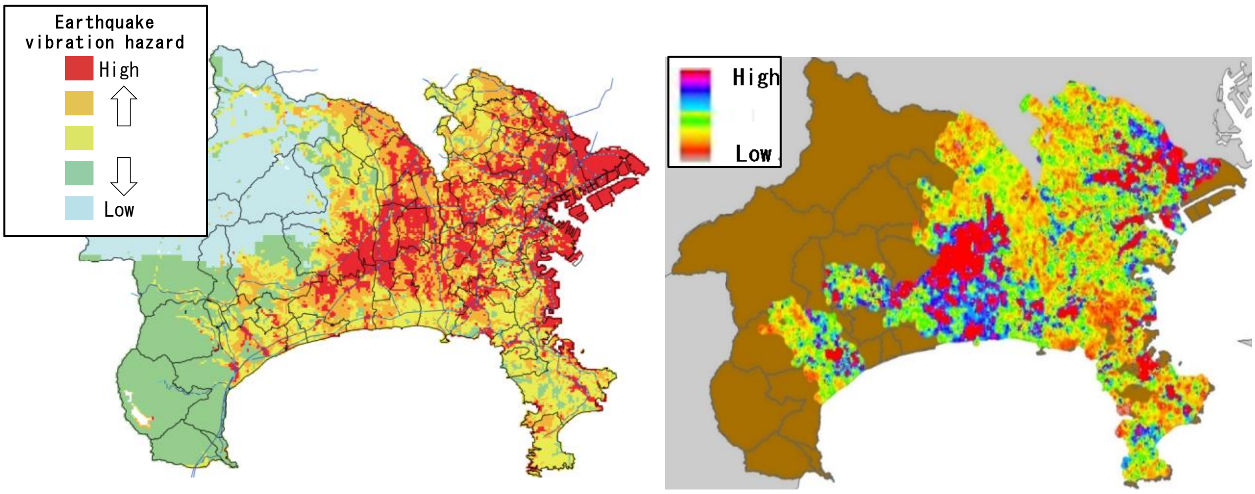
4.2 Hazard map production

With attention to the peaks of the H/V spectral ratio of microtremors, we attempted the production of a hazard map based on the dominant period and amplification factor data. Previously in creating an earthquake hazard map it has been common (Cabinet Office 2005, Kanagawa Earthquake Damage Investigation Committee 2015) to create a ground model using existing boring data. However, owing to the regional bias in the number of boring data, questions remain regarding the accuracy of the ground model in areas with a small number of data. Therefore, we prepared a uniform evaluation of the hazard level of the ground using the high-density microtremor observation results.
In general, the longer the period of the seismic motion and the wider the amplitude are, the larger becomes the effect on structures. The reason is, in other words, the increase in the energy of the seismic motion. Therefore, for the production of a hazard map, we assumed that the product of the dominant period, which is the vibration characteristic of the surface ground, and the amplification factor, which indicates the degree of amplification of the surface layer, equals energy. We attempted to create a hazard map by evaluating the relative magnitude of that energy as the relative risk associated with the ground at that point. Formula (1) was used as the hazard evaluation formula.

$$PE = TO \times Am \quad (1)$$

PE : Hazard
TO : Dominant period
Am : Amplification factor

Fig. 8 shows the hazard map created from the calculation results. It shows that Kawasaki ward of Kawasaki city as well as Kohoku ward and Nishi ward of Yokohama city have many areas with high hazard levels and that an extensive range of the central area of the prefecture features also high hazard levels. For comparison purposes, Fig. 8 (a) shows the earthquake vibration hazard map from Reference [10]. It can be seen that both maps display locations considered hazardous due to similar tendencies. Different tendencies can be seen around Yamato City, but this may be due to the fact that the boring data of the vacillation propensity map is scant.



(a) Earthquake vibration hazard map
(Kanagawa Earthquake Damage Survey Report)

(b) Hazard map using the proposed indicators

Figure 8. Hazard map

5. SUMMARY

In this study we integrated the data for the ground vibration characteristics obtained by high-density single point microtremor observation continuously carried out to date and constructed a microtremor H/V spectral ratio database. The database analysis shows that the dominant periods and the amplification factors of the microtremors correlate with the amplification factors obtained from the micro topography classifications and micro topographies. Using these results, we attempted to create a hazard map solely from the information on microtremors' H/V spectral ratio. The result is shown below.

・Based on the dominant periods of microtremors and micro topography, at points with short dominant periods like hilly land or loam plateaus, variation is small and dominant periods are stable. On the other hand, dominant periods are long and variation is large in landfills, natural embankments, and back marshes.

・From the dominant periods of microtremors and the amplification factors of the micro topography, a certain extent of consistency of both was found to exist as well as an accommodative tendency such that large amplification factors combine with long dominant periods.

・We created a hazard map solely based on tremor results. Kanagawa prefecture overall features high hazard levels in limited areas such as the southern part of the Sagami Plain and the coastal area of Tokyo Bay (mainly Yokohama city and Kawasaki city), which is largely consistent with earlier studies.

The area (Kanagawa Prefecture, especially in the northeastern Yokohama neare the Yokohama area) targeted for this study has a soft ground on the surface layer and is composed of rapidly hard ground. In other words, it is a case with a relatively simple stratum structure. Investigation of applicability of complex stratum structure is a future subject.

In future, we will study hazard evaluation methods using dominant periods and amplification factors and conduct analyses based on differences in Kanagawa prefecture with respect to topography and water systems. In addition, the authors have been working also on underground structure estimation in Kanagawa prefecture by structural surveying using miniature array observation (Ikuo Cho et al. 2016) which has rapidly become widespread in recent years. We will use the results also for comparisons (Tsutomu Ochiai et al. 2014, etc.).

6. ACKNOWLEDGMENTS

The microtremor observation data used in this paper were prepared from the research results of many generations of graduate students, graduate research students, and co-researcher Norio Abeki Laboratory of Kanto Gakuin University. We would like to thank Mr. Toshio Yamamoto, formerly at Kanagawa University, for the generous support regarding the observation plan and observation implementation. Lastly, from the perspectives of topography and geology we received valuable guidance from Professor emeritus Iware Matsuda throughout the research. We would like to express our deep gratitude.

7. REFERENCES

Architectural Institute of Japan: Ground Vibration - Phenomena and Theory -, 2005

Barad, P.-Y.: Microtremor measurements A tool for site effect estimation?, The Effects of Surface Geology on Seismic Motion, Balkema, 1251-1279, 1999

Cabinet Office (Disaster Management): Technical Materials for the Production of Earthquake Disaster Prevention Maps, 2005

Disaster Prevention Frontier Website: http: //bousai-frontier.net/

Ikuo Cho, Shigeki Senna: Constructing a system to explore shallow velocity structures using a miniature microtremor array -Accumulating and utilizing large microtremor datasets-, Synthesiology Vol.9 No.2, pp. 86-96, 2016

Kanagawa Earthquake Damage Investigation Committee: Kanagawa Earthquake Damage Survey Report, 2015

Koji Tokimatsu and Shuji Tamura: Contribution of Rayleigh and body waves to displacement induced by a vertical point force on a layered elastic half-space , Transactions of AIJ. Journal of structural and construction engineering No. 476, pp. 95-101, 1995

Lermo Javier Francisco J. Chavez-Garcia: Are microtremors useful in site response evaluation?, Bulletin of the Seismological Society of America, Vol.84, No.5, pp.1350-1364, 1994

Matsushima Shinichi, Hirokawa Takanori, Florent De Martin, Kawase Hiroshi, and Francisco J. Sanchez-Sesma: The Effect of Lateral Heterogeneity on Horizontal-to-Vertical Spectral Ratio of Microtremors Inferred from Observation and Synthetics, Bulletin of Seismological Society of America, Vol.104, No.1, pp.381-393, 2014

Nakamura Yutaka: A method for dynamic characteristics estimation of subsurface using microtremor on the ground surface, Quarterly Report of RTRI, 30:1, 25-33, 1989

Naohiro Ueno, Takahisa Enomoto, Toshio Yamamoto: Organization and examination of the dominant period distribution of high-density microtremor observation results in Yokohama city using GIS, The 13th Japan Earthquake Engineering Symposium, pp. 2011-2018, 2010

Statistics Bureau of the Ministry of Internal Affairs and Communications: Regarding regional mesh statistics

http://www.stat.go.jp/data/mesh/m_tuite.htm

Tsutomu Ochiai, Shigeki Senna, Ma He, Tetsushi Inubushi, Takahisa Enomoto: Estimation of surface soil structures of the Hadano Basin by shallow underground structure exploration through permanent observation of microtremors - The 14th Japan Earthquake Engineering Symposium, pp. 3017-3024, 2014

Tsutomu Ochiai, Toshio Kuriyama, Mitsufumi Hashimoto, Takahisa Enomoto, Nobuo Tsuyuki, Toshio Yamamoto: Research on detailed regional digital risk map creation and support for disaster prevention activities, The 13th Japan Earthquake Engineering Symposium, pp. 2035-2038, 2010

Tsutomu Ochiai, Toshio Yamamoto, Hideto Hattori, Takahisa Enomoto: Study on Zoning for Ground Shaking Characteristics of Surface Soil Structure in Sagami Plain Using Spatially Dense Microtremor Measurements , Proceedings at the Regional Safety Association, No.5, pp. 21-26, 2003

The Japanese Geotechnical Society, Kanto Branch, Kanagawa Prefecture Group: The Great Ground of Kanagawa, 2010