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MICROZONING MAP OF PREDOMINANT PERIODS IN KUSATSU CITY ESTIMATED FROM MICROTREMOR MEASUREMENTS

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ABSTRACT

Ground vibration characteristic generally has a relationship with surface ground conditions. Ground vibration characteristic was analyzed from the distribution of predominant periods by measuring micro-tremors at Kusatsu city in Shiga prefecture. The seismic micro-zoning map was made by using geographic information system (GIS). The distribution of predominant periods were visually compared with surface ground conditions such as topographic and geological characteristics. The round ranges of predominant period in every ground conditions could be grasped, in which the predominant period increased as the thickness of surface layer increased.

Keywords: geographic information system, microtremor, microzoning, predominant period

INTRODUCTION

Japan Central Disaster Prevention Conference had made ground vibration maps of surface ground to discuss the disaster prevention countermeasures against the Nankai and the East Nankai Earthquakes as shown in Figure 1 (Cabinet Office, Government of Japan, 2005). Magnitude of ground vibration has a relationship between magnitude of earthquake, distance from earthquake source and surface ground conditions. This means surface ground conditions is an important factor. Each mesh in Figure 1 has 1 kilometer square, however, actual ground vibration is connected with minute local conditions such as ground conditions.

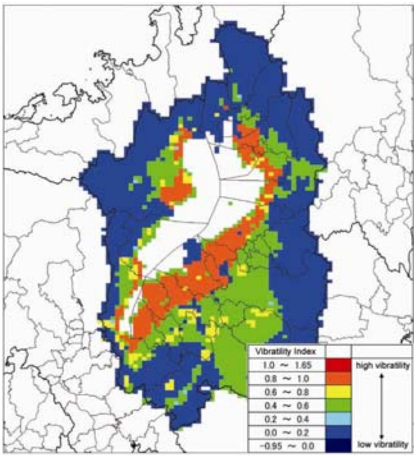

Figure 1. Ground vibration map in Shiga prefecture

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Kusatsu city area is divided into 229 meshes with 500 meter square, microtremor is measured at 153 points among 229 meshes. Microtremor measurement is a popular method to estimate ground vibration characteristics (Bour et al. 1998, Teves-Costa et al. 1998). Predominant periods are estimated from the spectrum ratio of microtremor measurements. Microzoning map of the predominant periods in Kusatsu city is made by using the geographic information system. The relationship between ground vibration characteristics and surface ground conditions such as geography, micro-topography and thickness of surface ground is discussed.

MESH DIVISION AND MICROTREMOR MEASUREMENT METHOD

Mesh division

To discuss minute ground vibration characteristics, Kusatsu city area is divided into 229 meshes with 500 meter square as shown in Figure 2. Microtremor measurement was carried out at least one point in the mesh. The microtremor measurement is a popular method to estimate the ground vibration characteristics. The time period of the microtremor is different form each ground as reflecting ground conditions. Generally, the time period in the solid ground is short with high frequency and that in soft ground becomes long with low frequency. The predominant periods estimated from microtremor measurements agree with those estimated from the *N*-values of boring data and the seismic response analysis (Hayakawa 2003, Nabeshima 2005).

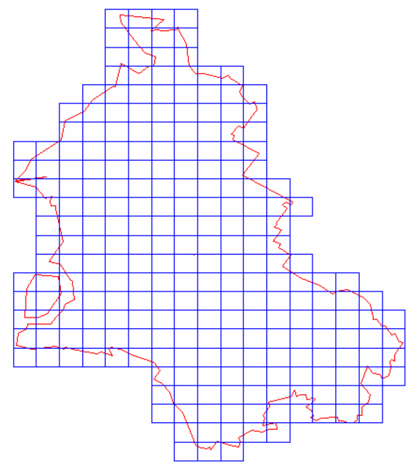

Figure 2. Mesh division in Kusatsu city

Outline of microtremor measurement

Microtremor is measured at 153 points in Kusatsu city as shown in Figure 3. Although the microtremor measurements were unable to carried out for all meshes in Figure 2, 153 measured points are roughly covered with whole city area and all surface ground conditions. Therefore, the ground vibration characteristics in Kusatsu city can be discussed in this study.

A portable vibrograph (Tokyo Sokushin, SPC-35N) and three servo-type speedmeters were used in the microtremor measurement as shown in Figure 4. As the measured points, the natural grounds without artificial cover such as concrete and asphalt were selected and they were kept away from clear vibration sources. Microtremor measurements were basically carried out during night time to avoid the effect of artificial disturbance. Motions in three directions of east-west, north-south and up-down were measured and recorded for ten minutes (300,000 data points) at each point. And the positioning of the measured points was made by using portable global positioning system (GPS) unit.

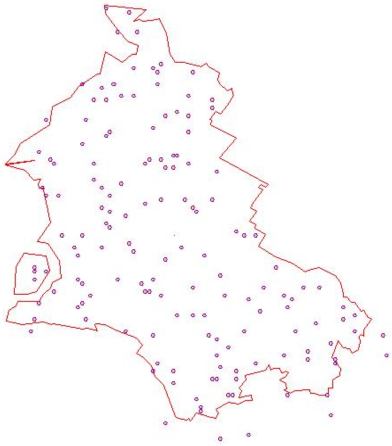

Figure 3. Measured points of microtremor in Kusatsu city

(a) portable vibrograph (b) servo-type speedmeter

Figure 4. Portable vibrograph and servo-type speedmeter

Estimation of predominant periods

To estimate the predominant periods at measured points in Kusatsu city, spectrum ratio between horizontal (H) and vertical (V) motions was used. The H/V spectrum ratio is estimated from three components in the microtremor measurement data without disturbance such as traffic vibration. The 8,192 points were selected from the measured 300,000 points in east-west, north-south and up-down directions. For the selected data points, the fast Fourier transformation analysis was applied. The H/V spectrum ratio was calculated by using Equation (1) and the predominant period was decided from peak value in the H/V spectrum ratio as shown in Figure 5 (Nabeshima, 2005).

$$H/V = \sqrt{(EW^2 + NS^2)/(2UD^2)} \quad (1)$$

where EW: motion in east-west direction, NS: motion in north-south direction and UD: motion in up-down direction.

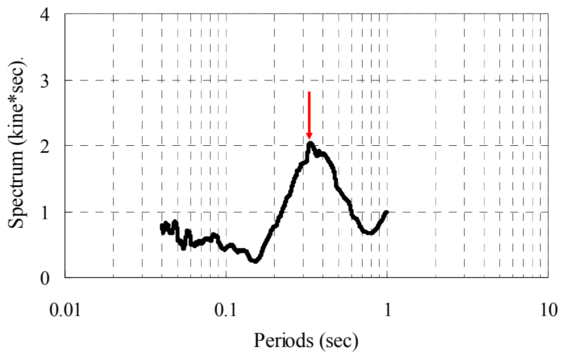

Figure 5. Determination of predominant period using H/V spectrum ratio

SURFACE GROUND CONDITIONS AND GROUND VIBRATION CHARACTERISTICS

Geographic information system of surface vibration characteristics

In this study, a commercial geographic information system (GIS) platform (SIS, Map Modeller ver.6.0) was used. As the built-in data, digital data including the geography, elevation, land conditions and boring data were installed in the GIS. Predominant periods measured at 153 points in Kusatsu city were also installed. By overlaying these data, ground vibration characteristics are able to compare with the surface ground conditions. Thickness of surface layer is calculated from the elevation and boring data by using various functions of GIS. Also, relationship between surface layer thickness and predominant periods can be discussed in this study.

General geographic characteristics at Kusatsu city

The alluvial low ground sweeps in the northwest part of Kusatsu city. The mountainous parts are located in southeast area, however, there is no place exceed 250 meters over the sea level. About 150 meters high hills continue and alluvial fans divide between hilly parts and alluvial low grounds. Small cliffs about 2 meters exist at the edges of alluvial fans. The ground in Kusatsu city becomes soft from southeast to northwest direction as changing from bedrock in mountain part, the diluvial deposits in the hill, alluvial deposits in the alluvial fan, alluvial soft soil in the low ground and reclaimed land.

Predominant periods and geographic characteristics

Figure 6 shows distribution of predominant periods in Kusatsu city. The areas where the long predominant periods appear are concentrated in the northwest part. The predominant periods in lake side areas shows comparatively longer than those in central part in Kusatsu city. The short predominant periods appear at central and southern parts and longish predominant periods partially appear in southwest part.

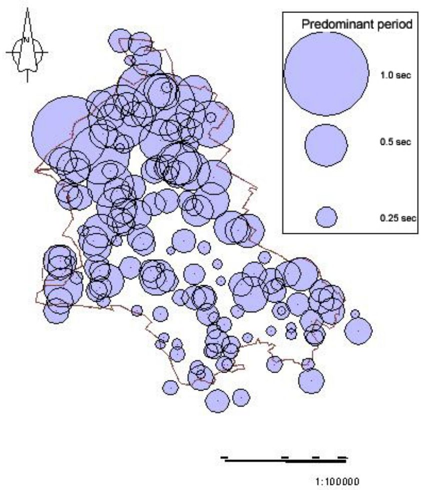

Figure 6. Distribution of predominant periods in Kusatsu city

Figure 7 shows the distribution of predominant periods and geography in Kusatsu city. Geography is represented by the elevation, the elevation increases as the green collar becomes dark in this figure. As clearly can be seen from Figure 7, the long predominant periods appear in the low elevation area and the predominant periods decrease as increase with the elevation. However, the short predominant periods appear in the central part in Kusatsu city and comparative long predominant periods appear in the high elevation parts. Although these reasons can not be elucidated from the geography, Distribution of predominant periods in Kusatsu city was generally correlated with geography of this area such as the elevation. To circumstantially investigate relationship between predominant periods and geography, the distribution of predominant periods is compared with the micro-topography.

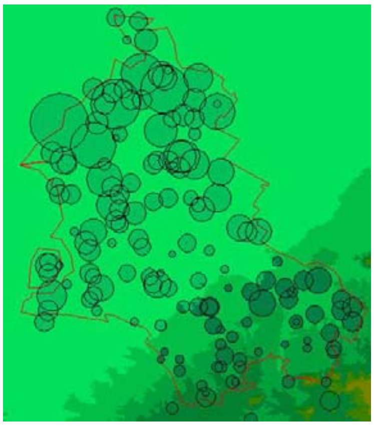

Figure 7. Predominant periods and geography

Figure 8 shows the relationship between predominant periods and micro-topography in Kusatsu city. The micro-topography is decided by the legend in the land condition map. The typical micro-topography in Kusatsu city, the number of measured points, minimum and maximum predominant periods in each category are summarised in Table 1. Microtremor was measured in each micro-topography at least one point, the relationship between predominant periods and the micro-topography can be investigated in this study. As can be seen from Figure 8 and Table 1, a certain range of the predominant periods exists in each category of the micro-topography. Especially, it seems that both minimum and maximum predominant periods are comparatively short in the categories such as slope, plateau, hill, alluvial fan and partly high ground. Meanwhile, it seems that the maximum predominant periods are longer in the categories such as flood plain, natural bank, delta and filling although the minimum predominant periods are no difference from the other categories. Thus, it is understood that the range of the predominant periods in flood plain, natural bank, delta and filling is very wide.

As mentioned above, it was confirmed that a certain range of the predominant periods exists in each category of the micro-topography. But it was very hard to decide the representative value in each category because of wide distribution range.

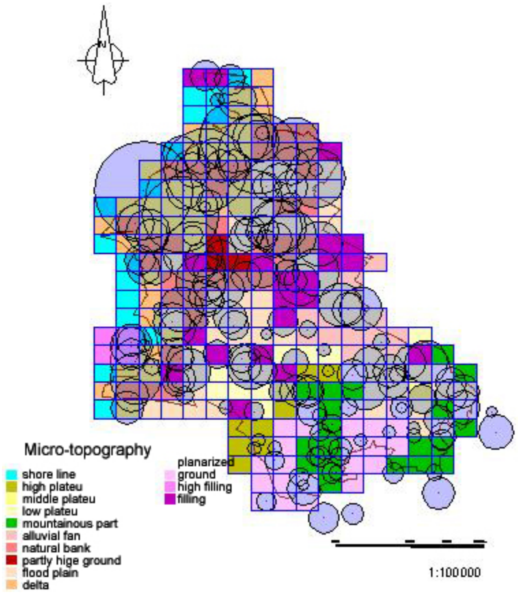

Figure 8. Predominant periods and micro-topography

Table 1. Micro-topography, the number of measured points,

minimum and maximum predominant periods

Macro-topography	Micro-topography	Number of measured points	Minimum predominant period (sec)	Maximum predominant period (sec)
Slope	Mild slope, ridge	1	0.19	0.19
	Mild slope, valley	3	0.17	0.28
	Mild slope, straight	12	0.13	0.42
	Steep slope, straight	1	0.15	0.15
Plateau, Hill	Higher level	1	0.12	0.12
	Upper level	1	0.28	0.28
	Middle level	1	0.42	0.42
	Lower level	3	0.12	0.27
Partly high ground in low ground	Alluvial fan	8	0.15	0.40
	Natural bank	16	0.16	0.74
	Partly high ground	3	0.29	0.40
Low ground	Flood plain	34	0.10	0.64
	Delta	14	0.10	0.76
Frequently flood ground	Raised bed river	2	0.12	0.13
	Flat	1	0.34	0.34
	Tidal flat	1	0.30	0.30
Artificial ground	Planarized ground	14	0.10	0.38
	High filling	4	0.12	0.39
	Filling	26	0.10	0.90
	Reclaimed ground	3	0.12	0.19

Predominant periods and thickness of surface layers

Effect of the thickness of surface layers on the ground vibration characteristics is discussed in this section. 142 boring data around Kusatsu city were collected by the Kansai Geological Survey Association (2003 and 2005). To estimate the thickness of surface layers, these boring data, the elevation and the depth to the bedrock in the land condition map were used. First, because the depth to the bedrock is illustrated in central and northwest areas in the land condition map, the thickness of surface layers was calculated from the difference from the depth to bedrock and the elevation. By using GIS functions, thickness of surface layer was calculated in the southeast area from the depth where the *N*-value was less than fifty. By combining these two areas using GIS function, the distribution of thickness of surface layer in Kusatsu city was completed.

Figure 9 shows the distribution of surface soft soil layer in Kusatsu city. The area with thick surface layer widely exists in northwest part. Also, it partly exists in southeast part. The area with very thin surface layer exists in central area of Kusatsu city. The surface ground structure in Kusatsu city was understood.

Figure 10 shows the predominant periods and thickness of surface soft soil layer. It was generally understood that the predominant periods were correlated with thickness of surface layer. That is, the predominant periods basically became long as the thickness of surface layer increased. Although the short predominant periods appear in the central part in Kusatsu city and comparative long predominant periods appear in the high elevation parts as shown in Figure 7, it is explicable from Figures 9 and 10 that thickness of surface layer in some central parts is very thin and that in south and southeast areas is comparatively thick.

As mentioned above, by considering the thickness of surface ground layer, the relationship between the distribution of predominant periods and the surface ground conditions can be visually understood.

Therefore, it was confirmed that the geographic information system was a powerful and useful tool to analyze and elucidate the ground vibration characteristics by installing various data and information about surface ground conditions.

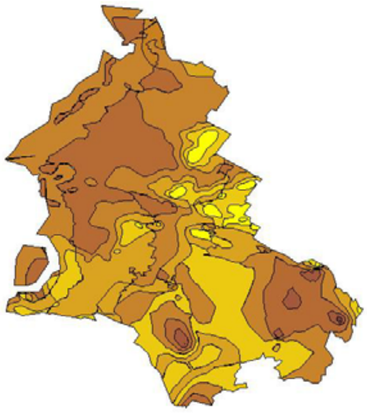

Figure 9. Distribution of surface soft soil layer in Kusatsu city

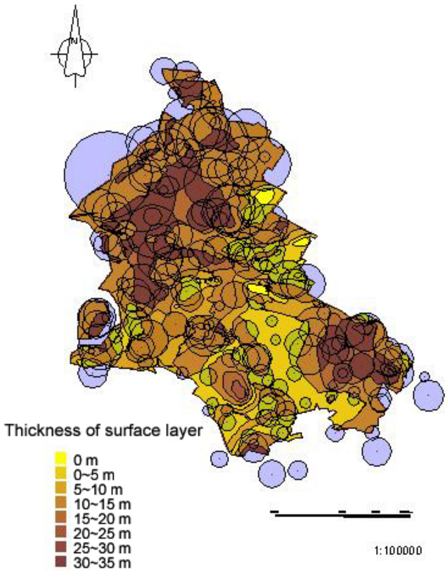

Figure 10. Predominant periods and thickness of surface soft soil layer

CONCLUSIONS

In this study, microtremor measurements were carried out in Kusatsu city and the predominant periods were estimated from microtremor recordings. Microzoning map of ground vibration was made by using the geographic information system and the relationship between the predominant periods and ground conditions are investigated. Main conclusions in this study are as below.

1) Distribution of predominant periods in Kusatsu city was correlated with general geographic characteristics such as the elevation and the micro-topography. However, it was very hard to decide the representative value in each category because of wide distribution range.
2) By combining the elevation and boring data in Kusatsu city, distribution of thickness of surface layer was made. Thick soft layers widely spread in the northeastern part in Kusatsu city and also in the southwestern part of hilly part.
3) The predominant periods were correlated with thickness of surface layer. The predominant periods basically became long as the thickness of surface layer increased in some topographic categories.

4) Geographic information system (GIS) was a powerful and useful tool to analyze and elucidate the ground vibration characteristics by installing various data and information about surface ground conditions.

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