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LOCAL SITE AMPLIFICATION OF PEAK HORIZONTAL GROUND VELOCITY BASED ON MICROTREMORS

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SUMMARY

The method for estimation of peak horizontal ground velocity on surface (PGVs) has been proposed. PGVs is obtained by multiplying peak horizontal ground velocity on engineering oriented base (PGVb) and the local site amplification factor (Vamp). PGVb is estimated by the "improved" attenuation equation based on Joyner & Boore(1981). Vi value is proposed as the index of local site amplification to estimate Vamp and derived from integration for H/V spectrum which represents Fourier amplitude spectral ratio between horizontal and vertical components of microtremors.

The assumption that Vi value ratio will equal to Vamp ratio between arbitrary 2 sites, is most important for this estimation method. It has been verified based on many microtremor records, strong ground motion records and soil profiles. It was found that Vi value ratio conformed well with Vamp ratio between 2 sites and their standard deviation was less than 20%.

At about 300 sites in Kyoto city, microtremor measurement had been done to obtain Vi value and to evaluate Vamp. The distribution of Vi value can express characteristic site amplification. To verify the method for prediction, the regional distribution of PGVs in Kyoto city during 1995 Kobe Earthquake had been estimated and compared with the regional distribution of damaged wooden houses.

Conclusions are (1)Vi value can express the difference of the local site amplification factor (Vamp) at each site.(2)Estimated PGVs in Kyoto city during 1995 Kobe Earthquake in Japan can explain the concentrated stricken area.

INTRODUCTION

The earthquake ground motion strongly reflects the effect of a local site amplification factor due to subsurface soil conditions. Thus, the microzoning of the local site amplification factor on a subsurface is important in a case of estimating the earthquake ground motion on surface and the distribution of the damage in a city.

H/V spectrum (the ratio of the Fourier amplitude spectrum between the horizontal component and the vertical component in the microtremor, hereafter referred to as H/V) is typically used as index of microzoning because of the simple and easy method. Accordingly, in many cases, it is assumed H/V itself to be a S wave transmission function of a subsurface at local site or defined respectively its peak period and its peak value as the approximations of a predominant period and an amplification factor of the local site [1) 2)]. The predominant period has a high relativity with depth of base and the physical basis is relatively evident [3)]. However, the theoretical basis whether or not amplitude value of H/V implies the amplification factor of the local site is not evident, and this is still the investigation subject.

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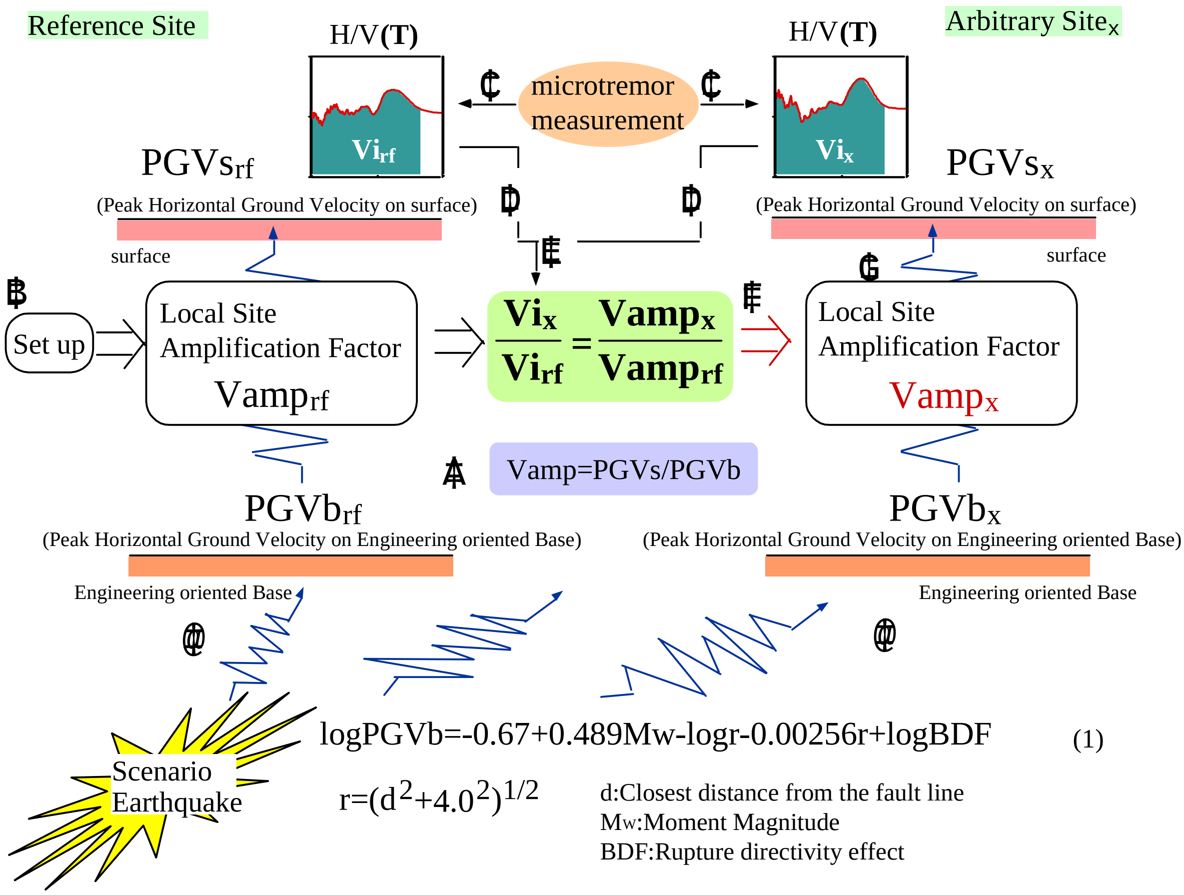

Fig.1 Estimation flow of Peak Horizontal Ground Velocity

Hence, new index which is named Vi value is defined as the integration value of H/V with respect to a particular period range in this research , and points out that Vi value ratio between the 2 sites becomes the index of representing the difference of the relatively shaking degree (concretely as for the peak horizontal ground velocity on surface, hereafter referred to as PGVs) between the sites resulting from the local site amplification factor of subsurface, and further describes the method of evaluating PGVs by using Vi value. Figure.1 shows an estimation flow of PGVs proposed here.

1. Scenario fault is determined as modeled line. The peak horizontal ground velocity on an engineering oriented base (hereafter, referred to as PGVb) is estimated by improved Joyner and Boore's attenuation (hereafter, referred to as a JB equation) [4) 5)] as equation (1), in which a directivity effect is considered, from the shortest distance between the reference site and a fault line and an assumed magnitude. **2.**The index Vamp of the local site amplification factor is introduced in this paper which is defined as the ratio of PGVs to PGVb. **3.**$Vamp_{rf}$ at the reference site is set by using strong ground motion records and a local site information such as a boring log. PGVs at the reference site is determined by multiplying PGVb at the same site by $Vamp_{rf}$. **4.** Microtremor measurement can be done at the arbitrary site which have no information (hereafter, referred to as $site_x$) as well as the reference site. **5.** Vi value is determined by H/V which is the observation result of the microtremor. Vi value is the index of representing the shaking degree at the site. **6.** The Vi_x/Vi_{rf} (hereafter, referred to as a Vi value ratio) implies the shaking degree of any $site_x$ to the reference site. It is assumed that Vi value ratio will equal to Vamp ratio between arbitrary 2 sites. **7.** It is possible to evaluate the amplification factor $Vamp_x$ at any site by multiplying the known $Vamp_{rf}$ by Vi value ratio. **8.** PGVs at any $site_x$ is determined by PGVb and $Vamp_x$ at the $site_x$.

The assumption that Vi value ratio will equal to Vamp ratio between arbitrary 2 sites, is most important for this estimation method.

DEFINITION OF Vi VALUE

The maximum earthquake ground motion is determined by the effect of the various periods of waves. Hence, it is considered that the evaluation of the local site amplification factor based on only H/V peak value may result in a problem [3)]. So, Vi value which is an index of amplification factor and an integrated value of H/V with respect to a period, is proposed in this research. Vi value is defined as follows:

$$Vi = \int_{T1}^{T2} H/V(T)dT \qquad (2)$$

The integration with respect to the period causes the index having the weight on a side of a longer period. The difference of the local site amplification factor of Vamp between the respective sites can be represented by Vi value ratio.

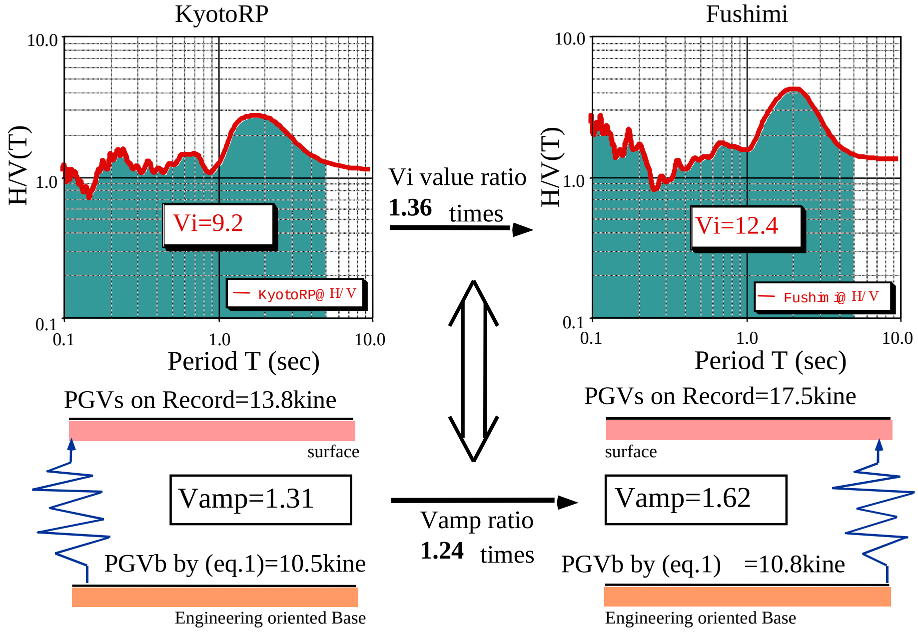

Fig. 2 Comparison between Vi Value ratio with Vamp ratio

Figure.2 explains the concept of Vi value. The observation record of the Kobe Earthquake and the JB equation were used to calculate Vamp at the two sites (KyotoRP and Fushimi) in Kyoto city. Vamp at KyotoRP is 1.31 and Vamp at Fushimi is 1.62. Hence, Fushimi has the shaking degree which is approximately 1.24 times that of KyotoRP. The integration ranges T1 and T2 of an equation (2) were determined such that Vamp ratio (1.24) was satisfied by Vi value ratio determined by the microtremor observation at both the sites (Fushimi/KyotoRP). The combination of T1=0.1 sec and T2=5.0 sec showed the most suitable value. Finally, T2=5.0 sec was adopted by considering the instrument performance used in the microtremor observation, the lower limit period by which a structure was damaged .

Vi value ratio between KyotoRP and Fushimi when assuming the integration period to be in the range from 0.1 to 5.0 sec becomes 1.36, which conformed well with Vamp ratio. Hereafter, Vi value is defined as the integration value in H/V period in the range from 0.1 to 5.0 sec. The similar investigation has been done at Kobe district (Fukiai/Motoyama) and similar result was obtained.

VERIFICATION OF Vi VALUE

Now, it is verified that Vi value ratio is the index of implying the difference of the local site amplification factor of PGV(Vamp) in many sites. Vamp is obtained from 3 methods which depend on deference of procedures. Figure.3 shows the way of thinking about 3 method. It has been confirmed that Vamp estimated by each method was equivalence each other. [6)]

Method1:Vamp estimated facilely[7)] by the local site information such as the boring log, PS logging. It is described as equation (3).

$$ALVM = (Vs30/Vsb)^{-0.6} \qquad (3)$$

Here, Vs30 is an average S wave velocity from a ground surface to a depth of 30 m at local site, and Vsb was an S wave velocity on an engineering base and was assumed to be 500 m/s.

Method2:Vamp described as the ratio of PGVs resulting from the earthquake observation to PGVb resulting from the JB equation

Method3:Vamp described as the ratio of PGVs resulting from the earthquake observation to PGVb resulting from the frequency domain analysis.

During 1993 Kushiro off Earthquake, 1994 East off Hokkaido Earthquake[8)], and 1995 Kobe Earthquake many strong ground motions was recorded. The soil condition and underground structure at observation sites was known from prior and an ex post facto survey. Vamp was estimated using the information mentioned above. The microtremor was observed at strong ground motion observation sites to determine H/V and Vi value at each sites.

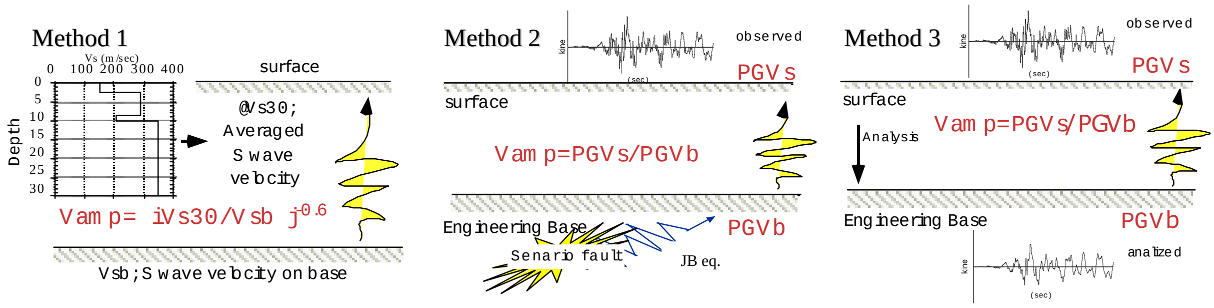

Fig. 3 Vamp estimated based on 3 methods

Figure.4 shows the relationship between Vi value ratio and Vamp ratio at each methods. It is known that Vamp ratio and Vi value ratio exhibit the substantially one-to-one response by any method. The standard deviation to one-to-one line was less than 15% at method1, equal to 20% at method2 and equal to 5% at method3. However the tendency that Vi value at reclaim land sites were little estimated was observed.

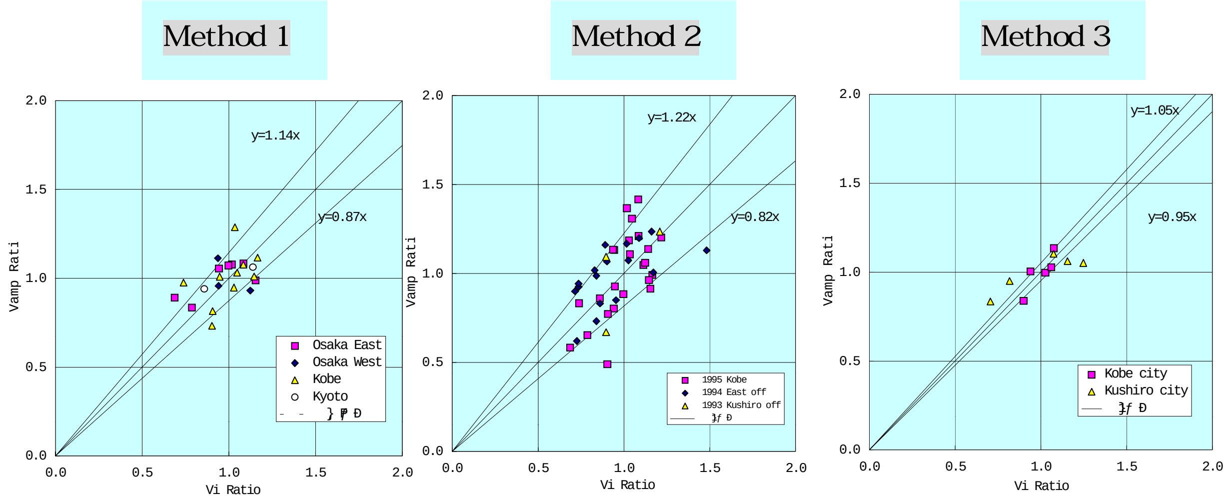

Fig. 4 Comparison Vi value ratio with Vamp ratio

DISTRIBUTION OF Vi VALUE IN KYOTO CITY

The microtremor was observed at about 300 sites in the Kyoto city to determine H/V and Vi value at each sites. In the method of processing the microtremor data [2)], 10 sets of numeral data were firstly selected in order starting from the portion having the less noise with regard to the observation records in horizontal two components and a vertical component with 20.48 sec as a unit. Two dimensional Fourier amplification spectrums synthesized by considering phases from the observed horizontal two components were defined as the horizontal components. As for the vertical component, the observed value was used. Each 10 sets of the Fourier amplification spectrums in the horizontal and vertical components were smoothed by a Parzen window of 0.3 Hz, and further a geometrical mean was calculated. After that, H/V was determined. Vi value was the integration value in H/V period in the range from 0.1 to 5.0 sec, mentioned above.

Figure.5 shows the distribution of Vi values in the Kyoto city. There is the tendency that Vi value is small at the northern area. The more southern, the larger Vi value conform. In the northern are of Kyoto, the exposure of base rocks is seen and it is known that the deposits are thin, from the boring log. Thus, they match that the area of small Vi value is difficult to shake. While the sites having large Vi values are concentrated in the periphery of Fushimi, it is known that there is the thick deposit called a deep clay layer in that vicinity. Moreover, while the regions having large Vi values are concentrated in the southern area of old Ogura pond, it is the flood plain of the Kidu River. Similarly, Vi values are large in the area in which the Kidu River, the Uji River and the Katsura River respectively joint the Yodo River, which suggests the existence of the thick deposit. In the Yamashina basin, Vi value cleverly represents the difference of the local site amplification factor between the site having the thick deposit at the center of the basin and the periphery base rock site.

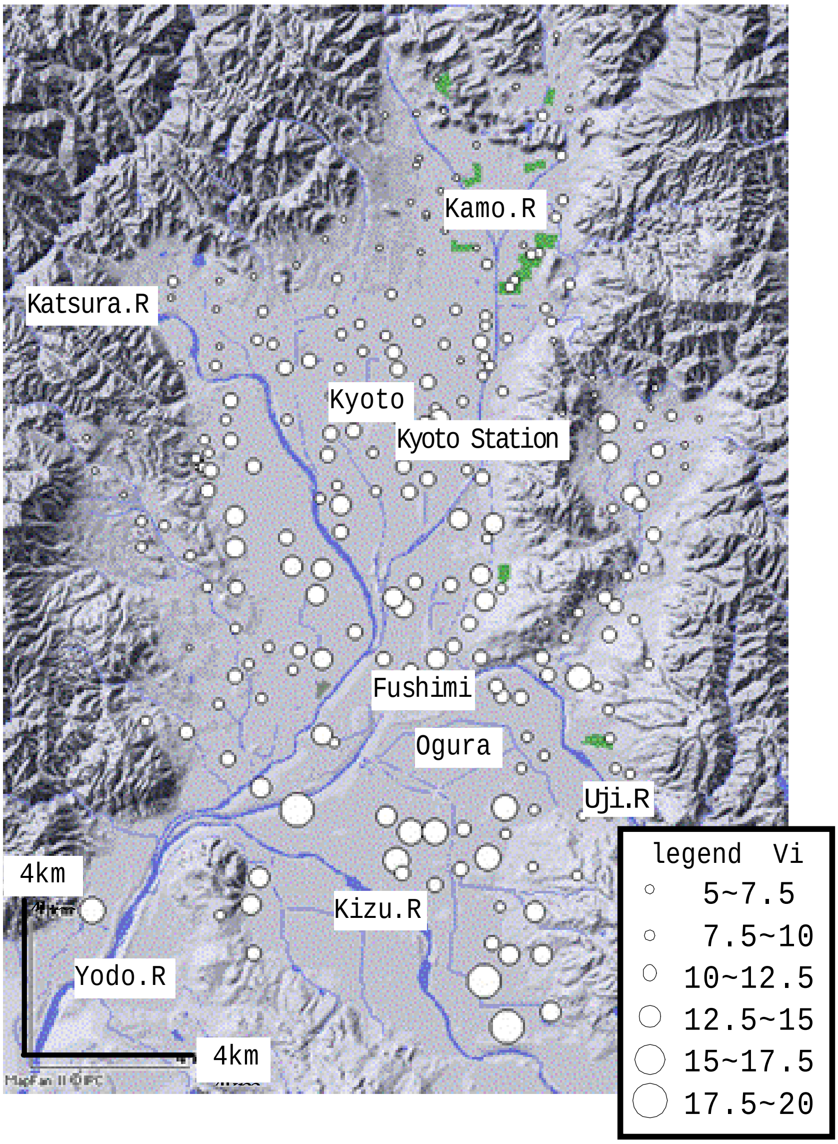

Fig. 5 Distribution of Vi value in Kyoto city

ESTIMATION OF REGIONAL DISTRIBUTION OF PEAK HORIZONTAL GROUND VELOCITY IN KYOTO CITY

The regional distribution with regard to PGVs in the Kyoto city in the Kobe earthquake was estimated in accordance with the method shown in Figure 1. The reference site whose $Vamp_{rf}$ had been known was set to the above mentioned KyotoRP site, and then $Vamp_{rf}$ was set to 1.31 with reference to strong ground motion record and site information. Figure.6 shows the regional distribution of PGVs in the Kyoto city during the Kobe earthquake. It is less than 10 kine in the northern area since there is far away in distance from the earthquake source fault and the amplification is small. The basin along the Kidu River shown in Figure.5 as the area whose Vi value was large had the shaking between 20 and 30 kine, since it was located closely to the earthquake source fault. The many sites of the Kyoto city are included in a range from 10 to 15 kine. There is the observation record in JMA Kyoto where PGVs was guessed almost 11 kine[9)], which conform to the result of this estimation. According to the situation of the damaged houses [9)] in the Kyoto city resulting from the Kobe earthquake, the damages were concentrated in the Katagihara and Yamada area located west from the Katsura River and the Ohyamasaki area located northerly from the junction of the three rivers to the Yodo River which are surrounded by frames in Figure 6. The Katagihara and Yamada area has the topographical characteristic that the ground level of a block surrounded by two raised bed rivers was raised after the Second world war. Furthermore, the ohyamasaki area may have the thick deposit at the joint of the three rivers.

It is understood that these damaged areas have the large PGVs and thereby Vi value is effective as the index of representing the local site amplification factor. Moreover, although there are such as large factories and parks at the joint of the Uji River and the Kidu River and on the southern side of old Ogura pond whose PGVs are large in the drawing, there are no densely house group. Therefore, it may be considered that the damaged houses were not reported.

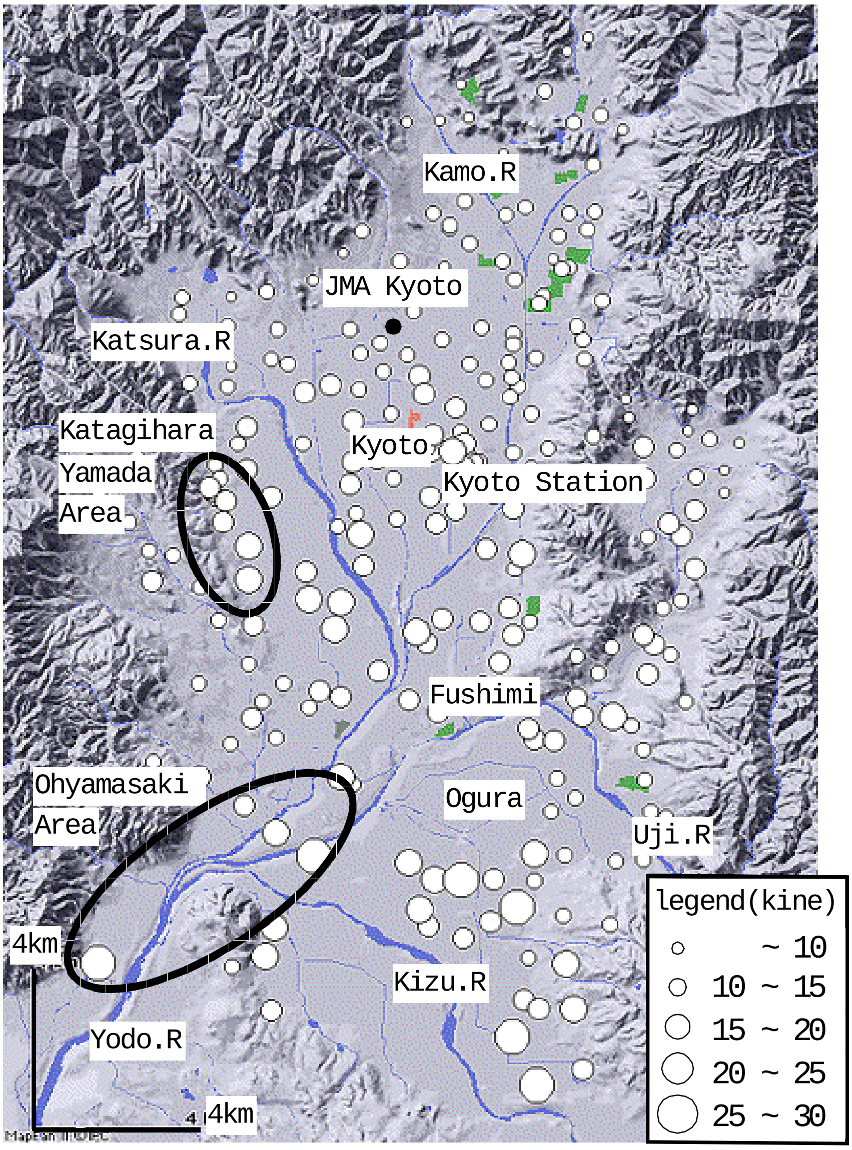

Fig. 6 Distribution of estimated PGVs

CONCLUSIONS

This research indicates that Vi value defined by the integration value of H/V of the microtremor becomes the index of representing the local site amplification factor, and proposes the simple method to estimate the peak horizontal ground velocity by using Vi value ratio of any site to reference site. Moreover, this method is utilized to estimate the regional distribution of the peak horizontal ground velocity in the Kyoto city during 1995 Kobe earthquake. Accordingly, it is com-pared with the regional distribution of the damaged houses and it is found out to indicate the preferred correspondence between them.

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