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LOCAL SITE EFFECT OF KOBE BASED ON MICROTREMOR MEASUREMENT

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ABSTRACT

The Hyogo-Ken-Nanbu Earthquake caused heavy damage in Kobe city and its surrounding area. To clear the relationship between damage and local site effect, a month after the earthquake, microtremor measurement was performed for about a year. According to the measurement results in the damaged zone, the amplification factor (A) ranges between 2 and 3 which is not so high. However the predominant frequency (F) ranges between 1.5 and 2 Hz which corresponds to that of strong motion. Distribution of vulnerability index Kg value for ground confirmed the damage belt.

Introduction

The 1995 Hyogo-Ken-Nanbu Earthquake caused heavy damage to Kobe city and its surrounding area. Especially, a part of area where extensive damage concentrated, spreads from east to west in the region. With its appearance the area called as Damage Belt. Many studies have been done for investigating the reason why did the damage occurred in such a belt shape.

In this paper, to clear the relationship between damage and local site effect, microtremor measurement was made in damaged and surrounding area. Dynamic characteristics of surface ground (predominant frequency F, amplification factor A) are estimated. Furthermore, vulnerability index Kg value (Nakamura,1996) is also calculated, and compared with real observed damage information. As a result, 1: Predominant frequencies (F) have a trend to gradually small value from mountain side to sea side. 2: Amplification factor (A) and vulnerability index Kg value have a trend to the high value in damage belt area. 3: As the measurement points come nearer to a sea side, Kg value become higher these points corresponded to liquefaction area. Therefore, it is suggested that the distribution of damage is caused by local site effect.

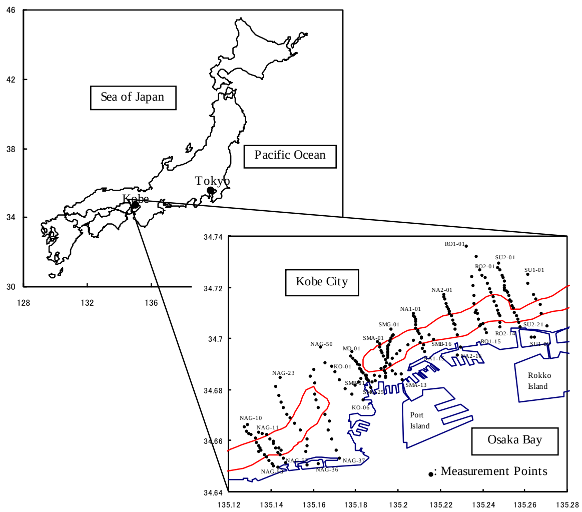

Fig.1 Measurement points in Kobe city

Measurement

The investigated area was in Kobe city and showed in Fig.1. The area is surrounded by Mt. Rokko in north side, Osaka bay in south side, and after the earthquake this site was

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damaged like a belt spread from east to west. Kobe city which had huge damage is a narrow area about 5km from northern mountain side to southern sea side, has grown on the typical irregular ground. This was the reason, that the damage occurred in a belt of 1-2km width to east-west direction which attracted many researchers to concern this phenomenon.

In this paper, our main purpose is to prove that the cause of damage belt was because of the influence of local site effect. A month after the earthquake microtremor measurement was made from February 1995 to February 1996 for this purpose. Measurement points showed in Fig.1. Each profile has 15-20 points, total 25 profiles spreaded north-south through mountain side, damage area, and sea side. The distance between each points was 100 to 300m, and each profiles length was 1-2km. Total measurement points were about 400. In this paper analyzed 15 profiles will be discussed, to be concentrate on a central part in Kobe city.

Analysis

An instrument named Portable Intelligent Collector (PIC) was used for microtremor measurements. A sensor is set on the asphalt or the soil, are measured at the 2 horizontal components (NS and EW direction) and a vertical component same time. Sampling interval is 1/100 sec and the length of each record is 40.96sec. Measurements was repeated three times at each observation points. After measurements, Fourier spectrum for each components are calculated. One frequency spectrum of one component was estimated by averaging the three Fourier spectra. Then, from a spectral ratio of horizontal to vertical components QTS spectrums (Quasi-Transfer Spectrum) are calculated, Nakamura(1989). Predominant frequency F and amplification factor A which represents dynamic characteristics of the ground are found from this analysis and Vulnerability index Kg are calculated as explained below. Details of the methodology can be found in Nakamura(1989, 1996).

Vulnerability Index Kg values for Ground

For the vulnerability index Kg of surface ground, shear strain γ is considered (Nakamura, 1996). According to the Ishihara (1982) ground soil becomes plastic state at about γ=1000 x10^{-6} and for γ>10000 x10^{-6} landslide or collapse of foundation occurs. Fig. 2. Shows the simplified shear deformations of the surface ground.

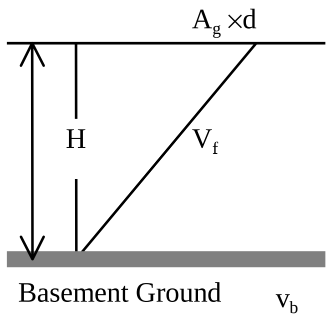

Figure 2. Shear deformation of surface ground.

Average shear strain γ can be estimated as γ=Ad/H, where **A** is amplification factor of surface layer, **H** is thickness of surface layer, and d is seismic displacement of basement layer. Details about formulation can be find in Nakamura(1996). Without going into a details, we are going to write shear strain as follows (Nakamura, 1996);

$$\gamma = \frac{A^2}{F} \cdot \frac{a}{\pi^2 \cdot v_b}$$

In this equation, A^2/F is called as Vulnerability index, **Kg value** for surface ground. **a** is the acceleration in the basement. $\mathbf{v_b}$ is the S wave velocity of the basement.

Results and Discussion

Relationship between the damage and Predominant frequency (F), Amplification factor (A), and Vulnerability index (Kg) value calculated from microtremor measurement is discussed.

Distribution of Predominant frequency F

Fig.3 shows distribution of predominant frequency (F) estimated from QTS in each measurement points. The value of F divided into 4 ranges (F<1.5Hz, 1.5<F<2.5Hz, 2.5<F<3.5Hz, 3.5<Hz) to easily catch the whole tendency. This area is Mt. Rokko in northern part, and sea in southern part. Distribution of F in the Fig.3 presents large F value on northern part overall, and small F value on southern part. However, the area of seismic intensity of 7 (on the Japanese scale) does not show the same phenomenon as F.

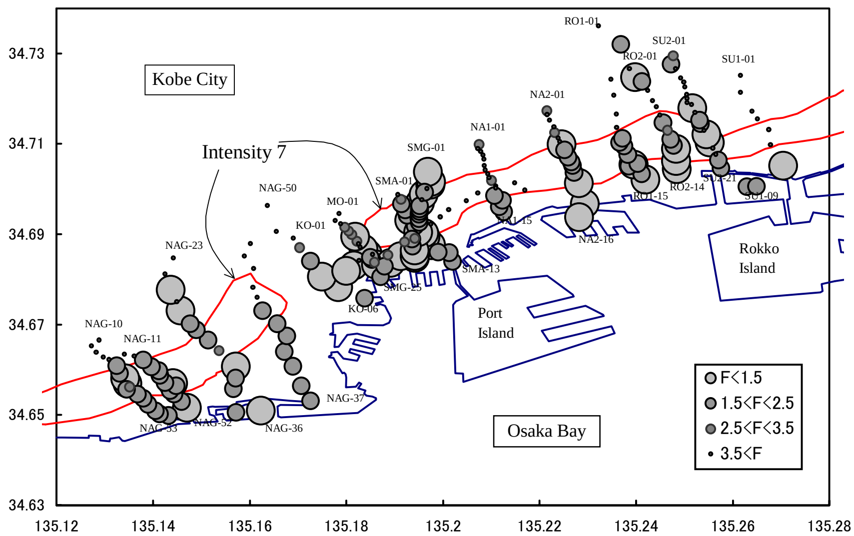

Fig.3 Distribution of Predominant Frequency F

More detailed graph of F in the damage belt is shown in Fig.4, F values are little less then 2Hz in general. This frequency is predominant frequency of strong motion records in 1995 Hyogo-Ken-Nanbu Earthquake recorded in this area, this was guessed to be a reason of resonance of strong motion in this area.

Distribution of Amplification factor A

Fig.5 shows distribution of amplification factor (A) in each points. This distribution again divided into 4 ranges as we did in F, intervals are A<2.0, 2.0<A<2.5, 2.5<A<3.0, 3.0<A. For whole area, while damaged area of seismic intensity of 7 have larger A value in measurement points, slightly damaged area have smaller A. Overall distribution has the characteristic that A has large value in the highly damaged area.

Fig.4, shows more detailed graphs of A. A does not show clear and characteristic trend as F. However, in lots of measurement points on high damage area, A increase and tends to show value of 3. On the other hand, distribution of A in MO and KO lines, in the slightly damaged area (the place was cut the damage belt.) A in almost all the points in this area show smaller value same as the points in mountain side .

Briefly, we can say that amplification factor (A) has large values in the area where heavy damage occurred. If we consider the behavior of F and A together we can say that these characteristics caused severe vibration of strong motion coming from basement.

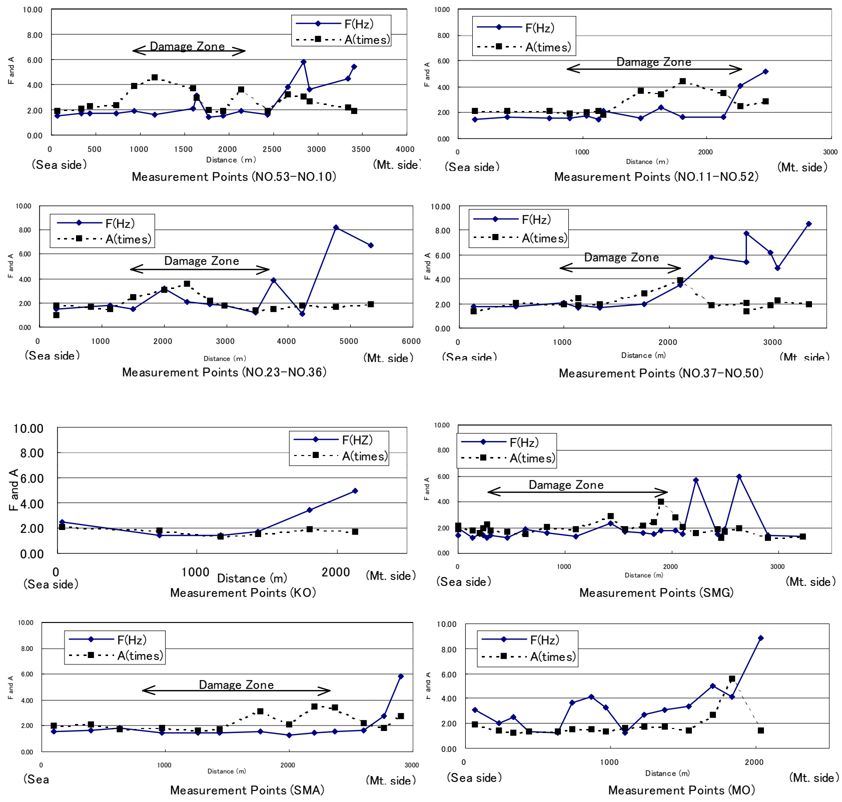

Fig.4 Distribution F and A in each profile

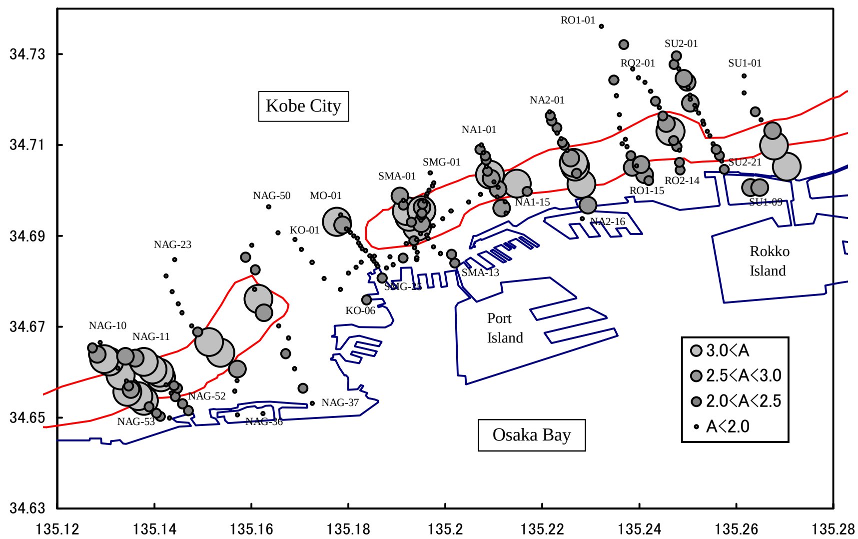

Fig.5 Distribution of Amplification Factor A

Distribution of Vulnerability index Kg value, comparison between Kg value and detail damage data

Fig.6 is a distribution of vulnerability index Kg value calculated from the relationship of F and A. This figure also given for 4 ranges like F and A. Kg has larger value in the damage area spreaded like a belt, and small value in the other areas. Kg value is related to damage distribution. In measurement points of large Kg value near coastline (NA2 and SU1 lines), although the area is out side of seismic intensity of 7, liquefaction was observed extensively.

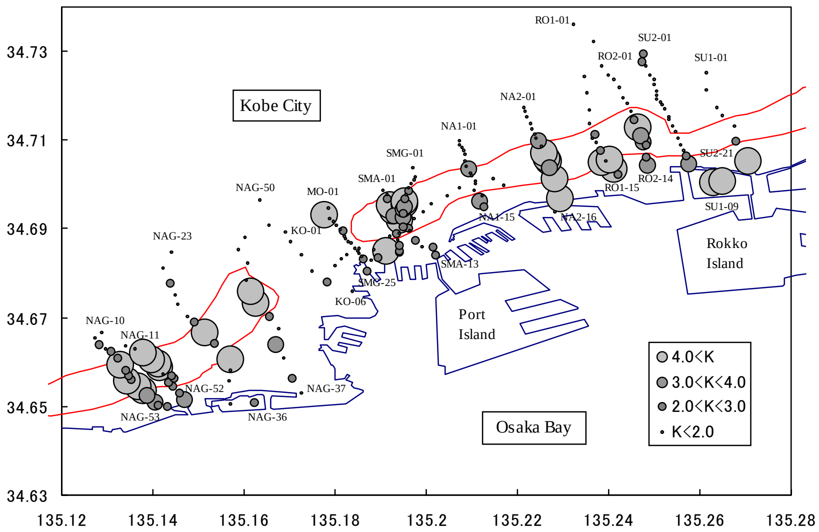

Fig.6 Distribution of Vulnerability index Kg

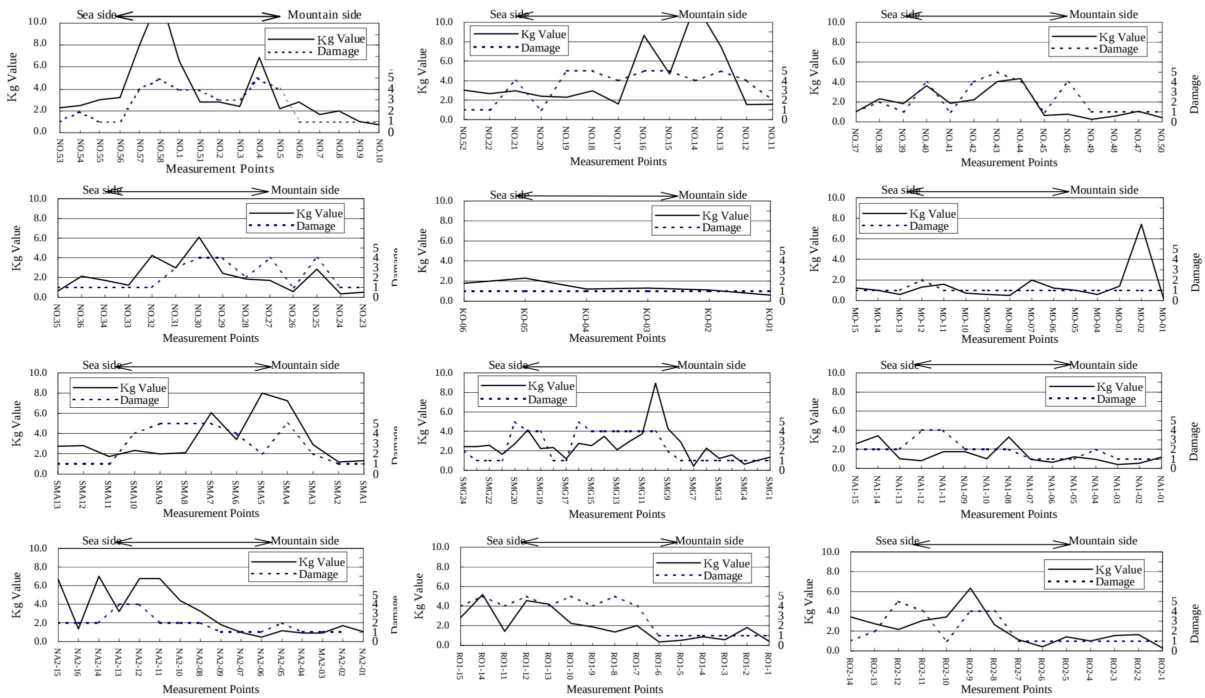

Fig.7 Comparison between Kg and damage ratio

Kg value reflects local site effect and corresponded with the damage belt and liquefaction as well. It is possible to conclude that the damage of 1995 Hyogo-Ken-Nanbu Earthquake was related to dynamic characteristics of the ground.

Fig.7 compares Kg value and damage ratio for small-scale structures. Damage ratio divided into 5 ranges; 1: no damage, 2: 0-12.5%, 3: 12.5-25%, 4: 25-50%, 5: 50-100%. In each figure, distribution form of Kg value and damage ratio has similar tendency. Especially, in NAG, SMA, SMG area, distribution form of Kg, very well corresponds with damage ratio of structure from mountain side to sea side. The damage area between mountain parts and sea parts shows larger Kg value and bigger damage ratio. On the other hand, distribution of Kg in in almost all the points on MO and KO lines (in lightly damaged area), show smaller value. With these results Kg value which is defined as vulnerability index for ground, found to be related also with damage ratio of structures.

To compare Kg value and damage ratio overall, in Kobe city, it has been found that some damage occurred for Kg>2. For acceleration value of 200-300gal and S-wave velocity of 300m/s in the basement of this city, ground strain estimated as $\gamma = 1 \sim 2 \times 10^{-3}$ when earthquake occurred in the area. This value corresponds to arise ground damage.

In Fig.7, Kg value does not agree with damage ratio in some parts. Points with large Kg value in spite of small damage ratio are almost located in liquefaction area. To find out the reason for this, building characteristics in this area will be checked in detail in further part of the study.

Conclusion

To explain dynamic characteristics of the ground in the damage of 1995-Hyogo-Ken-Nanbu Earthquake, microtremor measurement was made in Kobe city. Amplification factor A and vulnerability index Kg value are showed larger value in damage belt. Vulnerability index Kg value in spite of for the ground agreed with damage ratio for structure very well. Therefore, it can be conclude that damaged belt occurred after the earthquake had a unique character of local site effect in the area.

Acknowledgment

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References

Nakamura, Y,. A Method for Dynamic Characteristics Estimation of Subsurface using Microtremor on the Ground Surface, Quarterly Report of RTRI, Railway Technical Research(RTRI), 1989, Vol.30, No.1.

Nakamura, Y,. Seismic Vulnerability Indices For Ground and Structures Using Microtremor, World Congress on Railway Research in Florence, Italy, November, 1997.

Building Research Institute Ministry of Construction, The report of damage on the 1995 Hyogo-Ken-Nanbu Earthquake, 1996