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A DISCUSSION ON THE RELATIONS OF SITE EFFECT AND DAMAGE OF WOODEN HOUSES USING WITH MICROTREMORS IN FUKUI PLAIN AFFECTED BY THE 1948 FUKUI EARTHQUAKE.

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SUMMARY

Authors observed microtremors in Fukui Plain to discuss on the relationships between dynamic characteristics of surface geology and the damages of wooden houses caused by the 1948 Fukui Earthquake. By the distribution maps of predominant periods using H/V spectral ratio and damaged ratios of wooden houses, the distribution of the short periods corresponded to the low damaged ratios. And the areas of predominant long periods distributed on alluvial deposit in the western part from the earthquake fault. The high damage ratios at the sites of alluvial deposit are located within 8km from the earthquake fault, but the ratios decreased and varied widely in the areas farther than 8km. The predominant periods are related with the thickness of alluvial deposit. We can conclude that the earthquake damages were related with the dynamic characteristics of surface geology in this area.

INTRODUCTION

The 1948 Fukui Earthquake occurred at July 28, 1948 and it affected the buildings, railway, road, bridges and another social facilities. 3,763 persons had been killed, 36,134 houses completely and 11,816 houses partially destroyed, and 3,851 houses burned down by The Earthquake.[1)]

The epicenter located at Maruoka town where is in the Fukui Plain, and the seismic fault went through from south to north in the plain. So in the Fukui Plain, there are wide areas where damaged by very high percent ratios of complete collapse of wooden houses, between eighty to one hundred percents.

After the Earthquake, Japan Metrological Agency added one more higher grade from 6 to 7 in the JMA scale of seismic intensities. By the reconnaissance reports from some institutions show high percent damaged areas were in the Fukui Plain where was composed with alluvial deposits. On the other hand, damages in sand dune zones in the plain and coast zone of Japan Sea were not severe. □@

Several research reconnaissance teams from US and Japanese[2), 3)] surveyed on the earthquake damages with related wooden houses. The reports by these teams are very useful to study and discuss on the relationships with wooden house damages and another physical factors. From after the 1948 earthquake to today, many researchers and institutions studied and discussed on the relationships with damages and surface geology, topography and distances from earthquake fault.

Authors had conducted on a project of microtremor observations in whole Fukui Plane to discuss on the relationships with wooden houses damages and dynamic characteristics of surface geologies[11)].

MICROTREMOR OBSERVATION

OBSERVATION SITES OF THIS PROJECT

Authors observed microtremors with two type's method;
One of them was continuous type observation during few days, three minutes observation at every hour on the hour at four sites in Fukui City. These observations were used to check on the stabilities of microtremor in this area.[9)]

And another was the moving observation type. By this observation, authors had estimated predominant periods in each observation sites and compared with the periods and damage ratios of wooden houses. The area of microtremor observation of moving type was covered in whole Fukui Plain including Fukui City where was suffered by the fire after the earthquake. Total numbers of observation site were 431 sites in local communities where were reported by some institutions on the damages of wooden houses caused by the 1948 Fukui Earthquake, and especially damage ratios of wooden houses with percentages to whole houses in each community.

All observed sites are shown in Fig.1.

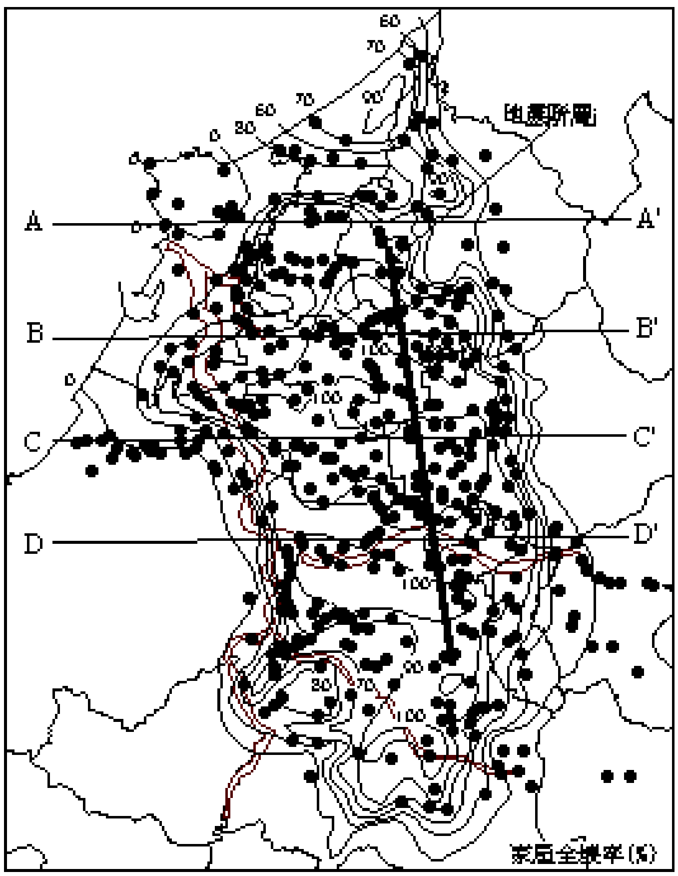


Fig.1 Observed sites of moving type observation of this project.
(Bold line: fault line, black circle: observed site, contour lines: damage ratios of wooden houses by the 1948 Earthquake with numbers of percentage[3)] horizontal lines: line for geological sections as will be seen later)

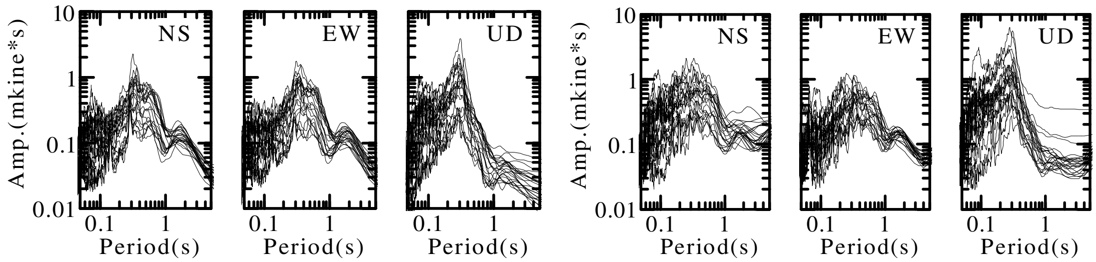
STABILITY OF MICROTREMOR CHECKED BY CONTINUOUS OBSERVATIONS

Above wrote, continuously type micro tremor observation during few days at 4 station sites as followings:

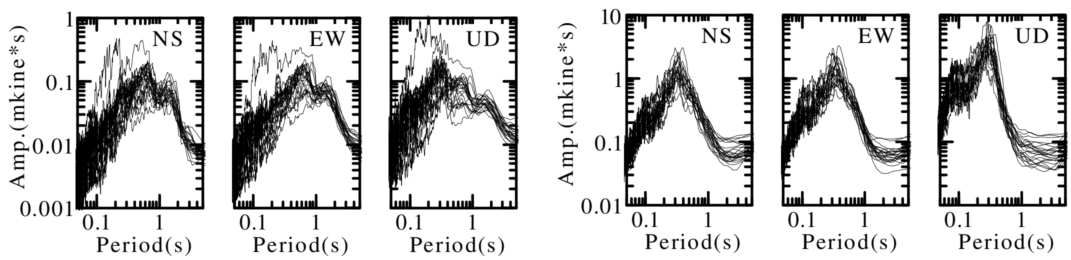
(a) Fukui Daigaku Jisin Kansokusyo-Observatory of Earthquake of Fukui University- (FUEQ)

Observed periods: May 29:12:00-May 31:17:00,2000, at every hour on the hour, five minutes duration.

(b) Fukui Daigaku Sekisetu Kenkyusitsu-Laboratory on Snow of Fukui University- (FUSL)
Observed periods: May 29:11:00-May 30:13:00,2000, at every hour on the hour, five minutes duration.

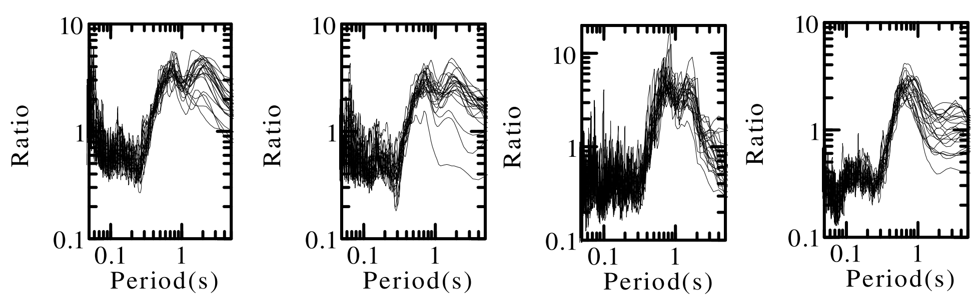


(a) Fukui Univ Eq. Observatory (FUEQ) □@□@□@□@ (b) Fukui Univ. Snow Lab.(FUSL)



(c) Jinai Women's High School(JWHS) (d)Fukui Prefecture Civil Engineering Office(FPDJ)

Fig.2 Fourier Spectra of Continuously Observed Microtremor at 4 sites



(a)FUEQ (b)FUSL (c)JWHS (d)FPDJ

Fig.3 H/V Spectral Ratios of Continuously Observed Microtremors at 4 sites

(c) Jin-ai Joshi Koukou- Jin-ai Wemen's High School- (JWHS)
Observed periods: August 9:9:00-August 12:17:00,1997, at every hour on the hour, three minutes duration.
(d)Fukui Doboku Jimusyo-Fukui Prefecture Civil Engineering Research Center- (FPDJ)
Observed periods: May 30:15:00-May 31:16:00,2000, at every hour on the hour, five minutes duration.

All observations were down with one second natural period seismometer and sampling frequency were 100 Hz.

Fig.2 shows Fourier spectra of all observed data at each four sites. These figures show that microtremors of these sites are unstable and time dependent without site FPDJ. So we can say that microtremors affected by artificial noises as noises of traffics, because amplitudes in daytime are higher than in nighttime and peak periods are not clear. Only one site microtremors at FPDJ are very stable and the peak periods are very clear that shows about 0.3 seconds in all components. It is considered that the predominant periods of traffics shows generally about 0.3 second. So the site of FPDJ is in the noisy area by traffics at all time, from daytime to nighttime.

But Fig.3 shows H/V spectral ratios[8)] made by these Fourier spectra at all these four sites are very stable and predominant periods are shown clearly.

So we can say that the observed microtremors are useful by using with H/V spectral method to estimate on the characteristics of surface geology in this area, Fukui Plain.

Predominant Periods Distribution Using with Microtremors By Moving Observation

Observed Area and Sites

Above wrote, and shown in Fig.1, microtremors were observed at 431 sites of each local community, 35 sites of schools in Fukui City and 35 sites where are at the sites where had down bore hall penetration surveys and P-S survey. So total number of observation sites are 501 by this type. These observations had conducted between 3 years as followings.

(a) Observation in 1997 and 1998 years.
Observed periods: Duration August 4-12/1997, and September 16-18/1998
Observed Area was covered north part of Fukui Plain including Fukui City.

(b) Observation in 2000 year
Observed periods: Duration May 28-31/2000
Observed sites were 26 sites at bore hall surveys, and 9 sites on the P-S Survey line in Maruyana Town in the Fukui Plain.
All observations were down with a seismometer of one second natural period and sampling frequency were 100 Hz. Observation time periods were three or five minutes in each observation.

Data Processing

Several data sets with 2048 data (20.48 sec) were selected from low noisy parts in 18,000 data (3 minutes) observed at each sites. Fourier spectra of three components had been calculated with these data sets using FFT method.
Smoothing operation had down for those spectra with 0.3 Hz wide band of Parzen Window. And after the smoothing, those spectra had averaged to get a spectral ratio for each component.

H/V Spectral Ratio

In this paper, authors used H/V spectral ratio after Nakamura's technique to estimate the dynamic characteristics of surface geology. Horizontal component was composed by geometric mean with N-S spectral and E-W spectral. Finally H/V spectral ratio had gotten a quotient with horizontal spectral and vertical spectral. □@

COMPARISON BETWEEN PREDOMINANT PERIODS WITH DEPTH OF GEOLOGICAL SURFACE DEPOSITS

Four transverse geological sections of the Fukui Plain[10)] are shown in Fig.4, and those section lines are put on the map of Fig.1. We can see from Fig.4 that the underground structure of the plain

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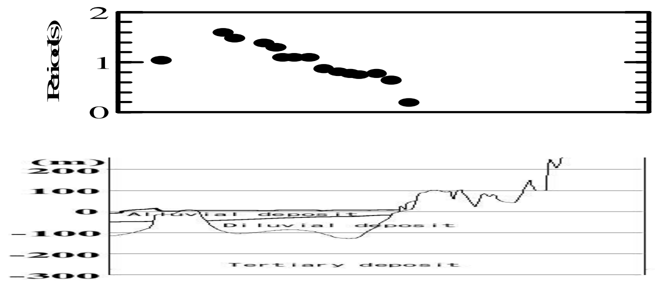
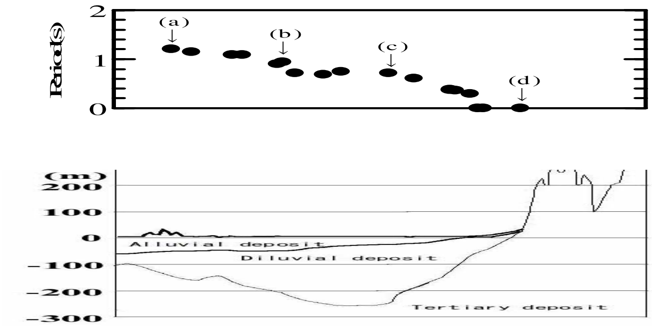
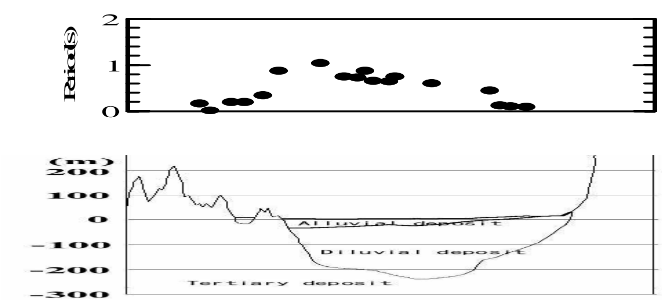


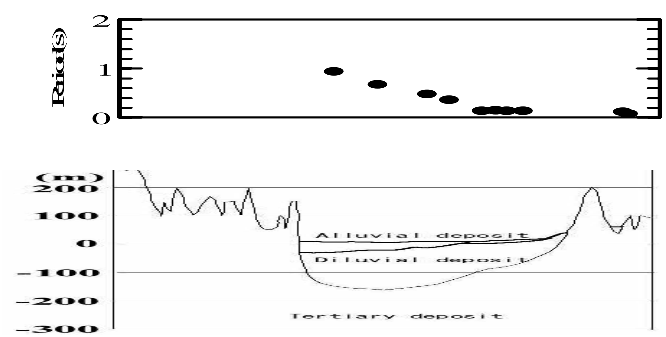
(a)A-A′ line



(b)B-B′ line



(c)C-C′ line



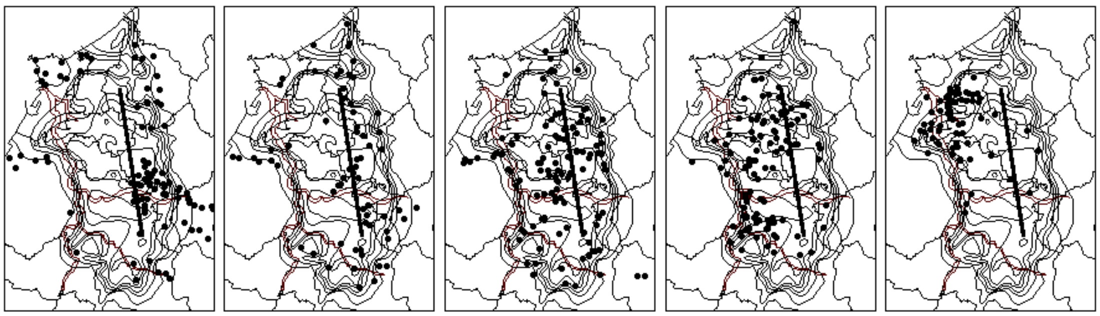
(d)D-D′ line

Fig.4 Fluctuation of the predominant periods depended on the geological section

composed irregular form with three layers deposits, tertiary, diluvium and alluvial layer from the bottom to the top. And mountain's areas locate on the both sides of east and west of the plain. Alluvial deposits on the top of the layers are inclined from east to west in all section lines.

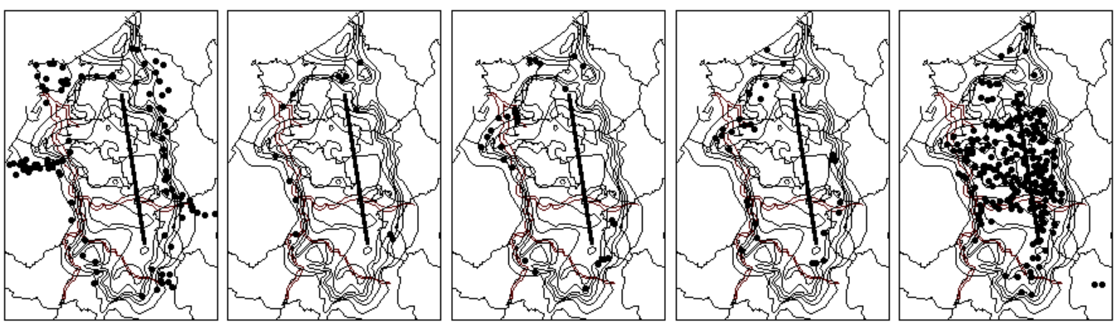
We can say that predominant periods of the ground in short period range are affected by shallow surface geology as alluvial deposits in the plane.

In the Fig.4 estimated predominant periods by microtremors using with H/V spectral ratio technique are shown on the tops of the figures from (a) to (d). The periods are corresponding with the depths of the alluvial layers in each geological section. So the predominant periods are becoming longer from east side areas to west side areas in proportional to the depth of alluvial deposits.
By this tendency, we can say that the distribution map of predominant periods will be corresponding to surface geology conditions.



(a) T: -0.2(s) (b) T: 0.2-0.4(s) (c) T: 0.4-0.6(s) □@ (d) T:0.6-0.8 (e) T:0.8(s)-

Fig.5 Distribution of the predominant periods estimated by H/V spectral ratio of observed microtremors.



(a) R: -20% (b) R: 20-40% (c) R: 40-60% (d) R: 60-80% (e) R: 80%-

Fig.6 Distribution of the damage-ratios of wooden houses in each community after references.

DISTRIBUTION OF THE PREDOMINANT PERIODS IN THE PLAIN ESTIMATED BY MICROTREMORS

Predominant periods had been estimated by using observed microtremors at each community of 431 sites and at the sites of 35 schools in Fukui City. Five maps in Fig. 5 show predominant distribution in each classe with black circle divided with 0.2 second.
Fig. 5(a) shows the sites of short periods shorter than 0.2 second, and we can see the sites are distributed outside area of the plain and eastern part of the fault.

Fig. 5(b) for 0.2-0.4 sec shows that still yet the sites are very few in the plain. But as the period are becoming longer gradually, the sites put on the inner area of the plain gradually, Fig.5(c), Fig. 5(d) and Fig. 5(e). This distribution of predominant periods is correspond with geological section in Fig. 4(a)-(d). For example, the area in directed to north-west part of the plain show long predominant periods in more longer than 0.8 second in Fig.5 (e), these tendency depend by deep alluvial deposits in Fig.4 (b).

DISTRIBUTION OF THE DAMAGE-RATIOS OF WOODEN HOUSES IN EACH COMMUNITY

Five figures in Fig.6 show the distribution maps of the communities damaged by the 1948 Fukui Earthquake with wooden housings damage levels of percentages in each community that are divided by each 20 percent.

We can see the following tendency by these five figures:
1. The communities where are light affected by the earthquake less than 20%, located in the surrounding mountain sites (see Fig.6 (a)).

2. The communities where were affected by the earthquake between 20-40%, 40-60% and 60-80%, are located at the boundary sites of the plain, and the numbers of these level damaged communities are not so many in comparison with light and heavy affected sites outsides from these damage percentage levels(see Fig.6(b), (c) and (d)).

3. The communities where were very severe affected, larger than 80% damage ratio, by the earthquake, located in the inner sites of the plain, and those communities are in large numbers. We can say that this tendency is a distinctive character of damages by the earthquake.

Discussion on the relationships with the earthquake damages and the distances from the earthquake fault

The relation ships with predominant periods distribution and damage ratios distribution.
We can see from Fig.6 that the communities of damage ratios between 20% and less than 80% were very few with comparison of the communities less than 20% and over than 80%. We can say other word that the damages of houses were almost only two zones, slight damages and heavy damage zone.
Heavy damaged zones were inner area of the plain including near fault zone and slight damage zone located in the surrounding of the plain.

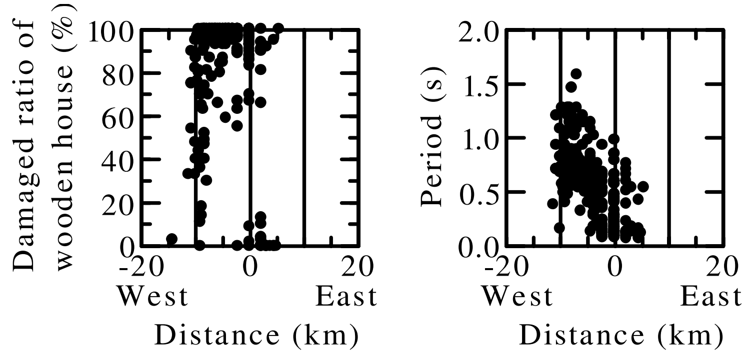
On the other hand, the distribution of predominant periods shows that shorter period zones less than 0.2sec locate in the area of surrounding of the plain and in a part of southeast zone of the earthquake fault in the plain. The sites of longer periods are spreading to west sites from the fault line with distance and in the same way proportionally with depth of the alluvial deposits.

By the comparison with Fig.5 and Fig.6, we can say that heavy damaged zone are corresponded with the area of longer predominant periods and very near fault zone nevertheless shorter periods.

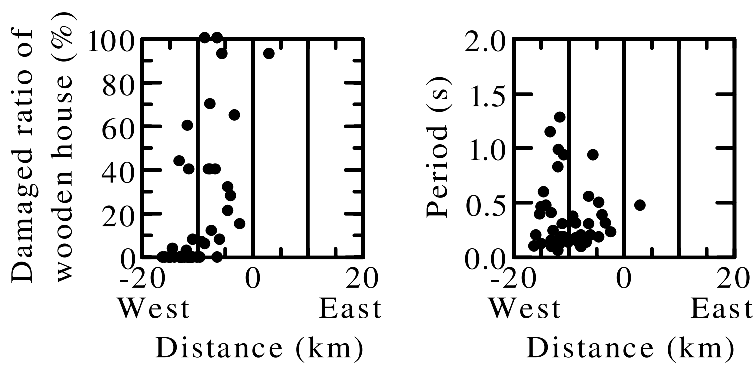
In the Alluvial Deposit Areas and the sand dune area
Authors discussed on the relationships with the damages and the distances from the earthquake fault line in the alluvial deposit area, and also in the sand dune area for the zone of the west side of the plain.

Fig. 7(a) shows the relations with the damage ratios and the distances from the fault line, and also predominant periods of the grounds and the distances in the alluvial deposit area. By this figure, we can see that predominant periods are being longer proportionally depend the distance from the fault line, nevertheless the dispersion of the periods are large. This tendency shows that the periods depend on the depth of the alluvial deposits, because the depths are being deeper to west from the fault line (Fig.4). Another figure of the Fig.7 (a) shows very interesting tendency that the damage ratios in the inner site about 8 km from the fault are more than 60 % without some areas very close the fault, in other way the ratios in the area from 8 km over are very dispersion. This dispersion was suggested us that in the far distance area from the fault, the damages were affected by the site effect more strongly than fault effect in the alluvial deposits area.

Fig 7(b) shows the relations with the damage ratios and the distances from the fault line, and also predominant periods of the grounds and the distances in the sand dune area. By this figure, we can see that predominant periods are short less than 0.5 sec without some unusual cases in whole area and are not depend the distance from the fault line. Another figure of the Fig.7 (b) shows that the damage of ratios were not so high, however they were dispersion from zero to 100 %.



(a) In alluvial deposit area



(b) In sand dune area

Fig.7 Correlation the predominant period and the damage ratio of wooden houses with the distance from the earthquake fault

CONCLUSION

Microtremors affected by artificial noises as like traffics. But H/V spectral ratios of microtremors are very stable and predominant periods are shown clearly.

The sites of short predominant periods shorter than 0.2 sec are distributed outside and surrounding areas of the plain and the eastern part of the fault. The sites of 0.2-0.4 sec are very few in the plain. But as the period are becoming longer gradually, the sites put on the inner area of the plain gradually. This distribution of predominant periods is corresponded with geological section. The areas in directed to the northwest part of the plain show long predominant periods in longer than 0.8 second. This tendency depends on deep alluvial deposits.

The communities where were light affected by the 1948 Fukui Earthquake less than 20%, located in mountain area of the surrounding of the plain. The communities where were affected by the earthquake between 20-40%, 40-60% and 60-80%, are located at the boundary sites of the plain, and the numbers of communities damaged in these level are not so many in comparison with light and heavy affected sites outsides from these damage percentage levels. The communities where are very severe affected, larger than 80% damage ratio, by the earthquake, located in the inner sites of the plane, and those communities were in large numbers.

In alluvial zone, predominant periods are being longer proportionally depend the distance from the fault line, nevertheless the dispersion of the periods are large. This tendency shows that the periods depend on the depth of the alluvial deposits, because the depths are being deeper to west from the fault line. The damage ratios in the inner sites of about 8 km from the fault were more than 60 %

without some areas very close the fault, in other way the ratios in the area from 8 km over are very dispersion. This dispersion is suggested us that in the far distance area from the fault, the damages were affected by the site effect more stronger than fault effect in the alluvial deposits area.

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