THE ATTENUATION CHARACTERISTICS OF NEAR FIELD GROUND MOTION

DUE TO STRIKE SLIP FAULT MOTION

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SUMMARY

Near field ground motions were estimated based on the damage distribution of wooden houses in the epicentral area of Kita-Tango Earthquake (March 7, 1927) and Fukui Earthquake (June 28, 1948) as typical examples due to strike-slip fault movement. The damage ratios were considered as related with relative displacement response spectral values. The base rock motions were estimated to yield the relevant response values which corresponds to the damage ratios at the sites. The effect of the subsurface layers are estimated through response analysis of the ground assuming strain dependent characteristics of soils and the input base rock motion as from a source spectrum of constant particle velocity. The results show that the spectral intensity of particle velocity is in the range of 30-50kines at the very near the fault and rather constant within some distance and the equi-intensity lines are found to form ellipses around the fault lines.

INTRODUCTION

Ground motions during earthquakes have been discussed by several researchers based upon recorded strong motions (Seed(1968), Housner(1969), Esteva and Villaverde(1973) and Brune(1976)). Most of these data were obtained at rather long distance from the epicenters. A few accelerograms have been recorded in epicentral area so far, but it is still considered far from to give complete image of the near field motions. Several earthquakes occurred in Japan have resulted severe structural damage in the epicentral area and the detailed records of the damage and its distribution in the area have been studied and available at present. The authors describe some efforts to understand the near field motion based upon these data with recently clarified dynamic characteristics of subsurface soil layers and presently available analytical method applied in the area to evaluate the effects of the ground condition to the structural failure.

EARTHQUAKES, DAMAGES AND GROUND CONDITIONS

Kita-Tango Earthquake: Kita-Tango Earthquake (M=7.5) occurred at the northern part of Kyoto prefecture on March 7, 1927 (Fig.1). Two faults system were found to have associated with the earthquake. The major fault is left lateral strike slip identified as 18km in length on land and found to extend northwards by 17km into Japan Sea. Horizontal movement of the fault was found as 270cm at the maximum. Earthquake damages were reported as 12,500 wooden houses in complete collapse, 3,700 houses in burnd down and 2,900 persons in death.

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The areal distribution of the damage ratio of wooden houses in complete collapse by Taniguchi(1927) is shown in Fig.2. The heavy damages are found near the fault line. The main base rock in the area is granite covered with quarternary sand and clay layers as subsurface ground except the northern part where the tertiary sand and mud stone formations exist as base rock. Thickness of subsurface ground is 5-40m composed from alluvial clay and sand formation.

Seismic refraction survey was carried out at several sites by a simple shear wave generator. Comparing the results of seismic survey and subsurface boring logs, the shear wave velocity for each layer were estimated as follows;

alluvium clay layer	130 - 150 m/sec.
alluvium sand layer	140 - 250
diluvium clay layer	200 - 250
diluvium sand & gravel	390 - 400
base rock (weathered)	700 - 950

Fukui Earthquake: Fukui Earthquake occurred on June 28, 1948 resulting heavy damages of 3,895 persons in death, 35,420 houses in collapse and 3,691 houses in loss from fire. The magnitude was reported as Mag.=7.3 and the fault was recognized based upon the geodesic survey which shows typical strike slip fault of left lateral type. The fault is N-S direction with 25km of length and about 2m of fault displacement at the very near the fault. Damage of the houses are found near the fault and especially in the alluvial ground area of 40x12 km^2 as shown in Fig.3 with the damage ratios quoted by Usami(1975). Base rock of the Fukui area is found as sand and shale stone of tertiary age. Fukui ground has been formed as alluvial delta plain along the river Kuzuryu and shows typical basin structure of the local geology. Alluvial layer of soft clays(SPT N value=0-3) and loose to medium dense sand (N less than 30) layers cover the most part of the Fukui plain with thickness of about 5-60m. Below the alluvium deposits, diluvium layers of stiff clay and dense sand and gravel continue to the depth of 90-150m where the tertiary formation is found as base rock.

Shear wave velocities of these layers were obtained by in-situ logging technique and the results are as follows;

alluvium clay layer	130 - 140 m/sec.
alluvium sand layer	170
diluvium clay	200 - 300
diluvium sand & gravel	400 - 500
diluvium - tertiary	800 - 1,000

CHARACTERISTICS OF ASSUMED BASE ROCK MOTION FOR SUBSURFACE RESPONSE

Recent theoretical seismology have made enable the estimation of the time history of the ground motion based upon dislocation of the fault model. However, the present applicability of this approach seems to be effective within the limited frequency range. The ground motion due to body or surface waves with period of longer than a few seconds have been shown good correspondence between the observed and the computed displacement time histories. Seismic motions with period less than 1sec., which are supposed to play main role in earthquake engineering, are considered as difficult to be estimated by a simple fault movement.

The authors assumed a possible characteristics of the motion based on physical aspect of material failure in dynamics and used it to estimate the ground motion near the fault as a guide line.

The particle velocity associated with shear movement in rock may be related with its shear strain as follows;

$$v = \gamma \times c$$

where; v : particle velocity

γ : shear strain

c : shear wave velocity in rock

Shear wave velocity is constant in a specified rock and the shear strain amplitude is generally limited by its maximum value at failure and may be considered as constant. The particle velocity due to shear wave motion may be limited by its maximum shear strain at failure. It would be appropriate that the spectral value of particle velocity near the fault is constant against period range less than say about the rise time of the fault movement. The characteristics of the base rock motion as an input to compute subsurface response was obtained by the following procedure of modifying the time history of a strong motion record at San Fernand Earthquake. The acceleration record of the Lake-Hughes #4 NS-component by the San Fernand Earthquake, Feb.9, 1971 is thought to be appropriate because of the record at the epicentral distance of 29km as keeping near field characteristics and on the rock formation. The time history(Fig.6) of the particle velocity was computed from the acceleration record by integration. Then the amplitude change with time for a specified frequency range is computed by filtering technique. Thus obtained maximum amplitude for each frequency range may be called as spectral intensity of the particle velosity and these amplitudes is modified in such a way that the intensity for each frequency component to be the same magnitude as shown in Fig.7. The modified time histories are then synthesized to compose a time history of the base rock particle velocity.

SIMULATION OF THE SUBSURFACE GROUND MOTION

Three base rock motions with dfferent amplitude levels were assumed for a site and used to compute ground surface motion and its response spectra. The ground conditions were modelled into horizontally layered ground with strain dependent characteristics of soils. Thus at a site of given ground condition and damage ratio, three response spectra were obtained corresponding to different level of base rock motion.

The relative displacement to cause failure of Japanese wooden houses have been estimated by experimental study and considered as follows;

relative displacement response	structural damage
7 - 10 cm	initial failure
20 cm	complete collapse

The natural period of the wooden houses were found about 0.2-0.4 sec. for small amplitude vibration. However, experimental results show that the increase of the period to 0.5 to 1.0 sec. under large amplitude condition resulting in failure. The damping ratio of the wooden houses at near failure is considered in the range of 10-20%. The reported damage ratio is assumed to be related with the relative displacement response value of the surface ground motion at the site as follows;

damage ratio	relative displacement response
0%	less than 5 cm
50%	12.5 cm
100%	greater than 20 cm

The changes of damage ratio away from the fault with ground conditions for several typical sections for Fukui Earthquake are shown in Fig.5.

The magnitude of the base rock motion is determined through interpolation so as to induce the computed relative displacement spectral value for period of 0.5-1.0 sec. to be the level compatible to the recorded damage ratio at the site.

ESTIMATED CHARACTERISTICS OF BASE ROCK MOTIONS NEAR FAULT

The results of the estimated base rock motion at various sites by Kita-Tango and Fukui Earthquakes are shown in Figs.8-9. Numbers shown in the Figs. are particle velocity in the base rock to correspond to induce response values with structural damping h=15%. The distribution pattern of intensity is symmetrical against the fault lines and forms ellipses around the fault. Fig. 10 shows the change of the spectral intensity of the particle velocity with distance from the faults with h=10-20%. The spectral value at the very near to the faults is found as 20-30kines for Kita-Tango and 40-60kines for Fukui Earthquake. The intensity keeps its maximum value within 3-5km from the faults and decreases its value inversely proportional with the distance. This corner distance may be considered to be related with fault dimention specially its width.

Study of fault parameters by the dislocation model(Kanamori(1973) shows rather similar in size but different in particle velocity by 2 times as shown in Table 1. It is interesting to note that the range of the estimated spectral intensities of the particle velocity from the damage ratios for each fault is the same order as those given by the dislocation model study of 25 and 50 kines. It should be noted however that in very near the fault area, where the damage ratio have reached 100%, the estimated ground motion at present study is considered as its minimum value.

CONCLUSION

Based on comparative study between the recorded damage ratio of the wooden house and the relative displacement response spectral values by different levels of base rock motions, spectral intensity of particle velocity of the base rock motion near the strike slip fault motion were estimated. The estimated level of the spectral intensity of the velocity at very near to the fault plane was 20-30 kines for Kita-Tango and 40-60 kines for Fukui Earthquake, which are the same order given by the dislocation model study of 25 and 50 kines respectively.
The intensity may hold its maximum value in the area of a few km from the faults. This corner distance was 3-5 km for Fukui and Kita-Tango Earthquakes of magnitude 7.3-7.5.In the area further than the corner distance the amplitude is found decaying inversely porotional with the distance.

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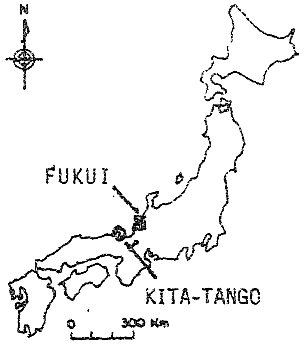

Fig.1 Earthquake Site.

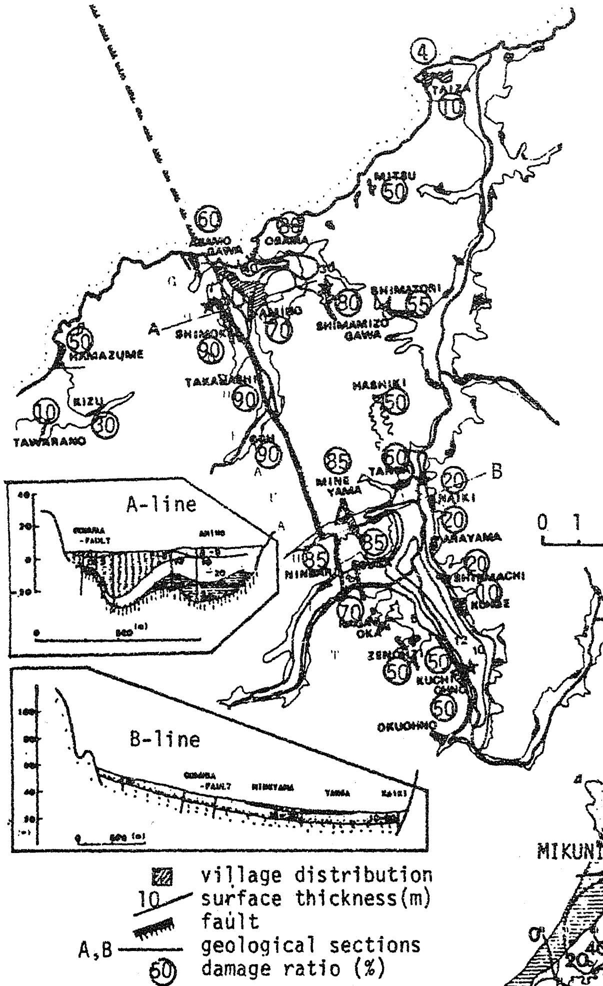

Fig.2 Damage Ratio and Geology in Kita-Tango Earthquake.

Table 1 Dislocation Model

	S	d	σ	$\overline{M}$	τ	v
Kita-Tango	35x13	3	100	4.6×10^{26}	6	25
Fukui	30x13	~2	83	3.3×10^{26}	2	50

S:dimension of the fault(kmxkm)
$\underline{d}$:dislocation(m) σ:stress drop(bar)
$\overline{M}$:seismic moment(dyne cm)
τ:rise time(sec) v:particle velocity(kine)
($v=d/2\tau$)

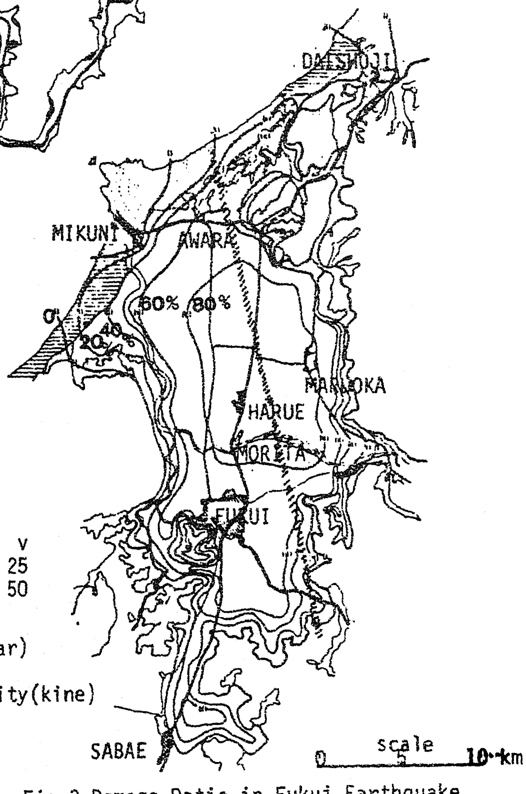

Fig.3 Damage Ratio in Fukui Earthquake.

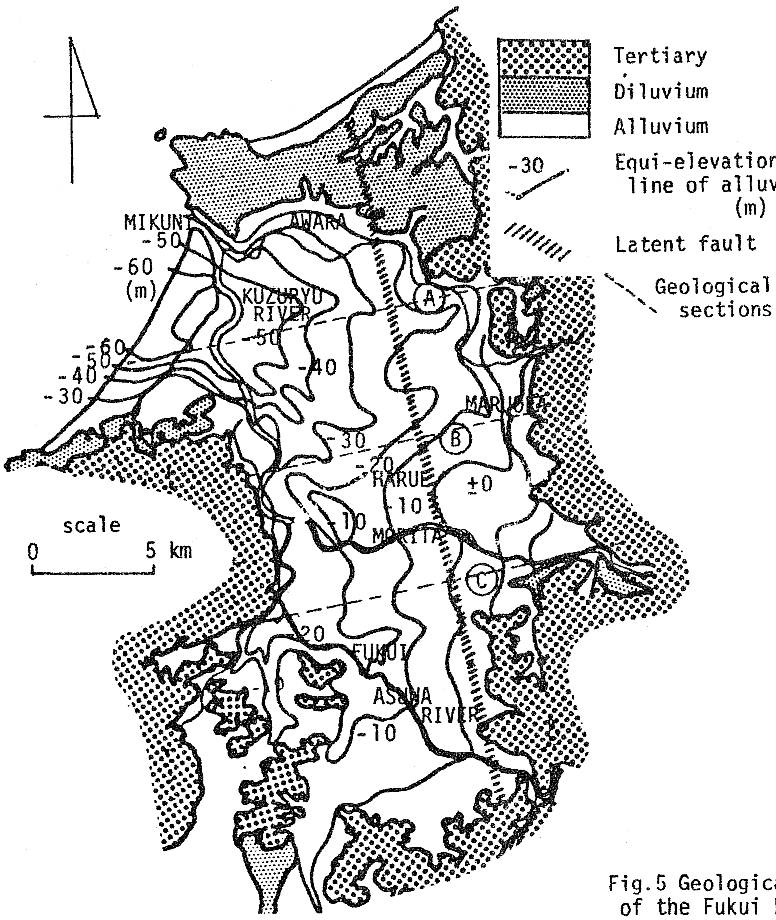

Fig.4 Geology of the Fukui Plain.

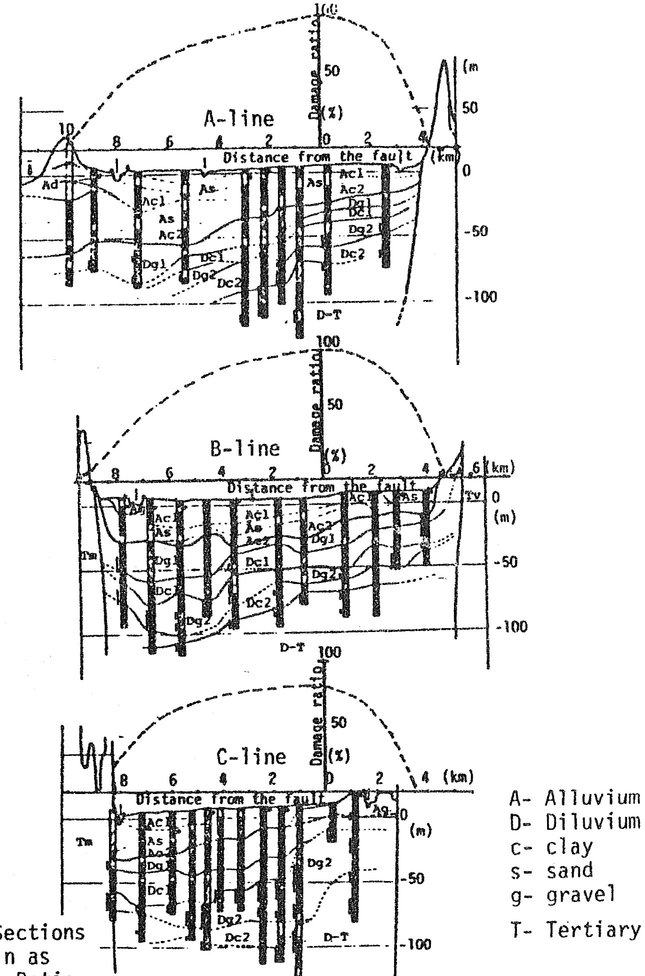

Fig.5 Geological Sections of the Fukui Plain as related to Damage Ratio.

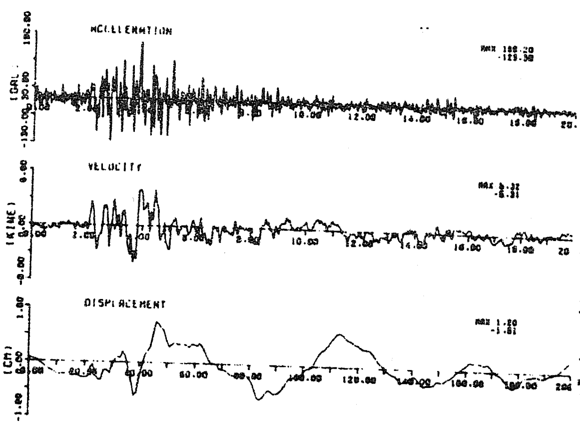

Fig.6 Acceleration Record at Lake Hughes #4 during San Fernand Earthquake.

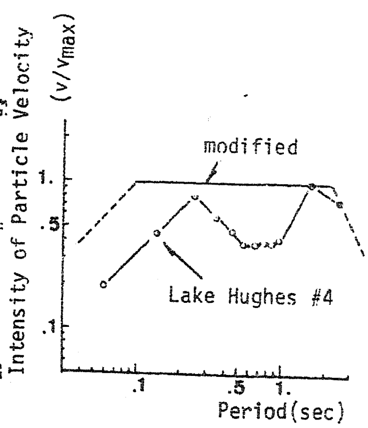

Fig.7 Intensity of Particle Velocity at Base Rock.

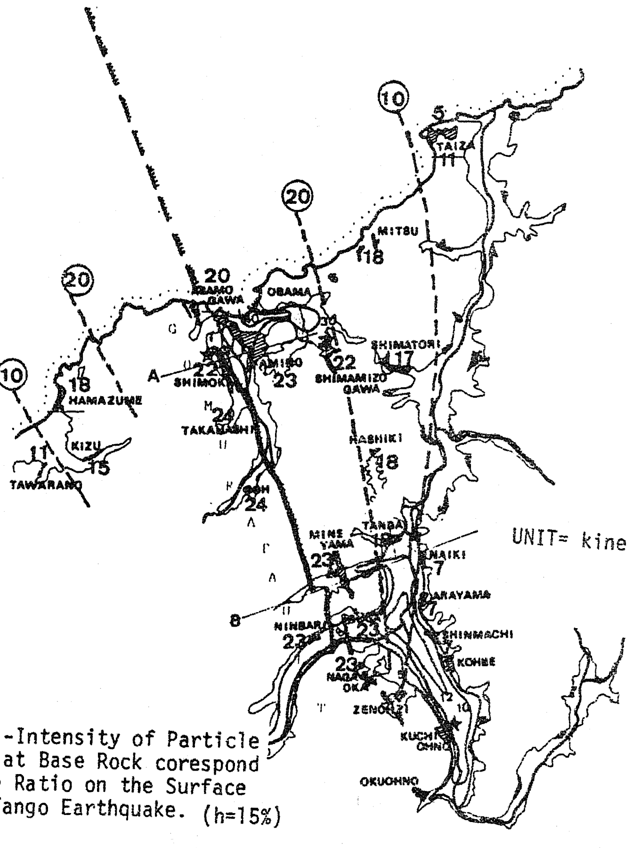

Fig.8 Equi-Intensity of Particle Velocity at Base Rock corespond to Damage Ratio on the Surface in Kita-Tango Earthquake. (h=15%)

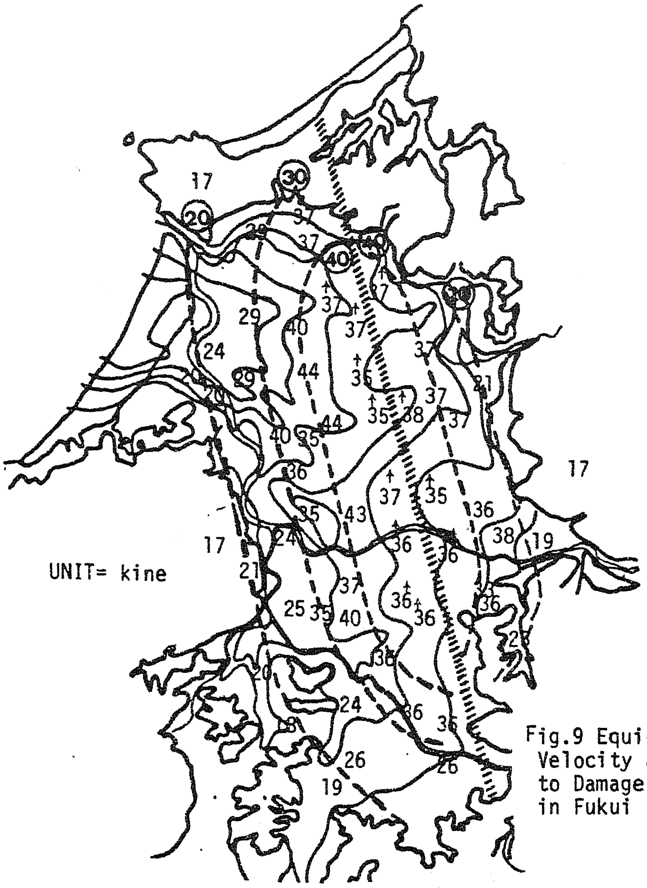

Fig.9 Equi-Intensity of Particle Velocity at Base Rock corespond to Damage Ratio on the Surface in Fukui Earthquake. (h=15%)

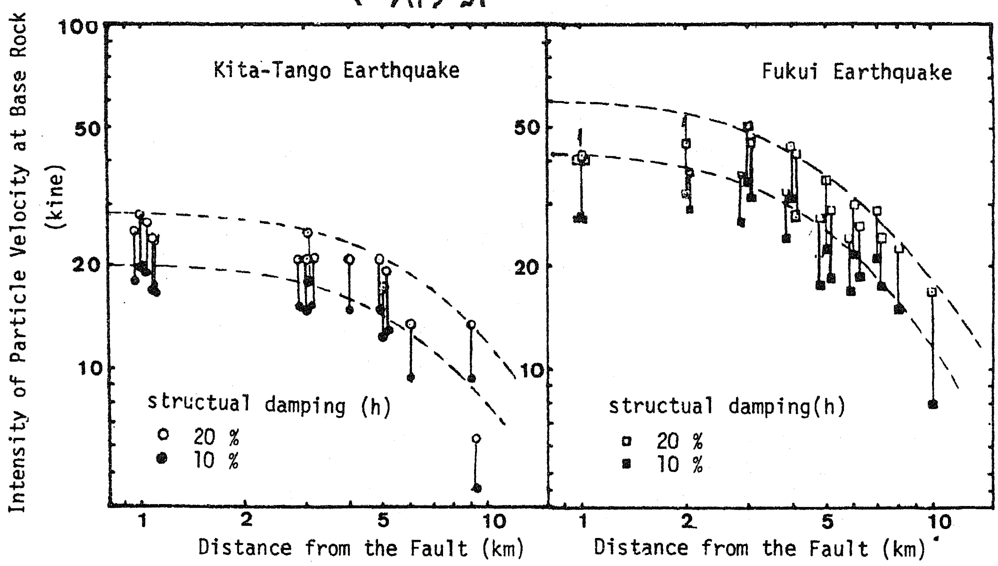

Fig.10 Attenuation Curve of Base Rock Motion in Kita-Tango and Fukui Earthquake.