AMPLIFICATION OF SEDIMENTARY LAYERS AND ESTIMATION OF THEIR STRUCTURES IN SHIGA PREFECTURE, JAPAN

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SUMMARY

At the 1995 Hyogo-ken Nanbu earthquake, precious data have been got at 13 sites in Shiga prefecture. Four sites of them are on rocks, nine sites are on sedimentary layers on bedrocks.

In these peak ground accelerations, there are several differences whose distances from the earthquake center are nearly equal. As one of this factors, amplification of earthquake waves in sedimentary layers is supposed.

So we have tried to estimate the underground structures in Hikone city (site KOJ) by seismic-array explorations of microtremors since 1997. This has made it clear that the estimation of S-wave velocity structure is possible to about 1000[m] depth, and S-wave velocity of the deepest layer is 3.2 [km/sec].

At site HTS, about 10 [km] south from site KOJ, observations of H/V microseisms and a 515m drilled hole has been performed. According to this, it has been clear that the depth of the bedrock is about 445 [m].

From the depths of the bedrock at sites KOJ, HTS and A2(EIG), the transition of depths of the bedrock has been clear.

INTRODUCTION

At the 1995 Hyogo-ken Nanbu earthquake, precious data have been got at 13 sites in Shiga prefecture (reference 1)). These sites are shown in Fig.1 and Table 1. Four sites of them are on rocks, and nine sites are on the sedimentary layers on bedrocks.

Peak ground accelerations at these sites, are plotted in Fig.2 at each distance from the earthquake center. According to this, it is noticed that there are some differences between a few sites whose distances from the earthquake center are nearly equal.

So we have tried to estimate the underground structures in Hikone city by seismic-array explorations of microtremors since 1997. In the following chapters, their details are written.

NATURAL PERIODS OF THE GROUND IN SHIGA PREFECTURE

Since 1981, the new aseismatic design standard have been applied to houses and buildings in Japan. To apply this standard, the informations of the sorts of the ground of each site are necessary. They are classified into 3 sorts, according to the ground natural periods *T*.

Reference 2) shows *T* in 1 [km] square meshes in Fig.1. From this the followings are known;

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T of 87 [%] of meshes are ≤ 0.4 [sec]. Especialy, almost meshes in the west district of the lake Biwa are in this sort.

T of 39 [%] of meshes are the stiff ground of the 1st sort ; $T \leq 0.2$ [sec].

T of 60 [%] of meshes are the medium ground of the 2nd sort ; $0.2 < T \leq 0.75$ [sec].

T of 1 [%] of meshes are the soft ground of the 3rd sort ; 0.75 [sec] < *T*. These meshes are found in the east district of the lake Biwa ; Kinomoto Town, Nagahama City, Hikone City, and the esturies of the rivers Echi, Hino, Yasu and Kusatu.

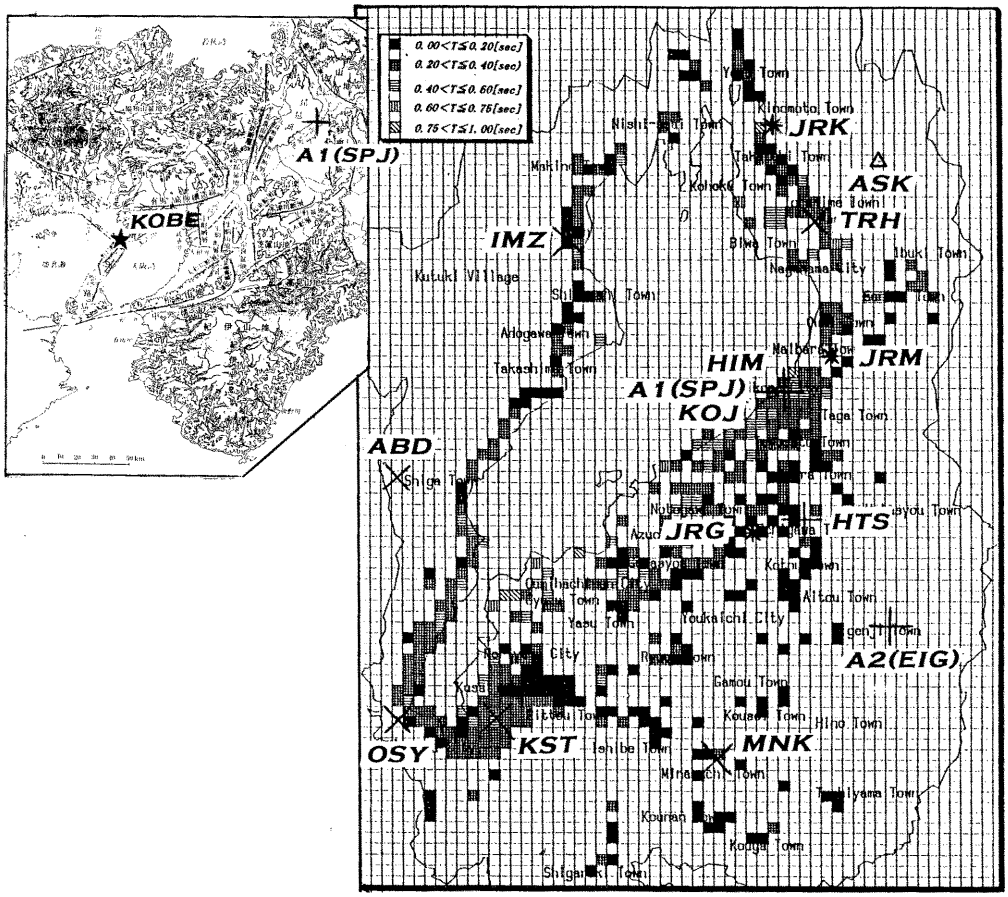

Fig.1 Distribution of ground natural periods and the sites, got data at the 1995 Hyogo-ken Nanbu earthquake in Shiga prefecture

RECORDED ACCELERATIONS AT THE 1995 HYOGO-KEN NANBU EARTHQUAKE

At the 1995 Hyogo-ken Nanbu earthquake, precious data have got at 13 sites in Shiga prefecture (reference 1)). Their sites except *A1, A2* are 6 sites, set by the fire and disaster prevention section of Shiga prefecture; 3 sites, set by JR (=Japanese Railway), and each 1 site set by Hikone meteorological station and Kyoto University Disaster Prvention Institute. The attenuation relation for peak accelerations of these sites are Fig.2, according to references 1), 5). The equation of real line is by Fukushima et. al..

At 4 sites (*=A2(EIG), ASK, ABD, OSY*) of these sites, seisemometers are set on rocks, and at other sites they are set on or in the ground, composed of sedimentary layers. In the effect, there are some differences in the peak accelerations at the sites of almost the same distances from the earthquake center.

Table 1 Sites got data at the 1995 Hyogo-ken Nanbu earthquake

Site Name	Site	Sort of the ground	North Latitude [degree]	East Longitude [degree]	Distance from E.Q center [km]	Max. Acceleration [cm/sec2]			Max. Velocity [cm/sec]		
						N-S	E-W	U-D	N-S	E-V	U-D
A1(SPJ)	Hikone City Y.	sediment	35.259	136.226	131.9	79.9	28	24.1	12.5	5.6	2.7
A2(EIG)	Eigenji Town	rock	35.073	136.339	132.5	28.0*	27.9**				
ASK	Azai Town	rock	35.477	136.324	152.5	24.5	22.5	10.9	2.5	2.2	1.1
ABD	Ohtsu City	rock	35.209	135.851	104.2	29.5	37	20.7	6.2	4	2.8
OSY	Ohtsu City	rock	34.998	135.861	89.9	46	47.1	42.1	6.6	4.1	3.6
HIM	Hikone City S.	sediment	35.273	136.247	134.9	136.8	146.9	39.1	15.2	14.7	3.3
TRH	Torahime T.	sediment	35.416	136.265	144.4	74.3	65.2	21.9	7	6.4	2.1
IMZ	Imazu Town	sediment	35.403	136.035	129.6	45.6	43.9	22.5	4.2	4	2
KST	Kusatsu City	sediment	35.011	135.958	100.1	135.7	91.1	38.2	11.7	7.9	4.9
MNK	Minakuchi T.	sediment	34.968	136.17	112.6	44.6	43	23.4	4.1	3	2.5
JRG	Gokasyocho T	sediment	35.139	136.184	122.1	125	119	44			
JRK	Kinomoto T.	sediment	35.505	136.224	150.1	50	53	13			
JRM	Maibara Town	sediment	35.316	136.293	139.5	217	135	25			

*: N-30°W ; ** :N-60°E

We have recorded earthquake waves in our campus since 1989. The accelerations at the 1995 Hyogo-ken Nanbu earthquake are the biggest in our data bases (reference 3),4)) , and the followings(= site *A1(SPJ)*, in Fig.1) ;

N-S : 79.9 [gal], E-W : 28.0 [gal], U-D : 24.1[gal]

The distance of this site from the earthquake center was 131.9 [km] .

On the other hand, the seisemometers in Eigenji dam (set by the agricultural section of Shiga prefecture) at the distance 132.5 [km] from the earthquake center, recorded the following accelerations (= site *A2(EIG)*, in Fig.1) at that time ;

Stream direction (N 30 degrees W) : 28.0 [gal], Along the dam axis (N 60 degrees E): 27.9 [gal],

U-D : 13.4 [gal]

Sites *A1(SPJ)* and *A2(EIG)* are almost the same distance from the earthquake center, but the peak ground accelerations are 79.9 [gal] and 28.0 [gal]. So their ratio is 79.9/28.8 = 2.77 . In Fukushima's equation , horizontal acceleration is the mean value of horizontal accelerations in two directions.

Each mean acceleration *a1*, *a2* of sites *A1(SPJ)*, *A2(EIG)*, and *a1/a2* is the followings ;

a1=(79.9+28.0)/2=53.95 [gal], *a2*=(28.0+27.9)/2=27.95 [gal]

a1/a2= 53.95/27.95=1.93

At site *A1(SPJ)*, the underground layers below the surface seems to be soft , but the depth of foundation layers for earthquakes (bedrock) is not clear. At site *A2 (EIG)*, the seisemometers are set at the bottom part of Eigenji dam, founded on the rock. The difference of the distances from the earthquake center is only 0.6 [km] , but the peak accelerations of site *A1(SPJ)* is bigger than those of site *A2 (EIG)*. It is speculated that the differences of accelerations result from the amplification in the soft layers on the bedrock.

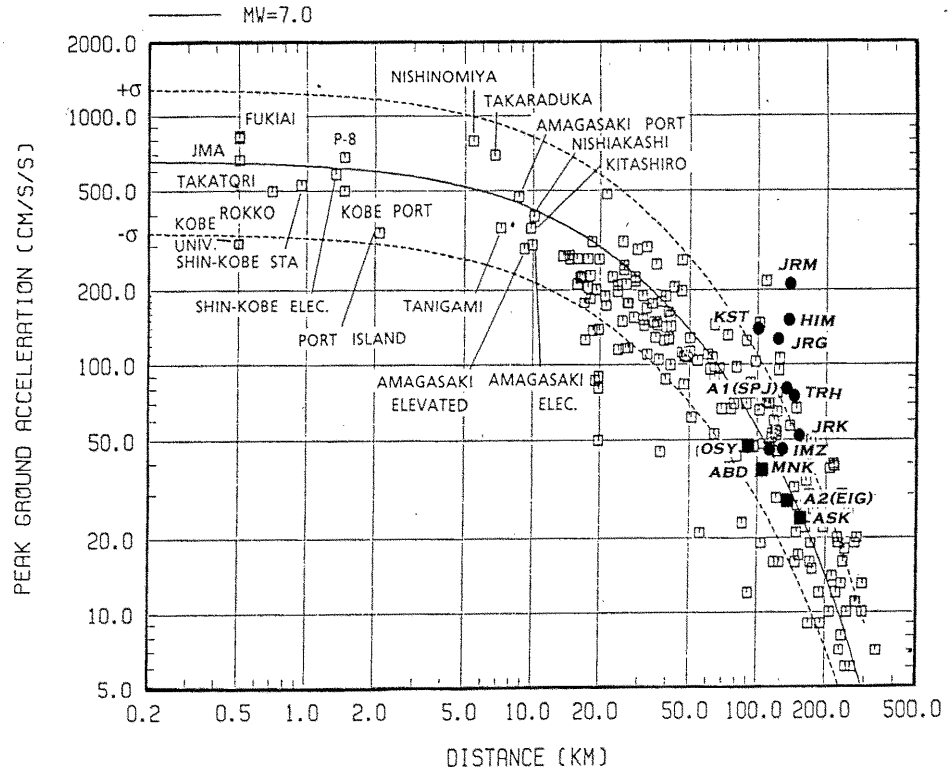

Fig. 2 Attenuation relations of peak horizontal accelerations

EXPLORATIONS OF UNDERGROUND STRUCTURES IN HIKONE CITY

So we are now exploring the depth of the foundation layers of earthquakes below the ground near our new campus in Hikone city since 1997, given assistances by Geotechnical Research Institute (reference 6)).

In 1997, we tried to estimate the ground structures near our new campus by seismic-array observations of microtremors (site *SGC* in Fig.3) , whose radii 0.25 and 0.5 [km]. The maximum phase velocity was 1.2 [km/sec] at 1 [Hz]. So the layer thickness deeper than 200 [m] was indefinite (Table 2 (a)).

In 1998, to estimate phase velocity less than 1 [Hz], we tried to estimate the underground structures, deeper than 200 [m], by seismic-array of radius 1.0 [km] (site *KOJ* in Fig.3). So phase velocities, normally distributing from 1.0 [km/sec] to 2.8 [km/sec], were got at from 0.4 [Hz] to 1.0 [Hz]. It has been clear that the thickness of the third layers is 700 ± 200 [m], and the Vs of the 3rd layer is 3.2 [km/sec] (Table 2 (b), Fig. 3).

Table 2 The undergrounds estimated at sites SGC (1997) and KOJ (1998)

(a) SGC

Thickness of layer [m]	P-wave velocity [km/sec]	S-wave velocity [km/sec]	Density [g/cm3]
100	1.7	0.4	1.7
120	1.9	0.6	1.8
200	2.5	1	2.1
<<	3	1.5	2.2

(b) KOJ

Thickness of layer [m]	P-wave velocity [km/sec]	S-wave velocity [km/sec]	Density [g/cm3]
100	1.7	0.4	1.7
120	1.9	0.6	1.8
700	2.5	1	2.1
<<	5.4	3.2	2.7

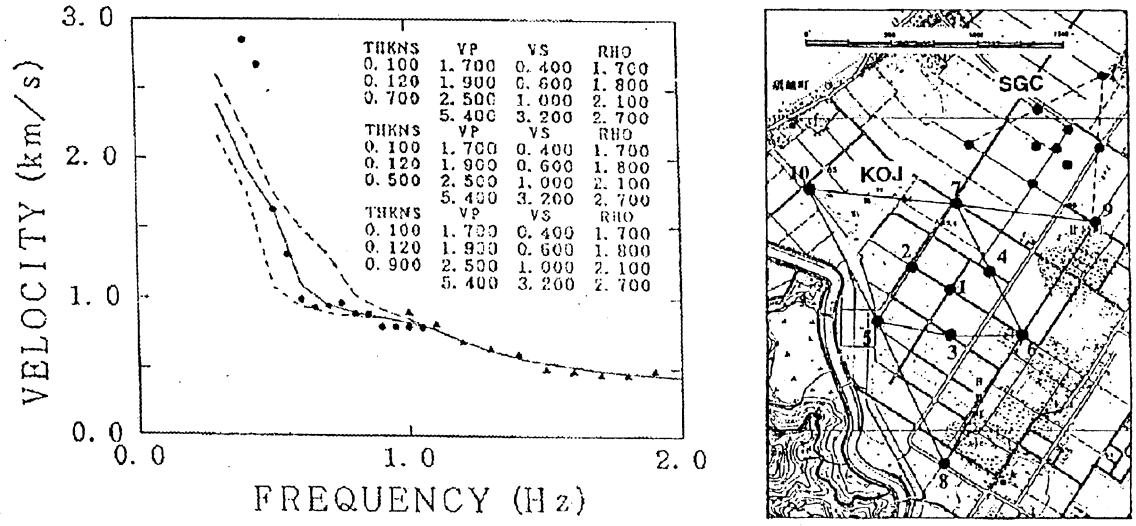

Fig.3 Changes of divergence curves of Reyleigh wave, in case of thickness 700±200 [m] of the 3rd layer (broken line : 500 [m], real line : 700 [m] , dotted line : 900 [m])

Near site *HTS*, about 10 [km] south from site *KOJ*, the observations of H/V microseisms and a 515 [m]-deep drilled hole have been performed recently (reference 7)). There are some differences in correspondence with P-wave velocity column at site *HTS* and S-wave velocity structure at site *KOJ*. But if Vs = 3.2 [km/sec] and Vp = 2.85 [km/sec] correspond to the bedrock, the depth of the bedrock at site *HTS* become 445 [m] shallower than the depth 900 [m] at site *KOJ* (Fig.4).

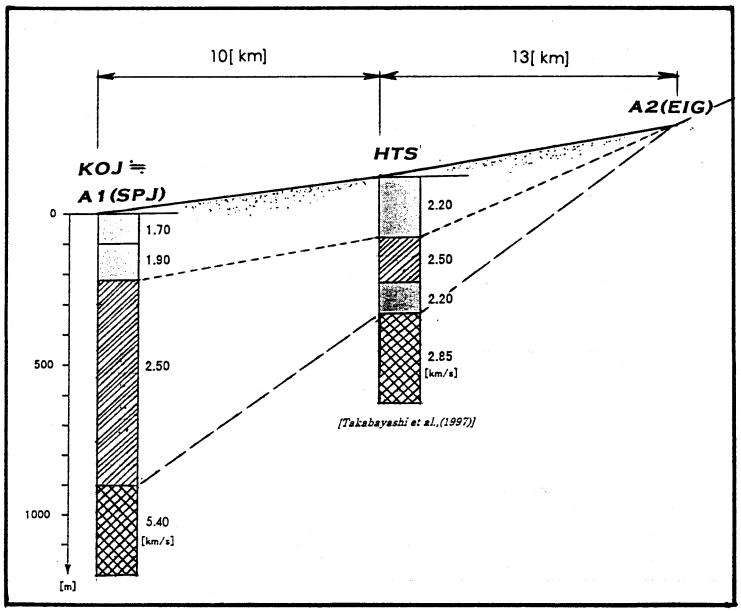

FIG. 4 Vp columns at sites *KOJ* and *HTS*, and transition of depths of the bedrock

CONCLUSION

In the peak accelerations, which got at 13 sites in Shiga prefecture at the 1995 Hyogo-ken Nanbu earthquake, there are some differences between those whose epicentral distances are almost the same. For example, those are 80 [gal] at site *A1(SPJ)*, and 28 [gal] at site *A2(EIG)*.

As one of this factors, amplification in the sedimentary layers on the bedrock is supposed. So we have tried to estimate the underground structures by seismic-array explorations of micro-tremors.

In the effect, it has been estimated that the depth of the bedrock at site *A1(SPJ)* [site *KOJ*] is about 900 [m] , and become shallower 445 [m] per horizontal distance 10 [km] to the depth of about 0 [m] at site *A2(EIG)*.

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