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Paper No. 894. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

SURFACE GROUND MOTION CHARACTERISTICS OF ZUSHI-SITE

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ABSTRACT

In order to verify the surface ground motion characteristics of Zushi-site with irregular ground condition, the microtremore measurements were carried out at about 200 points and the earthquake observation has been performed at the five stations on the ground surface in Zushi city from June 1994. About 20 earthquake events, 60 strong motion accelerograms were recorded, including Hyogoken Nanbu Earthquake(M=7.2). In this earthquake observation, the maximum acceleration is 75 gal for horizontal component and 28 gal for vertical component. From these results, dynamic characteristics of the surface ground were investigated and the microzonation of Zushi-city were made clear. Moreover,a new identification method is developed and the dynamic characteristics of the ground and the acceleration incident waves of bedrock were identified by this method using the acceleration data observed on the ground surface. The surface ground motion characteristics of Zushi-cite have been verified through the comparison of the simulation analyses and the observations.

KEYWORDS

Microtremore Measurements ; Earthquake Observations ; Identification Method ; Surface Ground Characteristics ; Zushi-site

INTRODUCTION

In order to make clear the local site effect for seismic vulnerability estimation based on the surface ground motion characteristics in Zushi city, microtremore measurements were carried out at about 200 points of the ground in Zushi city. And seismological array observation has started from June 1994 at five stations of the ground surface with different soil conditions in Zushi city as shown in Figure 1. About 20 earthquakes, 60 strong motion accelerograms were recorded including Hyougoken Nanbu Earthquake, Sagami Bay Earthquake(M=5.6), etc. A new identification method has been developed and the ground constants were identified using the observed acceleration data.

Moreover, the surface ground motion characteristics have been investigated through the comparison of the simulation analyses and the observations.

ZUSHI SITE

Zushi city is a local city located in Kanagawa Prefecture, south part of Tokyo Metropolitan area where the seismicity is very high, and was suffered severe damages by 1923 Great Kanto Earthquake(M=7.9). There are two main rivers in this city, one is the Togoshi River and the other is the Ikego River. This area is mainly divided into three zones with different ground conditions that is the alluvial low land zone spreading along and mouth of these rivers, the reclaimed land zone near the coast line and hill zone, as shown in Figure 2. The ground conditions are specified and classified into 34 soil types according to its characteristics and the depth of the soft surface ground layers based on the geological map and about 200 boring data as shown in Table 1.

MICROTREMORE MEASUREMENTS

Microtremore measurements were carried out at about 200 points subdivided into square grids of 200m x 200m in Zushi city. The resonant frequencies and the relative shaking amplitude of the ground surface which calculated by the amplification of maximum response spectra and resonant frequencies of the points were obtained from these data, as shown in Figures 3 and Figure 4. These results varied with the depth of the soft surface ground layers which are reasonable from comparison of the soil test data.

SOIL CLASSIFICATION MAPPING BASED ON ITS DYNAMIC CHARACTERISTICS

In Zushi city, the total 34 soil types of the site obtained from boring data were reduced to 5 soil types by the microtremore measurements and simulation analyses using Multiple Reflection Theory, having into account the similarity of its dynamic characteristics (the soil transmission coefficients, the amplification factor and the spectra). The obtained soil classification mapping of Zushi site are shown in Figure 5.

EARTHQUAKE OBSERVATION

Seismological array observation has started from June 1994 at five stations (K1 ~ K5) located on the ground surface in Zushi city. Among these stations, K1,K2,K4 and K5 are located on the alluvial low ground spreading along two rivers, and K3 is located on the rock outcrop (Figure2). Table 2 shows the soil deposit profile of K1,K3 and K4 stations based on the soil tests. The bedrock with Vs velocity over 700m/sec exists at -26 m for K1, -12m for K2, -15m for K4, and -7m for K5, respectively.

OBSERVED EARTHQUAKE RECORDS

About 20 earthquake events, 60 were recorded at five stations from June 1994 to July 1995, including Chibaken Nanbu Earthquake(M=5.2), Hokkaido Toho-oki Earthquake(M=8.1), Sanriku Haruka-oki Earthquake(M=7.5), Hyougoken Nanbu Earthquake(M=7.2), Sagami Bay Earthquake(M=5.6), etc. as shown in Table 3. The epicenter of the earthquakes in indicated in Figure 6 with circle symbol in which the diameter size means magnitude of earthquake. The recorded maximum accelerations are shown in Table 4. The largest value of peak accelerations at alluvial low ground were 75 gal in the horizontal direction, and at the outcrop(K3), the largest one is 21 gal in the horizontal direction in case of Sagami Bay Earthquake(EQ.19). The resonant frequencies of the surface ground were obtained which varies from

2.0 Hz ~ 6.0 Hz with the depth (-7.0 m ~ -25.0 m) of the soft surface ground layer. The results were agree with those microtremore measurements. .

From these results,the surface ground motion characteristics were clarified and the microzonation of Zushi city were made clear.

IDENTIFICATION OF GROUND CONSTANTS USING THE OBSERVED EARTHQUAKE DATA

In order to identify the ground constants contained density, shear wave velocity(Vs m/s), damping factor(h), and thickness of soil layer principally, a new identification method has been developed using observed earthquake data on the ground surface.

Based on Multiple Reflection Theory,the regression formula in this method is led as follows.

1 Outline of identification method

Even if the acceleration responses of ground surface of two sites away far on distance are different each other, the acceleration incident waves to both sites deconvoluted by Multiple Reflection Theory using the acceleration data observed on the ground surface of each site become same waveform nearly in the enough deep rock stratum(bedrock) which influence of surface ground can ignore (hereafter called'common basement' for short). Accordingly, under assumption that the deconvoluted incident waves and its spectrum of the common basement agree each other, the physical constants constituting ground can be identified.

Incident wave u which is function of ground constant is a solution of following differential equation.

$$\frac{\partial^2 u(\gamma,\rho,t,z)}{\partial t^2} = C^2 \frac{\partial^2 u(\gamma,\rho,t,z)}{\partial z^2} \qquad (1)$$

where y is Fourier spectrum of earthquake acceleration record observed on the ground surface, p is ground constant, t is time, z is coordinate of vertical direction and c is velocity.

Optimum ground constants are calculated by least squares method. Then objective function is represented by the formula below.

$$\varepsilon = \sum_i (U_{1j} - U_{2j})^2 = \sum_i \left[U_{10j} + \sum_k \frac{\partial U_{1i}}{\partial p_{1k}} \Delta p_{1k} - U_{20j} - \sum_k \frac{\partial U_{2i}}{\partial p_{2k}} \Delta p_{2k} \right]^2 \qquad (2)$$

where U_1 and U_2 are spectrum of incident wave u in (1) at each site, U_{10} and U_{20} are spectrum for initial values of ground constant, j denotes angular frequency ω_{j-1}, k is a number of ground constant considered. Δ p is quantity of infinitesimal change for non-linear parameter p. And objective function ε depends on Δ p. Optimum ground constants are provided by Δ p which minimize the objective function ε . A necessary condition for ε to be minimum is

$$\frac{\partial \varepsilon}{\partial \Delta p} = 0 \qquad (3)$$

From this, Δ p is found and ground constants are renewed. And, procedures, ① computation of U_1 and U_2 , ② computation of Δ p, ③ renewal of p, and ④ evaluation of ε , are repeated until minimization disposal results in a fractional decrease in ε of less than ε_0 ,where ε_0 is specified.

2 Identification of ground constants using earthquake data

This method was applied to identify the ground constants of K1, K3 and K4 stations. In this analysis, the accelerograms in EW components recorded on the ground surface during Sagami Bay earthquake (EQ.19) were used for input motions, the shearing wave velocity and damping factor were used as a parameter and the common basement were to be existed in -50 m deep. Under assumption that the deconvoluted incident waves agree in the common basement ,firstly, the ground constants of K1 and K4 stations were identified using the observed accelerograms of K1,and K4 stations, secondly, for fixed ground constants of K1 station, ones of K3 station were identified using the observed accelerograms of K1 and K3 stations.

The identified ground constants of K1, K3 and K4 stations are shown in Figure 7 and Tables 5 ~ 7 together with initial values. The Fourier spectrum of each identified incident waves are shown in Figures 8 and 9. Both spectrum agrees well each other. Figures 10 ~ 12 show the calculated acceleration time histories of the ground surface of K1,K4,and K3 stations(solid lines) due to the identified incident waves of the common basement for input motion compared with the observed ones(dot lines), respectively. In these figures,the calculated results agree well with the observed ones, so the identified ground constants and the incident waves are proved to be reasonable.

From these results, the identification method is significance as means to make clear ground structure and the surface ground motion characteristics of Zushi site were verified.

Hereafter,the seismic response analyses of the ground of Zushi-site are performed in detail using these identified ground constants and the observed earthquake data.

CONCLUSION

1. The surface ground motion characteristics were investigated and made clear the microzonation of Zushi city by the microtremore measurements which were performed at about 200 points in this city.
2. Seismological array observation have performed at five stations on the ground surface in Zushi city from June, 1994. In addition about earthquakes 20 earthquake events, 60 accelerograms including Chibaken Nanbu Earthquake(M=5.2), Hokkaido Tohou-oki Earthquake (M=8.1), Sanriku Haruka-oki Earthquake(M=7.2), Hyougoken Nanbu Earthquake(M=7.2), and Sagami Bay Earthquake(M=5.6) were obtained. The maximum acceleration was 75 gal for horizontal component and 28 gal for vertical component.
3. A new identification method of ground constants using observed earthquake data recorded on the ground surface has been developed. From this method, the ground constants of k1,k3and k3 stations were identified and the ground structure of these sites were made clear.
4. The surface ground motion characteristics of Zushi site have been verified from comparison of the simulation analyses and the observations.

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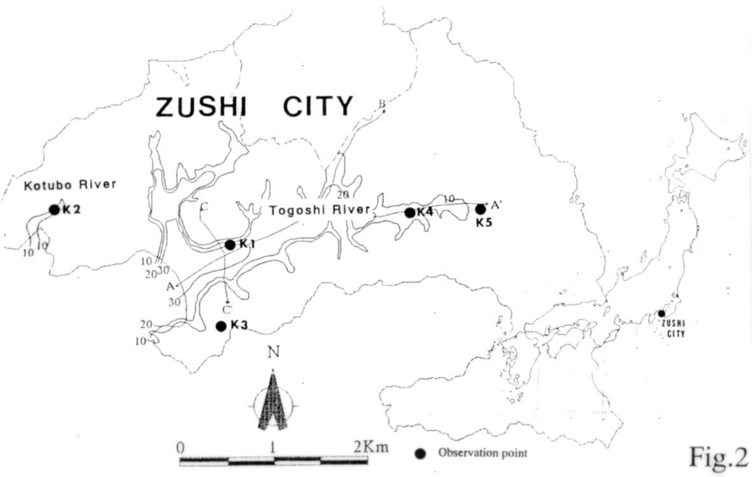


FIg.1 Location of five observation stations (K1～K5) at Zushi City

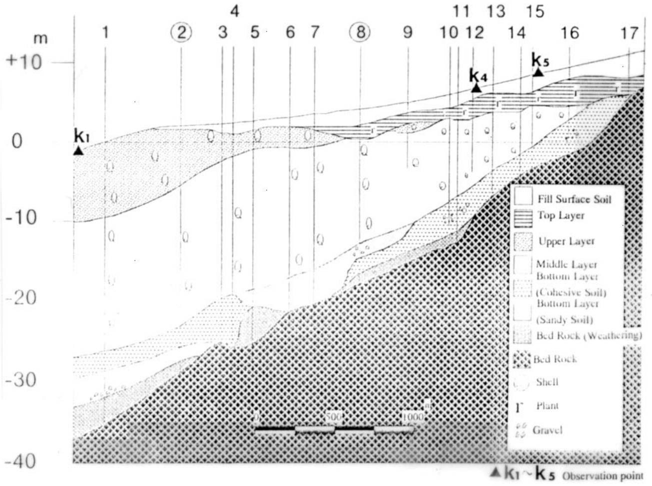


Fig.2 Geological section along Tagoshi river (A-A section)

Table.1 Soil types characteristics

FORMATION	CODE	SOIL TYPE	N VALUE (AVERAGE)	γ (g/cm^3)	S WAVE (m/s)
EMBANKMENT	FS	LOAM, SAND		1.7	150
	FG	GRAVEL		1.9	250
ALLUVIAL FORMATION	AP	ORGANIC	0 - 3 (1)	1.3	70
	AC1	CLAYEY	1 - 6 (3)	1.5	100
	AC2	CLAYEY	7≤ (8)	1.6	190
	AS1	SANDY	4 - 10 (7)	1.8	130
	AS2	SANDY	11≤ (20)	1.9	220
	AG1	GRAVELLY	10 -30 (20)	2.0	250
	AG2	GRAVELLY	31≤ (40)	2.1	400
MIURA FORMATION	BW	BEDROCK	<50	2.0	400
	BR	BEDROCK	50≤	2.1	700

Table.2 The soil deposit of K1,K3,K4

K1	Soil	N-Value	Vs(m/s)
Fill	Loam,Sand	-	150
Alluvial Deposit	Sandy Soil	4～10	130
	Cohesive Soil	1～6	100
	Cohesive Soil	11≦	220
	Gravel Soil	10～30	250
Miura Deposit	Bed Rock (Weathering)	<50	400
	Bed Rock	50≦	700

K3	Soil	N-Value	Vs(m/s)
Miura Deposit	Bed Rock (Weathering)	<50	400
	Bed Rock	50≦	700

K4	Soil	N-Value	Vs(m/s)
Fill	Loam,Sand	-	150
Alluvial Deposit	Cohesive Soil	1～6	100
	Sandy Soil	4～10	130
	Cohesive Soil	1～6	100
	Cohesive Soil	7≦	190
Miura Deposit	Bed Rock	50≦	700

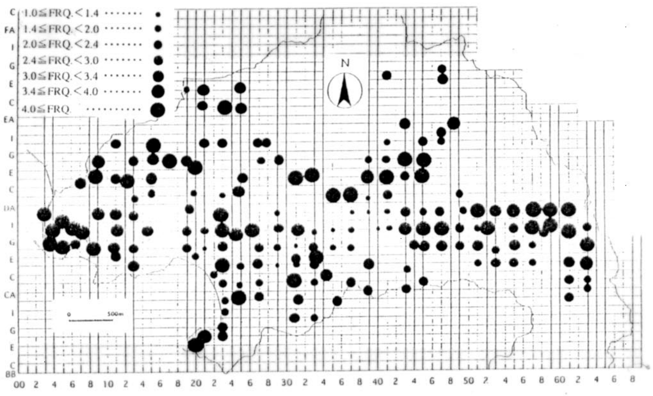


Fig.3 The response frequencies of the points by microtremore measurements

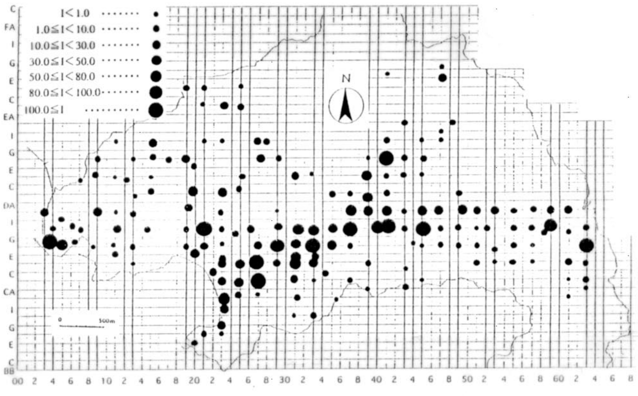
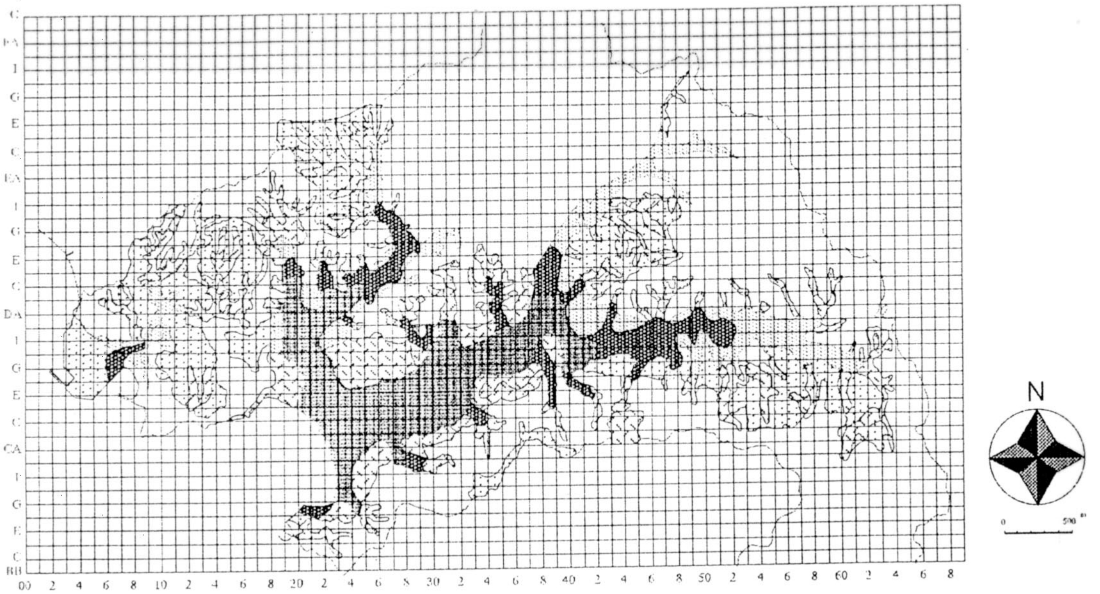


Fig.4 Relative Shaking amplitude of the ground surface



	Type of Soil	Transfer Function
⁙	PS,PC,PT,RU,M1	The predominant period can not be indentified,and the response amplification is small.
⤡	PM,RL,TLB1,TLN1,TLS1	The predominant period is among 7 to 10 HZ.
░	TI1,TI3,TU1,HN1,HU1,HLB1,KU1,KU2,KL1	The predominant period is 5 Hz. There is 7 to 10 meters of superficial sediment soil.
▓	TI2,TU2,TLV1,HN2,HU2,KL2,M2	The predominant period has peak among 2 to3 Hz. There are many other peaks.
▨	TLB2,TLN2,TLS2,TLS3,HU3,HLB2,HLB3,HLN1	The predominant period has a peak at 1 Hz. There are many other peaks. It is a very soft soil.

Fig.5 Soil Classification of Zushi-site

Table.3 List of earthquakes observed at Zushi-site

Number	Name	Date	Origine Time	Latitude	Longitude	Depth (km)	Magnitude
EQ1	Chibaken-Nanbu	Jun. 29 '94	11:01:58	34° 57'N	139° 53'E	60	5.2
EQ2	Chibaken-Hokubu	Jul. 20 '94	13:32:00	35° 46'N	140° 07'E	81	4.3
EQ3	Vladivostok	Jul. 22 '94	3:38	42° 17'N	133° 33'E	551	7.6
EQ4	Tokyo-Bay	Sep. 4 '94	10:19:10	35° 47'N	140° 08'E	83	4.3
EQ5	Bousou-Hantou-Oki	Sep. 11 '94	17:09:52	34° 35'N	140° 33'E	77	5.1
EQ6	Kanagawaken-Seibu	Oct. 4 '94	2:56:00	35° 11'N	138° 59'E	24	4.3
EQ7	Hokkaido-Touhou-Oki	Oct. 4 '94	22:22:57	43° 22'N	147° 40'E	30	8.1
EQ8	Kanagawa ken-Seibu	Oct. 25 '94	15:06:17	35° 11'N	138° 59'E	4	4.9
EQ9	Chibaken-Touhou-oki	Oct. 29 '94	23:43:06	34° 53'N	140° 43'E	70	4.9
EQ10	Ibaragiken-Nanseibu	Nov. 4 '94	19:06:25	36° 04'N	139° 55'E	59	4.5
EQ11	Izuhantou-Nanpuo-Oki	Nov. 9 '94	3:47:34	34° 29'N	139° 05'E	0	4.2
EQ12	Sanriku-HarukaOki	Dec. 28 '94	21:29:20	40° 27'N	143° 43'E	Very Shallow	7.5
EQ13	Tokyo-Bay	Jan. 1 '95	5:52:26	35° 37'N	140° 06'E	76	4.8
EQ14	Iwateken-Oki	Jan. 7 '95	7:37	40° 03'N	142° 04'E	30	6.9
EQ15	Ibaragiken-nanseibu	Jan. 7 '95	21:34:39	36° 17'N	139° 59'E	70	5.4
EQ16	Ibaragiken-nanseibu	Jan. 8 '95	4:28:17	36° 19'N	139° 58'E	72	4.6
EQ17	Ibaragiken-Oki	Jan. 10 '95	3:00:00	35° 09'N	141° 04'E	30	6.3
EQ18	Hyougoken-nanbu	Jan. 17 '95	5:46:52	34° 36'N	135° 03'E	14	7.2
EQ19	Sagami-Bay	July.3'95	8:53:45	35° 05'N	139° 20'E	122	5.6

Table.4 The maximum accelerations at K1,K3,K4 station of the main earthquakes

Number	Name	Magnitude	Maximum Acceleration (gal)								
			K1			K3			K4		
			NS	EW	UD	NS	EW	UD	NS	EW	UD
EQ1	Chibaken-Nanbu	5.2	19	23	26	8	8	5	45	26	28
EQ7	Hokkaido-Touhou-Oki	8.1	7	3	2	3	2	1	3	3	2
EQ15	Ibaragiken-Nanseibu	5.4	3	4	1	3	3	2	15	10	5
EQ18	Hyougoken-Nanbu	7.2	-	-	-	1	2	0	3	3	1
EQ19	Sagami-Bay	5.6	47	32	24	21	21	9	75	40	21

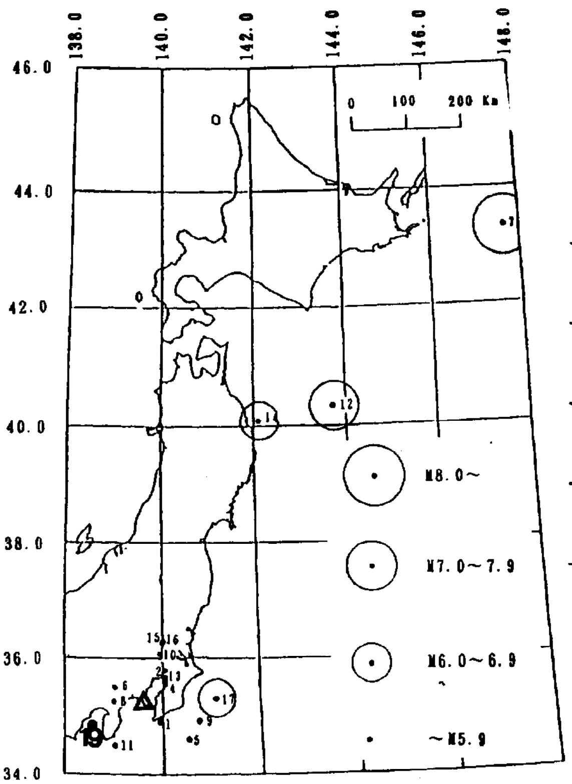


Fig.6 Locations of earthquakes of the observed earthquakes

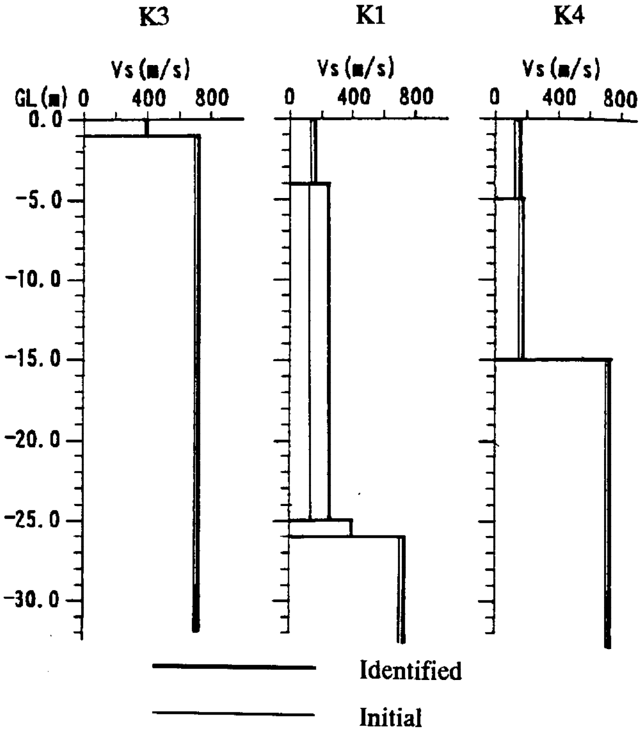


Fig.7 Identified Vs(m/s) of the ground models of K1,K3 and K4 station compared with the initial ones

Table.5 Identified ground constants of K1 station

Soil			H (m)	G.L.(m)	Vs (m/sec)		h	
	layer	fixed	fixed	fixed	initial	identified	initial	identified
Alluvial Deposit	1	1.78	4.0	4.0	135.0	142.0	0.050	0.050
(Loam,Sandy Soil	2	1.60	21.0	25.0	130.0	226.7	0.050	0.049
Cohesive Soil)	3	2.00	1.0	26.0	400.0	400.6	0.050	0.050
Miura Deposit (Rock)	4	2.10	24.0	50.0	700.0	703.9	0.020	0.019

Table.6 Identified ground constants of K4 station

Soil			H (m)	G.L.(m)	Vs (m/sec)		h	
	layer	fixed	fixed	fixed	initial	identified	initial	identified
Alluvial Deposit	1	1.60	5.0	5.0	116.0	126.4	0.050	0.049
(Cohesive Soil)	2	1.53	10.0	15.0	127.0	191.9	0.050	0.047
Miura Deposit (Rock)	3	2.10	35.0	50.0	700.0	703.9	0.020	0.019

Table.7 Identified ground constants of K3 station

Soil			H (m)	G.L.(m)	Vs (m/sec)		h	
	layer	fixed	fixed	fixed	initial	idebtified	initial	idebtified
Miura Deposit (Rock)	1	2.00	1.0	1.0	400.0	400.0	0.050	0.05
	2	2.10	49.0	50.0	700.0	703.9	0.020	0.019

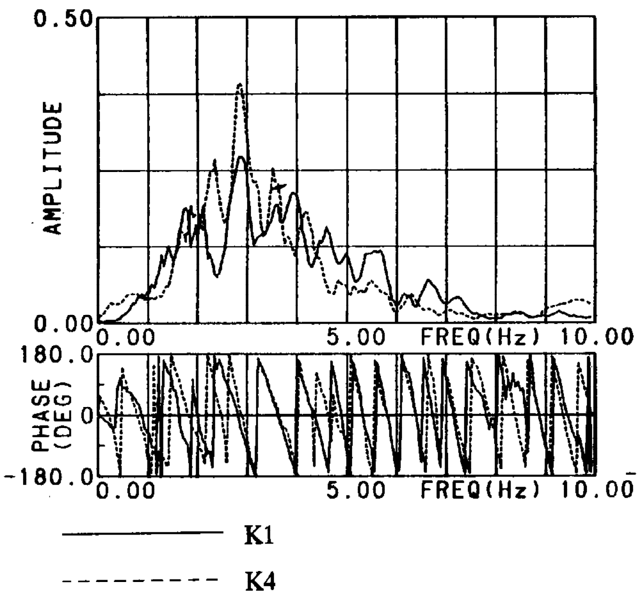


Fig.8 Spectra of acceleration incident waves of K1 and K4 in the common basement

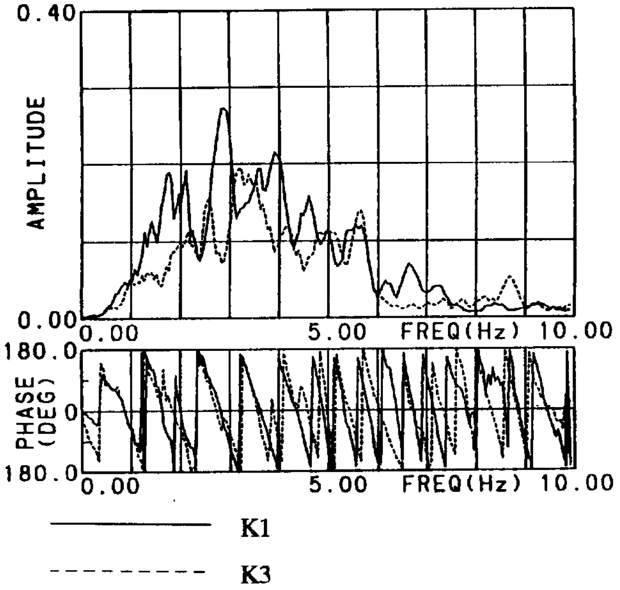


Fig.9 Spectra of acceleration incident waves of K1 and K3 in the common basement

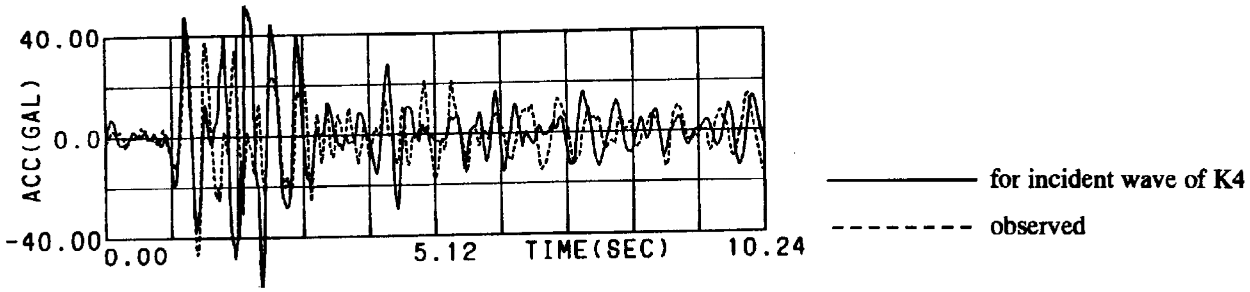
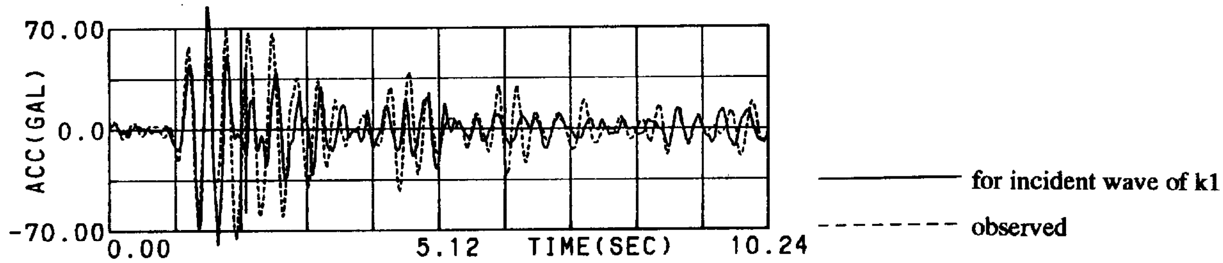


Fig.10 Comparison between identified and observed acceleration time history on the ground surface at K1



Fl g.11 Comparison between identified and observed acceleration time history on the ground surface at K4

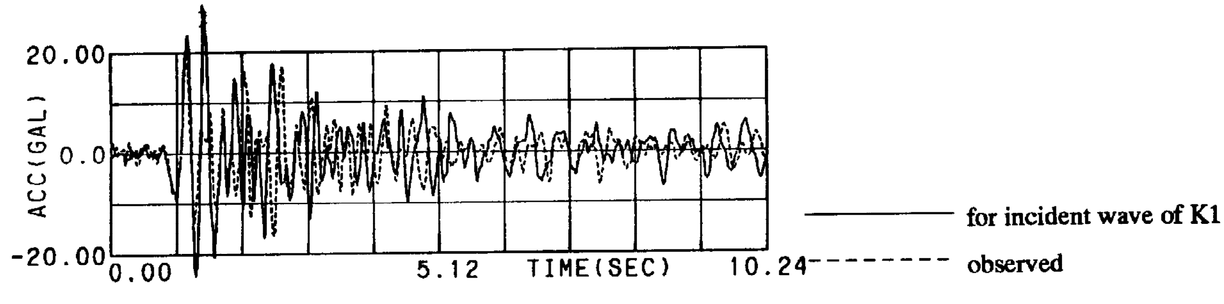


Fig.12 Comparison between identified and observed acceleration time history on the ground surface at K3