EVALUATION FOR EARTHQUAKE GROUND MOTION OF SEDIMENT-FILLED BASIN UNDER SEISMIC OBSERVATION

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ABSTRACT

Characteristics of Earthquake ground motion and seismic wave propagation were investigated with reference to earthquake records, which were obtained at K site of horizontal sedimentary layer and at O site of sediment-filled basin. Seismic response analyses were also examined by comparing with those records.

Amlificaion of earthquake ground motion between basic and surface layer at K-site, are quite stable in any recorded earthquake. For that reason, it was confirmed that one-dimensinal response analysis is good enough to evaluate earthquake ground motion at horizontal sedimentary layer like this site.

On the other hand, underground distributions of maximum accerelation and amplification at O-site, have strong local effect of surface geology and also have different dynamic characteristics between NS and EW components. Evolutionary power spectrum of ground motion for longitudinal and transverse components to epicenter were analyzed to realize these phenomena. As a result, dispersional Love-wave generated through surface geology were indicated.

Further, availability of the super-imposed method combined both of one-dimensional analysis by the SHAKE and two-dimensinal anlysis by the Aki-Larner method were investigated for earthquake in seismic response at O-site.

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INTRODUCTION

Seismic response of soil layer or local soil amplification due to strong earthquake plays an important role for the seismic safety of structure. Dynamic soil properties are among incident wave parameters, topographical and base-rock irregularities, etc.In this report, seismic response analyses is examined by the deep down-hole array earthquake measurement in the granular soil layer with horizontal and irregular interface. Numerial analyses is introduced with a focus on evaluation for effect of surface geology.

SITE CHARACTERISTICS AND SOIL PROPERTIES (K-SITE)

The array was set up in K-site in a coastal Flat area about 80km east of Tokyo (see Fig.1) by drilling several boreholes in the same site to accomodate the down-hole array instrumentation at nine different levels as shown in Fig.2. The deepest hole was drilled down to 502m from the ground surface so that the Pleistocene sedimentation rock with the shear-wave velocity of 650m/sec was reached. Above the rock a rather uniform horizontal layer consisting of Pleistocene cemented fine sand of about 480m thick is resting with a thin horizontal gravelly layer of about 2.5m thick and a loose to medium sand surface layer of 16m thick capping it. The P-and S-wave velocities measured down to 502m by the PS logging method are shown in Fig.2, indicating the shcr-wave velocity almost monotonically increasing with depth.

MEASURED SEISMIC RESPONSE (K-SITE)

Thirty six cartquake records were obtaind for about four years from Dec. 1988 to Jan. 1994.Among them the largest magnitude was M=6.0 with the epicentral distance △=27m and the largest value of the peak horizontal acceleration at the ground surface 114cm/sec^2 in a M=5.2 earthquake event(EQ-15) with △=43km (see Fig.1). In Fig.3, an example of the recorded motions are shown for an event of M=5.6 ,△=71.1km (EQ-8).

Fig.4 exemplifies the vertical distribution of the computed maximum horizontal acceleration compared with the measured values as well as the distributions of the mazimum shear stress and the maximum shear strain for a larger seismic motion recorded in the site. The dotted curve in the geaph correspond to the case in which the strain-dependency of the damping ratio, h, is modified so that the lowest value of h is fixed as 5% as shown in Fig.4 on the ground that the seismic records optimization evaluates the damping ratio of the sand layers as about 5%.

Fig.5 shows the distribution of the peak horizontal accelertion amplification alog the depth with respect to the reference value at the deepest G1 point(GL.-502m) for the recorded earthquake of M=4.9 ,△=33km (EQ-36). It is noted that the amplification factors do not increase but stay almost constant from the deepest G1 point up to the depth of 17m below the surface. Marked amplification takes place solely in the top part shallower than 17m . These amplification characteristics are quite similar in two perpendicular horizontal directions and also very stable for different earthquakes with various intensities, magnitudes and epicentral distances, Leading to the standaard deviations of the amplification factor for the 35 earthquakes being about ±20 percent of the average value and quite stable for all the down-hole levels,

In Fig.6 the transfer functions calculated as the average of the recorded larger earthquake motions between the ground surface level G9 (GL.-1m) and the down-hole levels, G3(GL.-50m), are shown for the two perpendicular horizontal motions. Evidently, the functions are much the same in two orthogonal directions, indicating the soil layer in this site is quite isotropic in its dynamic

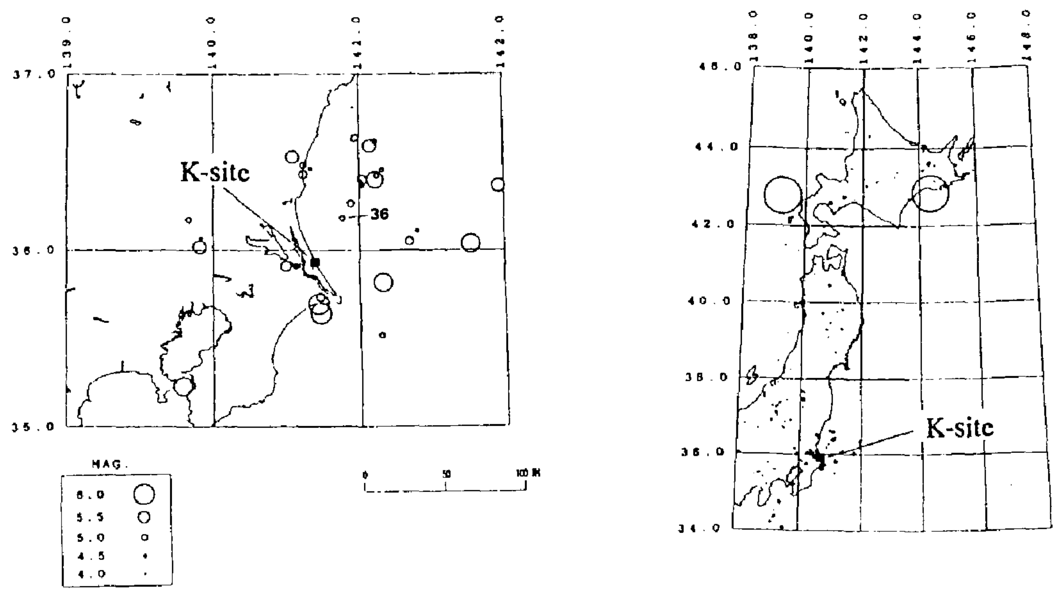


Fig.1 Location map of earthquake recorded at K-site

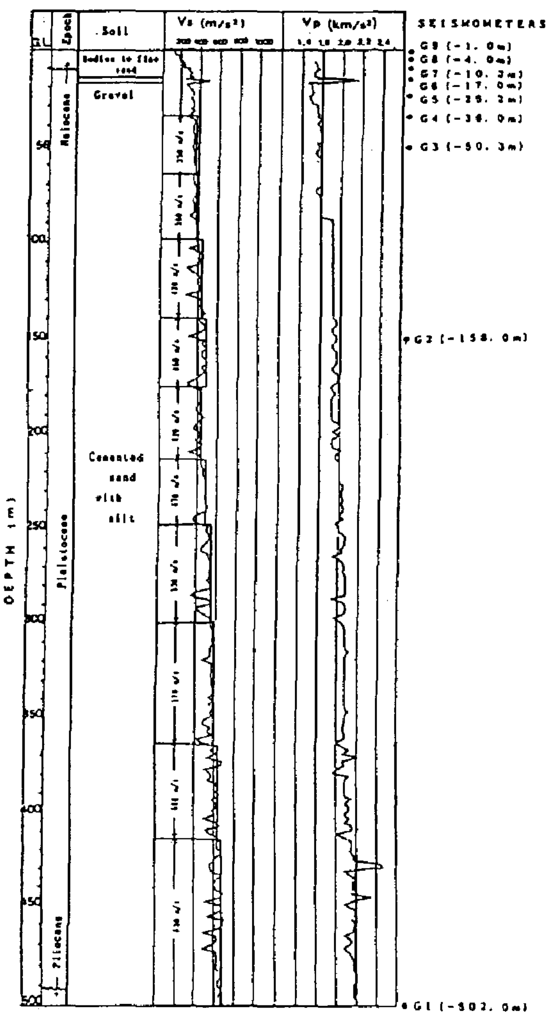
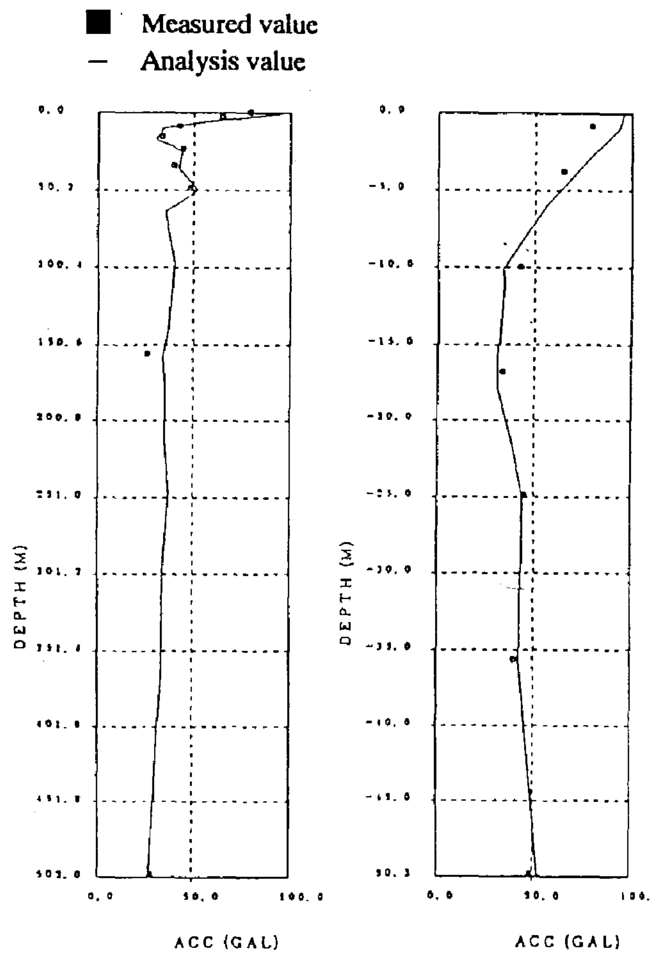


Fig.2 PS logging and down-hole seismometer



(a) Vertical distribution of down-hole array

(b)Vertical distribution of shallow part of array

Fig.3 Maximum horizontal acceleration (EQ-8)

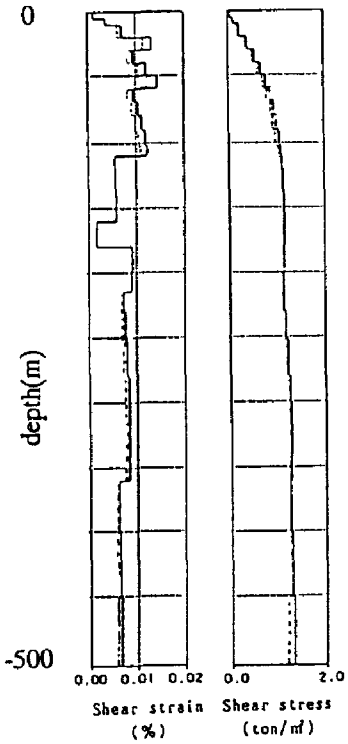


Fig.4 Distributions of Max. Values Computed by SHAKE Analysis (EQ-8, N55W)

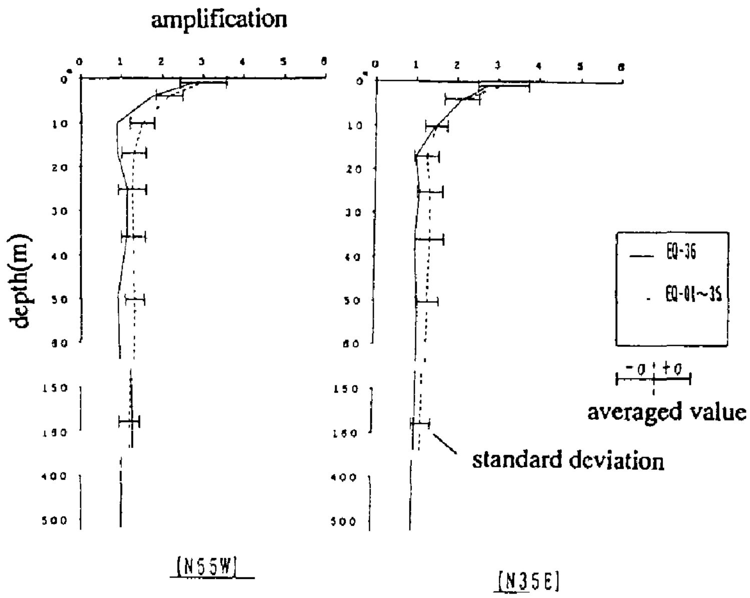


Fig.5 The average, standard deviation and EQ-36 of Max. Acc.

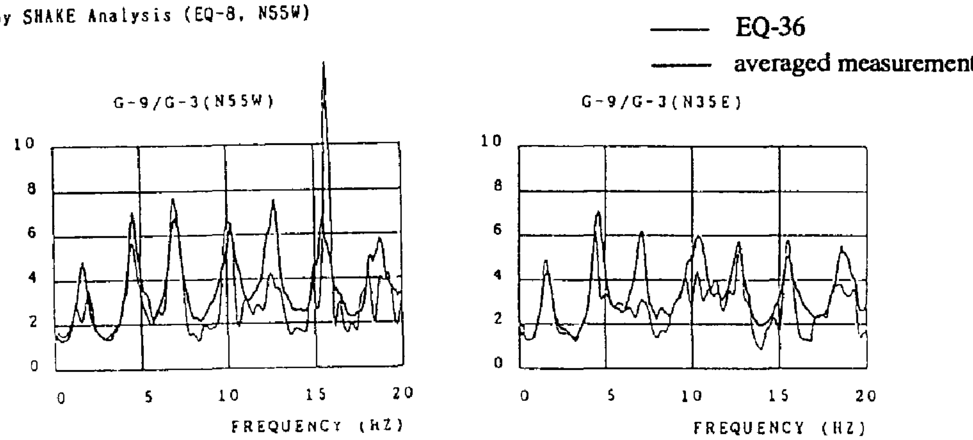


Fig.6 Transfer function compared between averaged and EQ-36

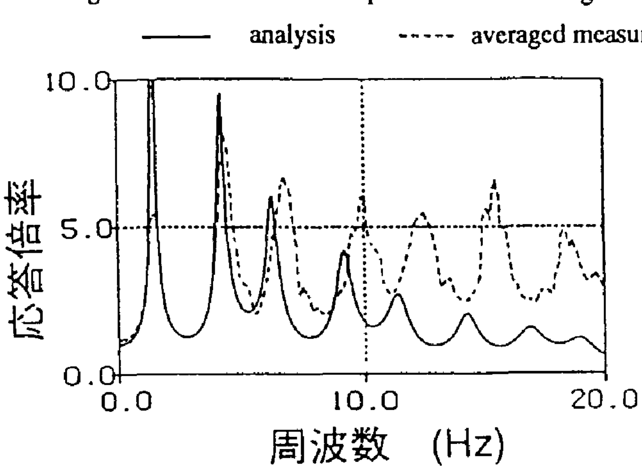


Fig.7 Transfer function (G9/G3) compared between analysis and averaged measurement

response.The transfer functions between G9 and G3 for the same earthquake motion is shown in Fig.7. Hower, there exists a striking difference between the actual and computed responses irrespetive of the damping values in that the peak amplitudes in the transfer function of the SHAKE analysis tend to monotonically decline for higher frequency while those of the actual response stay at almost the same level. This may imply the hysteretic damping incorporated in the SHAKE analysis may not approiately represent the actual damping mechanism exerted in the small strain oscillation.

TOPOGRAPHY AND GEOLOGY OF ASHIGARA VALLEY

The Ashigara Valley, about 80 km southwest of Tokyo, lie in the Southern Kanto region, which is located near the triple junction of the philippin Sea Plate, the Eurasian Plate and the Pacific Plate(See Fig.8). In particular,Ashigara Valley and its vicinities are geologically complicated and have high seismic activities, because they are on the extension of the Sagami trough on the boundary of the Philippine Sea Plate and the Eurasian Plate and under them the Philippine Sea Plate collides with the Eurasian Plate. Naturally, this region has often suffered significant earthquake damage. Under such a situation, the study on the topography and geology of this region has been conducted for a long time. Recent works, For example, are those done by Kanagawa Prefecture(1980) and Yamazaki et al.(1982).

As illustrated by the surface geological map in Fig. 8 and the Ashigara Valley, surrounded by the Hakone Volcano to the west, by the Oiso Hills to the east and by the Tanzawa Mountains to the north, is about 4 km wide and 12 km long. It is a rectangular alluvial plain developed along the lower reaches of the Sakawa River. O-Site is located on the west of this alluvial plain.

GEOTECHNICAL MODEL OF O-SITE

Fig. 9 shows the locations of the surface seismic observation points and three lines of profile in the O-site. The epicenter of the earthquake recorded on this site is indicated in Fig 10 with circle simbol whose diameter size means maghitude of earthquake, Fig.11(a)-(c) show the geotechnical cross sections along the three lines of profile, respectively, giving some image of the three-dimensional structure of the test area.

The O-site in Ashigara Valley and its vicinity have been geophysically explored for investigating the structure and the physical properties of the substructure. Logging provides valuable data for understanding the physical properties of the ground layers in and around the O-site. To estimate the P-wave and S-wave velocities which are indispensable for seismic motion analysis, P-and S-wave velocity logging has been carried out in three boreholes. the suspension method was used in the seismic wave velocity logging. Further,electrical logging (normal method) and density logging were also conducted in the three identical boreholes (OA,OC and OD) in the test site to determine the continuity of the geological structure and the soil layers.

MEASURED SEISMIC RESPONSE (O-SITE)

Seventeen eartquake records were obtaind for about three years from Feb. 1992 to Mar. 1994.Among them the largest magnitude was M=7.8 with the epicentral distance $\triangle$=955km (Kushiro-oki 1993) and the largest value of the peak horizontal acceleration at the ground surface 94.3cm/sec^2 in a M=5.9 earthquake event with $\triangle$=58.5km. An example of the recorded motions are shown for an event of M=4.9 and $\triangle$=65.3km (EQ-3). Fig.12 exemplifies the vertical distribution of the computed maximum horizontal acceleration compared with the measured values for a larger seismic motion recorded in the OA-site of deep down-hole array. It shows the distribution of the peak horizontal acceleration amplification along the depth with respect to the reference value at the deepest G1 point(GL.-300m) . It is noted that the amplification factors do not increase but stay almost constant

from the deepest G1 point up to the depth of 13m below the surface. Marked amplification takes place solely in the top part shallower than 13m. These amplification characteristics are almost similar in two perpendicular horizontal directions.
Revolutionary spectra with the transverse direction to epicenter of the recorded seismic data (EQ-3) was analyzed, which shows ampfification and wave propagation of subsurface seismic motion. Each spectral peak shows arrival time of predominant propagating wave with respect to the frequency. Those peaks' time as shown dot simbol in Fig.13 are gradually changing and dispersional in the frequency boundary from 1 to 3 Hz, but same in the other frequency boundary. It was recognized that those peaks' frequency agree to the sharp curve point of the dispersional curve for Love wave phase velocity on the subsurface structure up to the depth of 13m (See Fig.14). In Fig.15 the transfer functions calculated as the average of the recorded larger earthquake motions between the granular ground surface level G6 (GL.-13m) and the down-hole levels, G1(GL.-300m), are shown for the two perpendicular horizontal motions. The functions are not so much same in two orthogonal directions, indicating the soil layer in this site is quite heterogenuous in its dynamic response.

SEISMIC RESPONSE ANALYSIS(O-SITE)

North to south direction soil profile for the surrounding of OA-site was modelized like as sediment-filled basin in Fig.16,that consist of five lateral heterogeneous soil layers.Seismic response was analyzed by Aki-Larner Method with fast fourier transform, which has periodicity in the horizontal direction of soil model.Fig.17 shows propagating subsurface motion from the ridge side of sediment-filled basin due to incident SH ricker wave of 0.7 sec natural period.Some secondary surface waves are generating from the ridge of sediment-filled basin and then, propagating toward the deepest position of the basin.As a result, seismic response on the central part of the basin shows confused dynamic behavior by both of shear wave propagating from bottom layer and secondary surface Love-wave generating through the geological structure.
In this report, seismic response analysis was calculated by Super-Imposed method combined both of the AL-method in the frequency boundary lower than 3.0 Hz and the SHAKE analysis in the other one higher than 3.0 Hz. Pseudo velocity response spectra for two perpendicular horizontal components of event EQ-3 was obtained in Fig.18. Calculated response spectra in NS component almost agree to observed one except response spectral amplitude peak in the period of 1.0 sec.The amplitude peak in the period of 0.5 sec (2.0 Hz) indicate the seismic response depend on the two-dimensional geological structure. It was founded more clearly by comparing between the two-dimensional analysis(Super-Imposed method) and one-dimensional analysis (SHAKE). Response spectra in EW component are somewhat different with another one mentined above. This different dynamic characteristics is needed to research as site dependent phenomina taking account to the effect of three-dimensional soil structure.The availability of Super-Imposed method was approxemately confirmed on the seismic records of OA-site.

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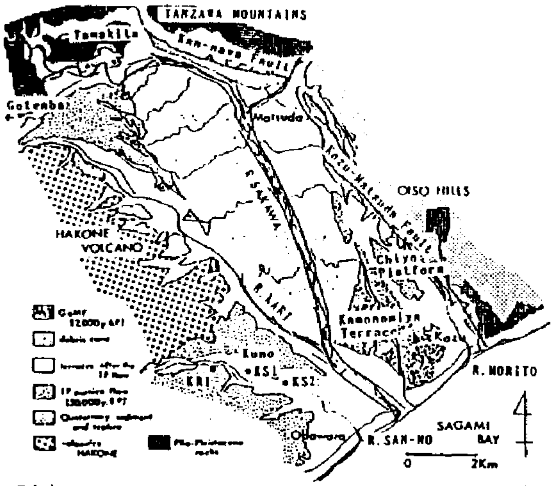


Fig.8(a) Subsurface geological map in and arround the Ashigara Valley (modified Yamazaki et al.,1982)

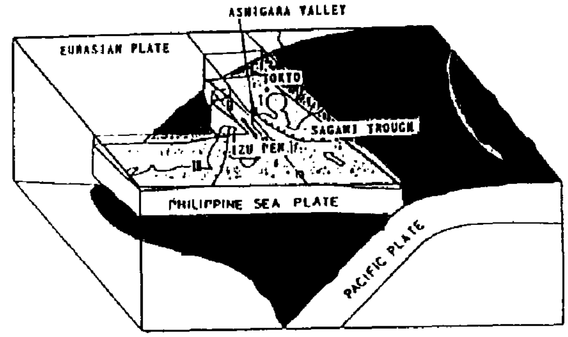


Fig.8(b) Unified plate model for interpreting the techtonics of the Kanto-Tokai area (modified Kasahara, 1985)

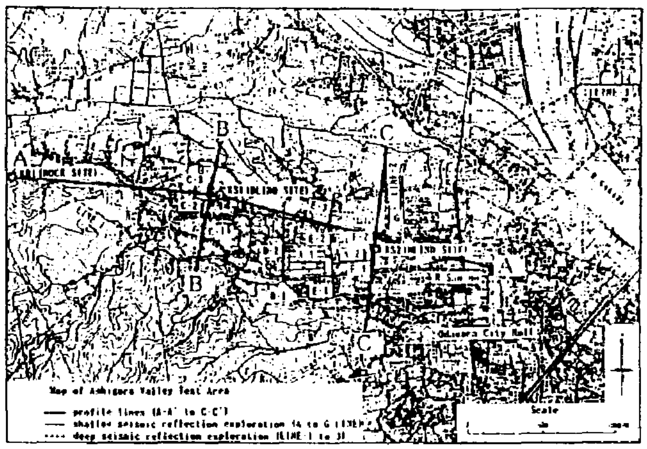


Fig.9 Location map of seismic observation point

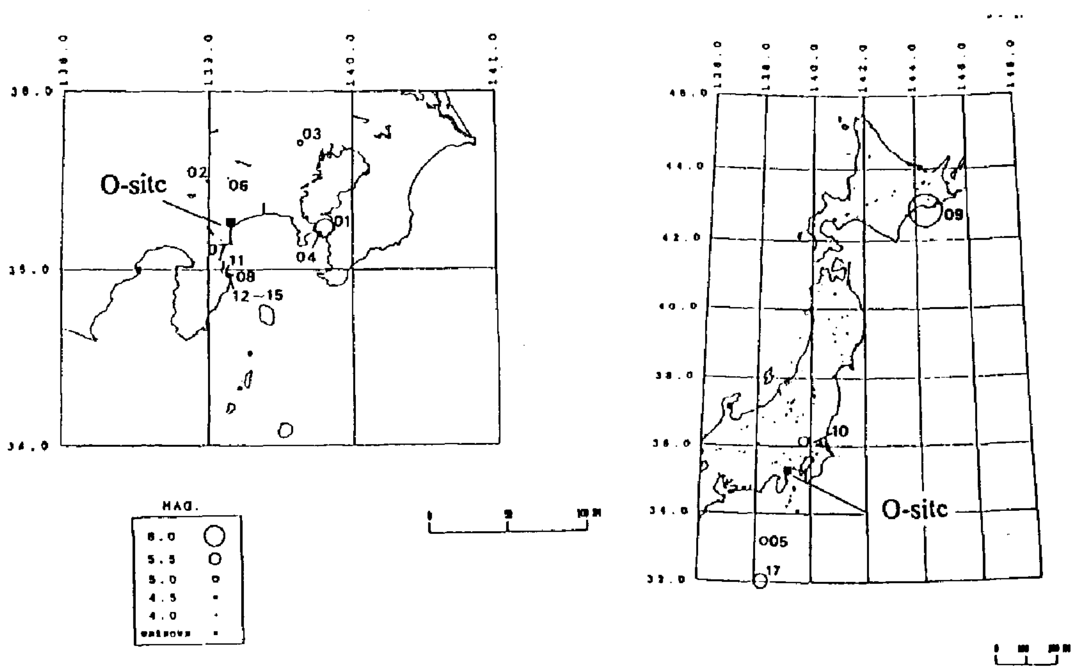


Fig.10 Location map of earthquake recorded at O-site

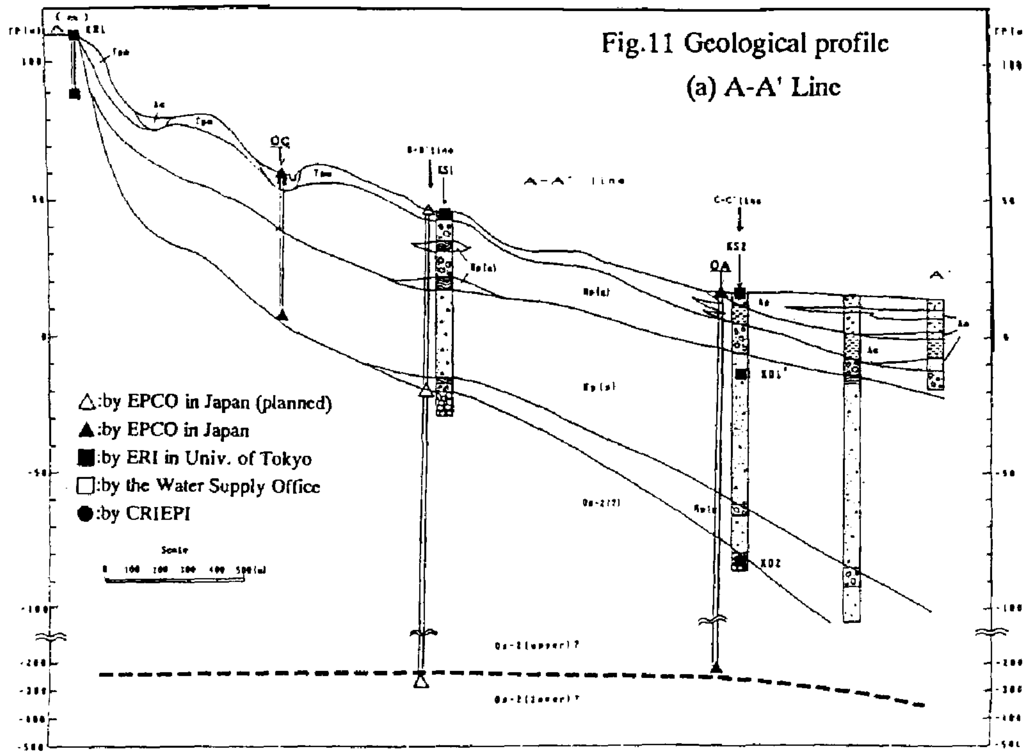
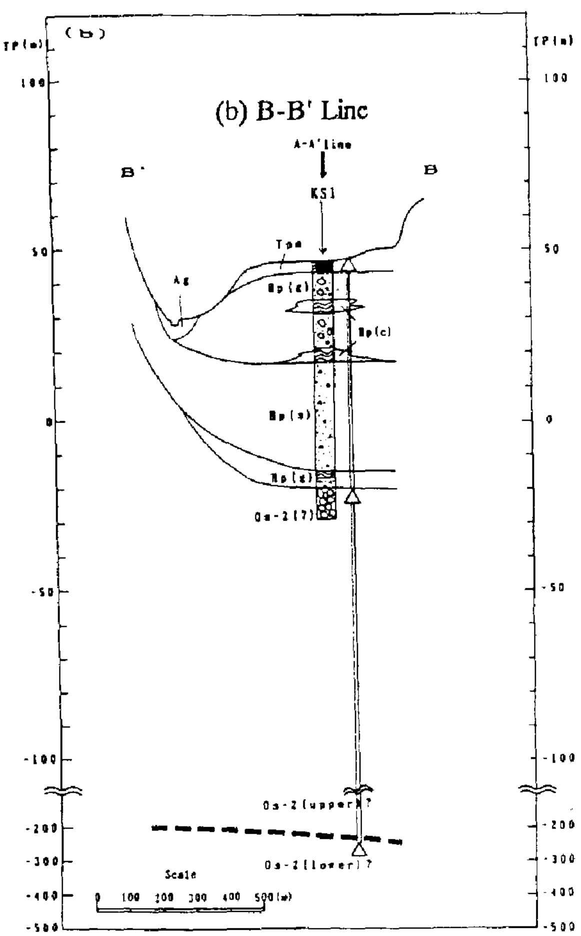
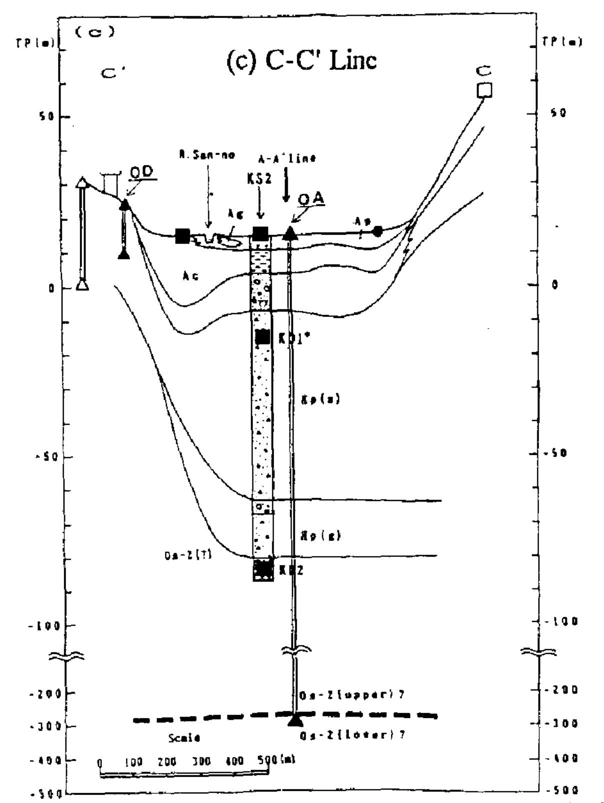


Fig.11 Geological profile
(a) A-A' Line

Fig.11 Geological profile



(b) B-B' Line



(c) C-C' Line

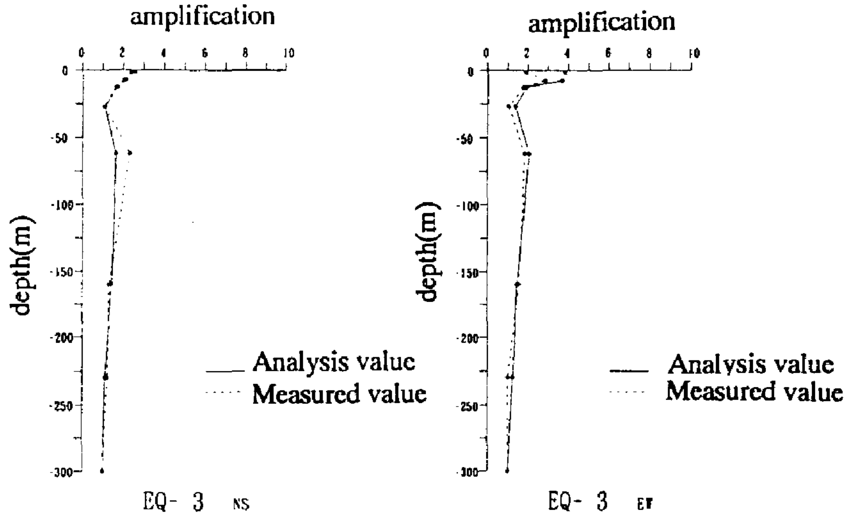


Fig.12 Maximum horizontal acceleration (EQ-3)

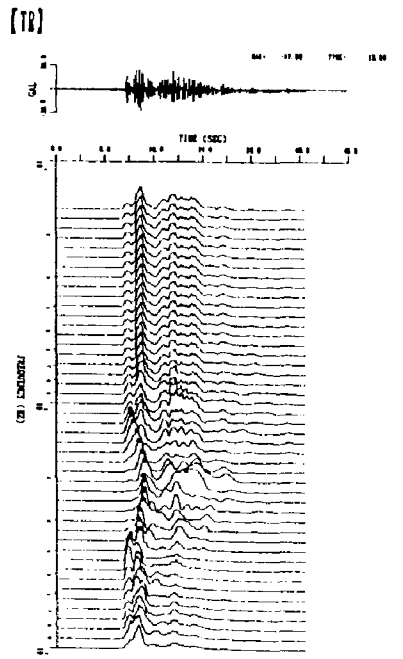


Fig.13 Revolutionary spectra (h=5%)

	H (m)	ρ (t/m³)	V. (m/s)
1	7. 0	1. 8	6 6
2	6. 0	1. 8	1 5 7
3	∞	2. 0	6 4 5

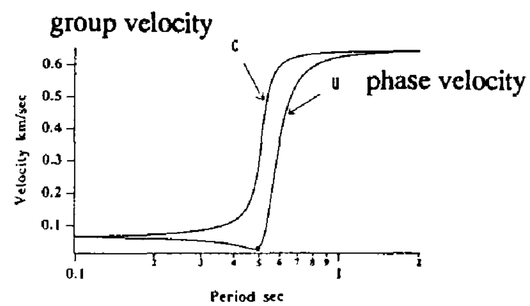


Fig.14 Love-wave dispersional curve of phase velocity

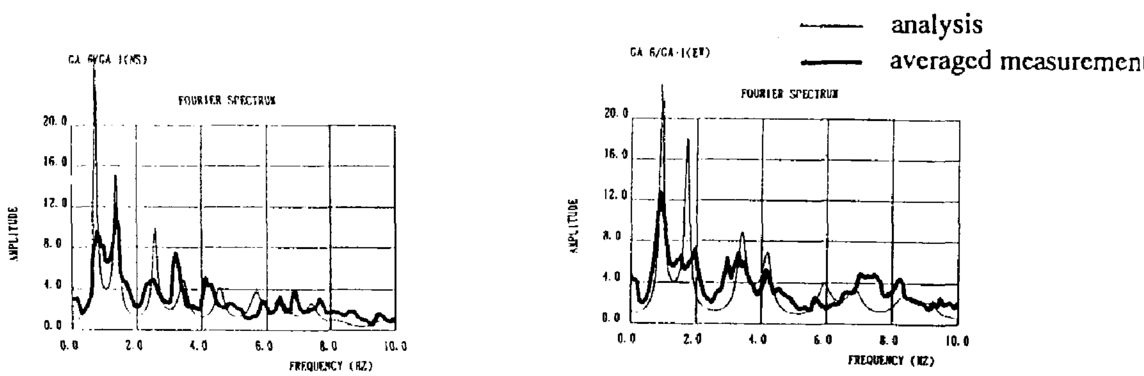
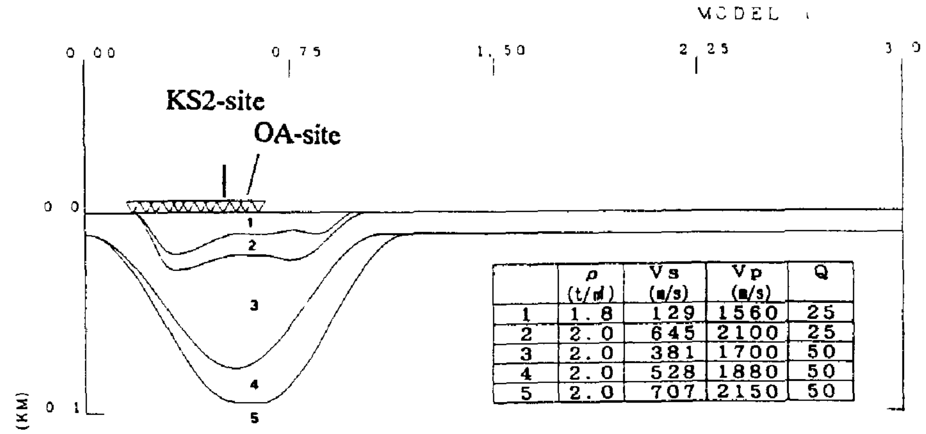


Fig.15 Transfer function (G6/G1) compared betweeen analysis and averaged measurement



	ρ (t/m³)	Vs (m/s)	Vp (m/s)	Q
1	1.8	129	1560	25
2	2.0	645	2100	25
3	2.0	381	1700	50
4	2.0	528	1880	50
5	2.0	707	2150	50

Fig.16 Sediment-filled model on C-C' line

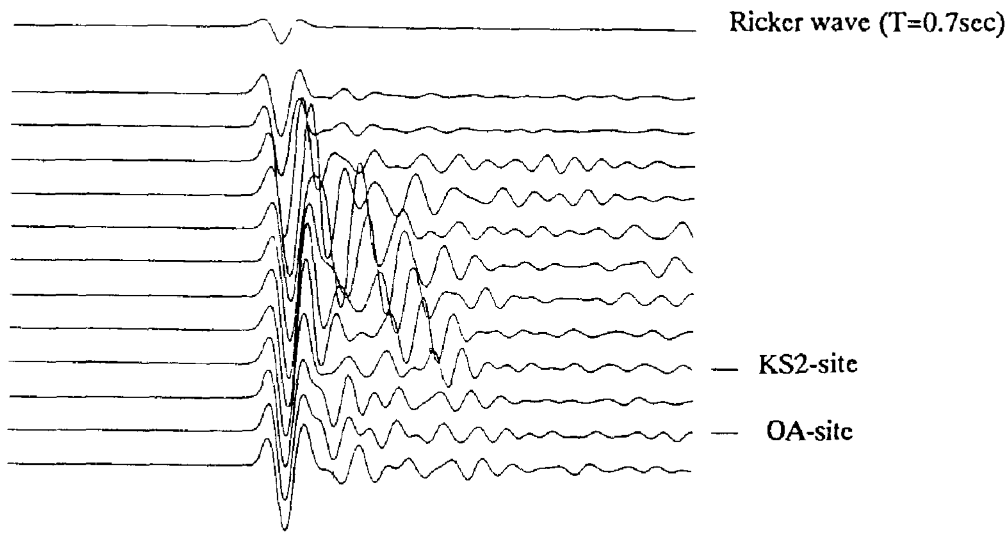


Fig.17 Subsurface motion by AL-method (EQ-3)

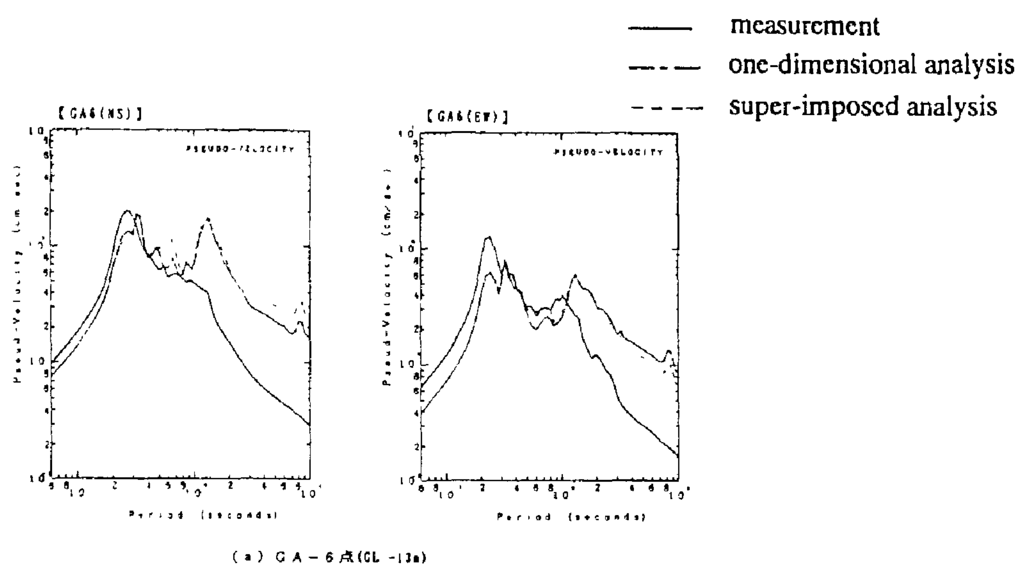


Fig.18 Pseudo-velocity response spectra (EQ-3)