

A STUDY ON THE EFFECTS OF SURFACE WAVES GENERATED IN DEEP SEDIMENTARY BASINS DURING A MAJOR EARTHQUAKE

K. Eto ¹⁾, K. Motoki ²⁾ and K. Seo ³⁾

1)Graduate student, Department of Built Environment, Tokyo Institute of Technology, Japan

2)Research Assoc., Department of Built Environment, Tokyo Institute of Technology, Japan

3)Prof., Department of Built Environment, Tokyo Institute of Technology, Japan

eto@enveng.titech.ac.jp, kmoto@enveng.titech.ac.jp, seo@enveng.titech.ac.jp

Abstract: In the Kanto basin, when we consider the case of next great earthquake, long period component will appear as the result of surface waves excited by deep sedimentary layers. By a series of Izu earthquakes on July 2000, the surface waves about 10 seconds predominate extremely at the central Boso peninsula in eastern part of the Kanto basin. In compared with the dispersion curve of group velocity calculated with underground structural model by Yamada et al. (2003), we confirmed that this phenomenon was amplified by the deep sedimentary layers at the central Boso peninsula. These amplified surface waves have the potential to cause the disaster of large structures, e.g. fuel tank.

1. INTRODUCTION

In the Kanto basin, when we consider the case of next great earthquake, long period component will appear as the result of surface waves excited by deep sedimentary layers. Consequently, we must understand this phenomenon to evaluate earthquake ground motions for larger structures. Several researchers have studied on the effect of long period motions at the Kanto basin; Kinoshita *et al.*(1992) and Zama(1992) pointed out that Love waves generated from edge of the Kanto basin are dominant in the long period later arrivals observed around Tokyo-bay area. Koketsu *et al.*(2000) showed the propagation of the 5 seconds low-pass filtered motions by 384 strong motion instruments across the Kanto sedimentary basin and its surroundings. They identified wave fronts with abrupt changes in the amplitude and trajectory of ground motion. On the other hands, Koketsu *et al.*(1992) made the 3D structural model of the Kanto basin. Miura *et al.*(2000, 2001) made the 3D underground structure by PS converted wave in Yokohama city to examine the characteristics of Love wave propagation. 3D simulation of the 1923 great Kanto earthquake are performed by Sato *et al.*(1999). Yamada *et al.*(2003) tried the simulation of earthquake motions and constructing new 3D underground structural model at the Kanto basin.

In this paper, we found out about the peculiar amplification characteristics for the prediction of the surface waves in the central Boso peninsula using a series of Izu earthquake on July 2000.

2. RISK OF SURFACE WAVES IN THE DEEP SEDIMENTARY BASIN

Earthquakes have never taken place larger than magnitude 7 after the great 1923 Kanto earthquake at the Kanto basin, many large structures, high-rise, base-isolated buildings and fuel

tanks, with long natural period have been constructed in decades. Strong earthquake motions have not subjected such kind of large structures. Figure 1 shows the distribution of these structures. Many structures concentrate around the Tokyo-bayside. Especially, the fuel tank at the industrial area around Tokyo-bay has the various natural periods based on the size of tank and liquid volume. Taking the recent disaster, in 2003 Tokachi-oki earthquake, some fuel tanks burned for two days at Tomakomai. Figure 2 shows the wave plot with EW component from strong motions site near the epicenter to Tomakomai, and long period motions were amplified around Tomakomai. It has been proposed that long period components are excited by deep sediment to seismic bedrock. Thus, the survey of deep underground structures and the amplification characteristics of long period earthquake motions have been important problems in case of next great earthquake associated with Tokai-earthquake and South-Kanto earthquake. In this paper, we used the strong motions data of two earthquakes observed on July 2000 at K-Net and SK-Net in the Kanto basin (Fig.3).

3. EFFECTS OF SURFACE WAVES GENERATED IN DEEP SEDIMENTARY BASIN

3.1 Features of Surface Waves in The Kanto Basin on July 2000 earthquakes

Many researchers have studied the propagation of long period strong motions in the southern part of the Kanto basin. For example, Fig.4 shows the trajectories of horizontal velocity using observed earthquake motions at the southern part of Tokyo by Koketsu *et al.* (2000). Similarly, we made the trajectories map including the Boso peninsula to understand the propagation at all of Kanto basin (Fig.5). Trajectories were made for long-period motions filtered from 6 to 12 s. We reconfirmed that surface waves generated from two different directions, the epicenter and the western mountain area in the Kanto basin from Fig.5. Besides, we remarked that two earthquakes have the different feature in terms of the amplification between the eastern and western part of Tokyo-bayside. Thus, we focused on this peculiarity, and separated Tokyo-bayside into three areas; western, northern and eastern, to compare with the surface waves characteristics. Figure 6 shows velocity Fourier spectra at each area with 15 July 2000 (EQ.1) and 30 July 2000 (EQ.2). And the wave-plots of time histories filtered around dominant periods on EQ.2 are shown Fig.7. These spectra have the eminent peak with long period, but their predominant periods are not same on each earthquake. In the case of EQ.1 (Fig6 (a)-(c)), predominant periods at the almost sites are from 7 to 9s, and only eastern area have the wide band periods including 10s. These components still remain the high amplitude even around northern area. In the case of EQ.2 (Fig6 (d)-(f)), almost sites have the predominant period between from 8 to 12s. The amplitude at western area and northern area are same, but ICH, CHB014 and SOD at the eastern area are higher than other area. The group velocity at the eastern area inferred from Fig.7 is slower than western area. As the surface waves propagate toward northern part of the Boso peninsula, they are amplified gradually.

3.2 Peculiar Case of Amplification Characteristics at The Boso Peninsula

As mentioned in the preceding section, the amplification characteristics at the eastern area of Tokyo-bayside are different from other area. Figure 8 shows the comparison of the multiple filtered ground motions with three sites, CHB023, CHB015 and CHB014. Earthquake motions on EQ.1 and EQ.2 are composed of the different wave band. Collections of marked periods are two; from 6 to 8s and from 9 to 12s. In periods of the former, Fig.8 (d)-(f) did not contain these phases, and amplitude of these phases at CHB014 is not higher than CHB023 in Fig.8 (a)-(c). That is to say, Love waves of the period from 6s to 8s were hardly excited at the Boso peninsula in the case of July 2000 earthquakes. The other hands, surface waves with period range from 9s to 12s were amplified much higher than other periods as these phases propagate toward northern parts of Boso peninsula. Next,

we use the 3D underground structural model in the Kanto basin by Yamada *et al.* (2003) shown Fig.9 to consider about this cause. The central part of the Boso peninsula have the most deepest sedimentary to the seismic bedrock. Also above layers with an S-wave velocity of 1.7km/s and 1.0 km/s are deeper than other area. Figure 10 is the dispersion curve of Love wave group velocity calculated using structural model by Table.1 excerpted from Fig9. Airy phase in which surface waves are excited can be seen around 10s. Therefore, these Love waves are amplified highly by these deep sedimentary layers located at central the Boso peninsula.

4. EXPECTATED SURFACE WAVES DURING MAJOR EARTHQUAKE

The scale of predicted magnitude for next major earthquakes at the Kanto basin is larger than 7. Figure 11 shows the observed spectral acceleration amplitude at bedrock by Ohta *et al.*(1976). The larger the magnitude of earthquake is, the longer periods surface motions are excited at the epicenter. Earthquakes of magnitude 7 or more have the prevailing energy with period of 10s. Thus, if the major earthquake occurs near the Kanto basin, the earthquake motions with predominant period of 10 seconds will be amplified at the central Boso peninsula. These motions will affect to the fuel tank and large bridge rather than high-rise and base-isolated buildings.

5. CONCLUSION

We examined the effects of surface waves generated in Kanto basin on a series of Izu earthquake on 15 July and 30 July 2000. Firstly, we remarked that two earthquakes have the different feature in terms of the amplification between the eastern and western part of Tokyo-bayside. Especially, the amplitude with period of 10s at the central Boso peninsula was much higher than other area. Next, we calculated the Love wave group velocity using the model of deep underground structure to consider this phenomenon. In the result, we confirmed that surface waves amplified by the deep sedimentary layers at the central Boso peninsula. These long period motions have the potential to cause the disaster of large structures, e.g. fuel tank.

Acknowledgments:

Observed Strong motions in this paper by National Research Institute of Earth Science and Disaster Prevention, K-NET and Seismic Kanto Research Project, ERI, Univ. Tokyo, SK-NET.

Reference:

- Kinoshita, S., Fujiwara, H., Mikoshiba, T., and Hoshino, T., (1992), "Secondary Love waves observed by a strong motion array in the Tokyo lowlands, *J. Phys. Earth*, **40**, 99-116.
- Zama, S. (1992) "Characteristics of long-period ground motions in Tokyo bay area, Japan", Proc. 10th World Conf. Earthq. Eng., 593-598.
- Koketsu, K. and Kikuchi, M. (2000) "Propagation of seismic ground motion in the Kanto basin, Japan", SCINENCE, **288**, 1237-1239.
- Koketsu, K. and Higashi, S. (1992) "Three-dimensional topography of sediment / basement interface in Tokyo metropolitan area, central Japan", *Bull. Seism. Soc. Am.*, **82**, 2328-2349.
- Miura, H., Midorikawa, S. and Kinoshita S. (2000) "Characteristics of Love wave propagation in the southern part of the Kanto basin", Proc. 6th Intern. Conf. Seismic Zonation, No.00019
- Miura, H. and Midorikawa S., "Effects of 3-D deep underground structure on characteristics of rather long-period ground motion -Examination in and around Yokohama City -", *JISIN*, **54**, 381-395. (in Japanese)
- Sato, T., R. W. 10Graves, and P. G. Somerville (1999), "Three-dimensional finite-difference simulations of long-period strong-motions in the Tokyo metropolitan area during the 1990 Odawara Earthquake (MJ 5.1) and the Great 1923 Kanto Earthquake (MS 8.2) in Japan", *Bull. Seism. Soc. Am.*, **89**, 579-607.
- Yamada, N. and Yamanaka, H. (2003) "Ground motion simulations of moderate earthquakes for comparison of performance of 3D subsurface structural models in Kanto plain for strong motion prediction", *JISIN*, **56**, 111-123. (in Japanese)
- Ohta, Y., and Kagami, H., (1976) "Ultimate values of period and amplitude on seismic input motions in relation to a large-scale structure, **249**, 53-60. (in Japanese)

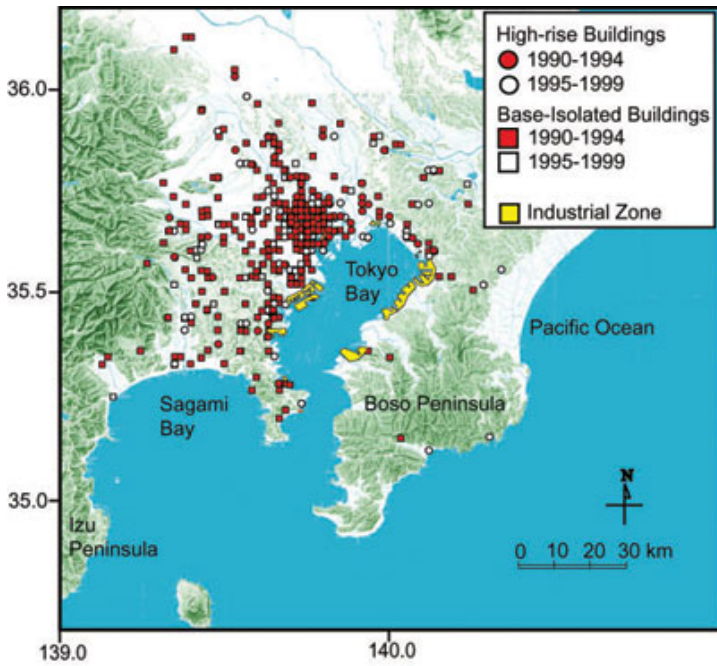


Figure 1 Distribution of large structures with long natural period, high-rise, seismically isolated buildings and fuel tanks.

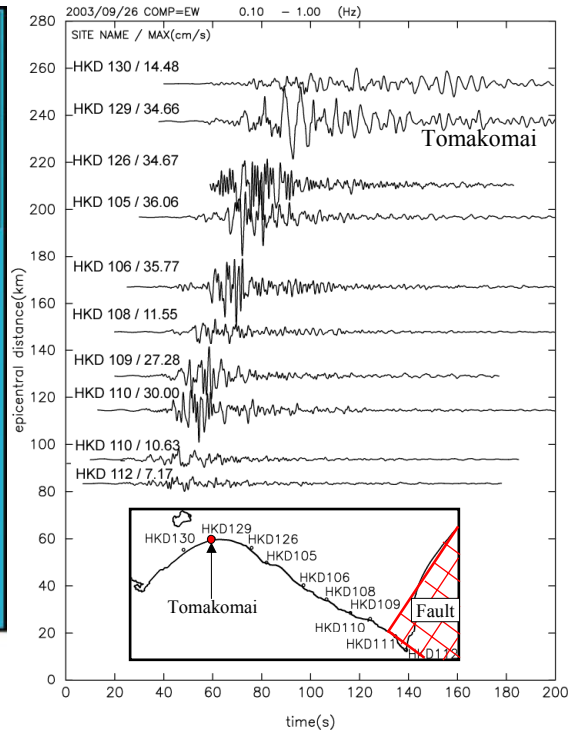


Figure 2 The velocity waves of E-W component with period of 1 to 10s from near fault site to Tomakomai on 2003 Tokachi-oki earthquake.

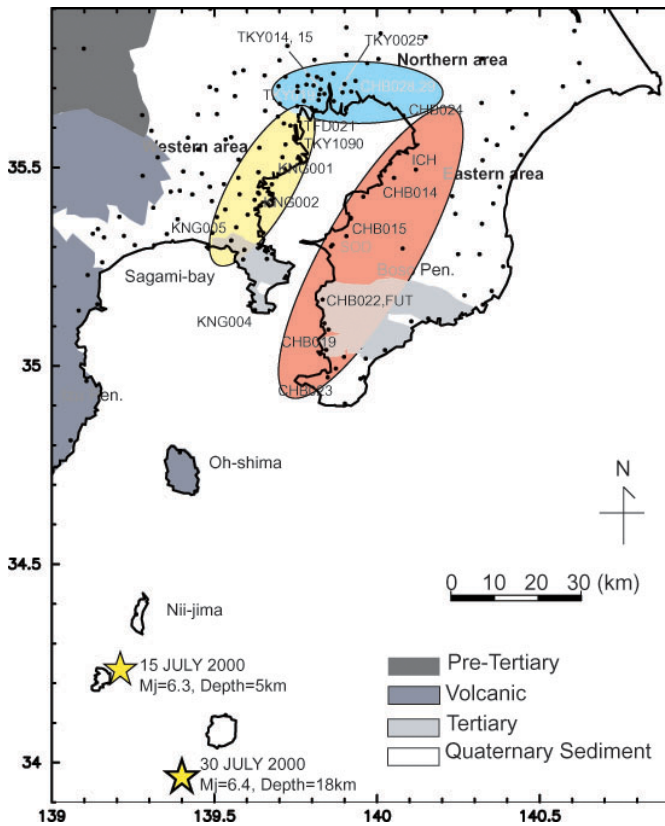


Figure 3 The strong motion sites observed on July 2000 earthquakes at the K-Net and SK-Net in the Kanto basin

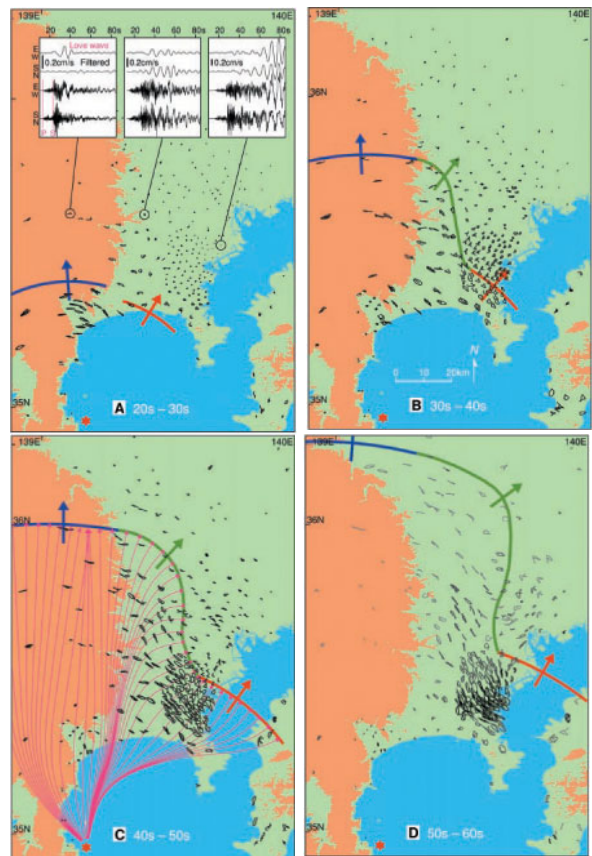
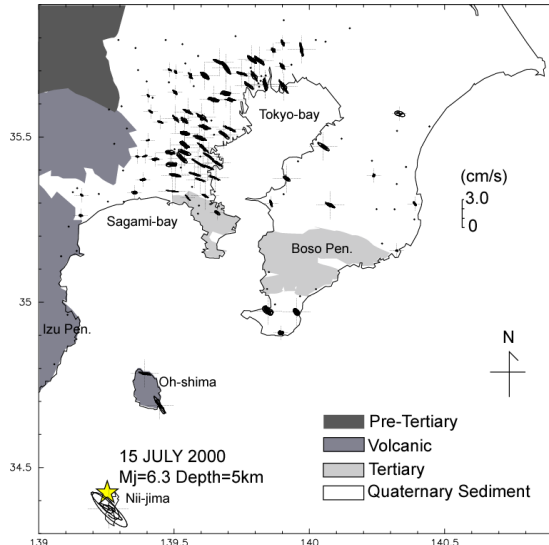
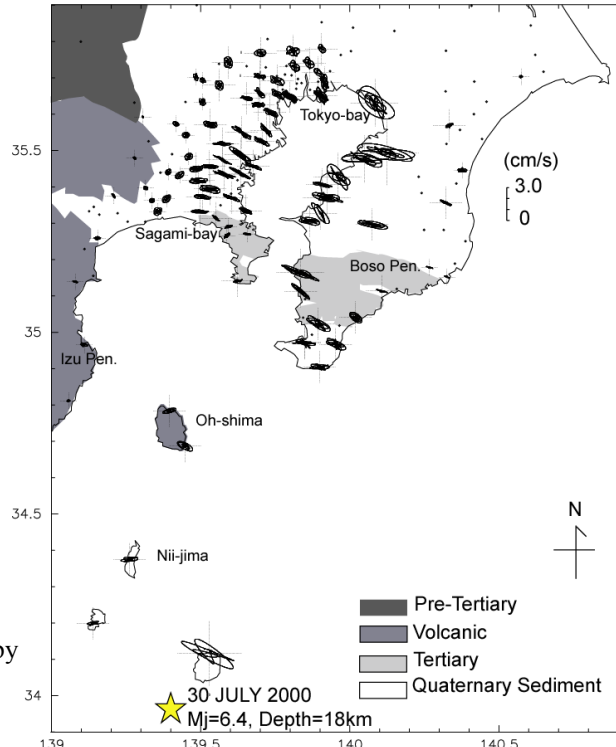


Figure 4 The trajectories of horizontal velocity at the southern part of the Kanto basin using the southwest of Tokyo earthquake 3 May 1998 (M5.7) by Koketsu *et al.* (2000)

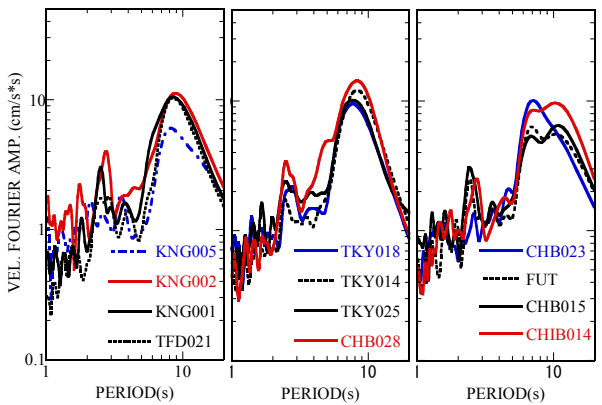


(a) 15 July 2000 (M6.3, Depth=5km)

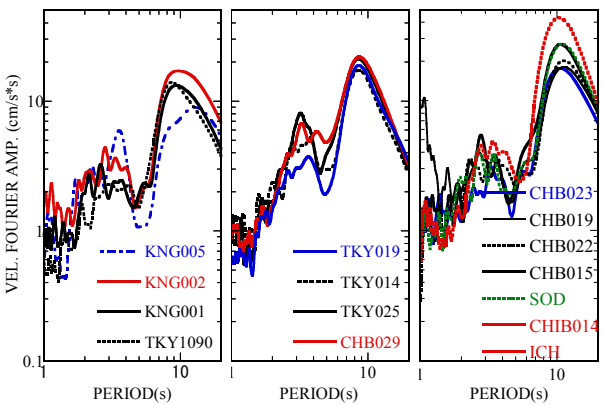


(b) 30 July 2000 (M6.4, Depth=18km)

Figure 5 Trajectories map in the Kanto basin by a series of Izu earthquakes on July 2000; (a) 15 July 2000, (b) 30 July 2000

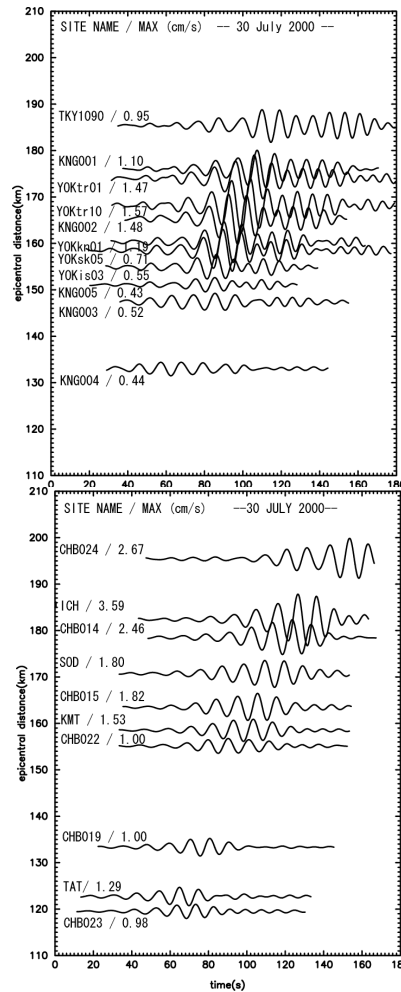


(a) Western area (b) Northern area (c) Eastern area



(d) Western area (e) Northern area (f) Eastern area

Figure 6 Fourier spectra of ground motions on July 2000 earthquakes; (a) – (c) : 15 July 2000 (d) – (f) : 30 July 2000



(a) Western area

(b) Eastern area

Figure 7 Velocity wave pest-up with period of 7 to 12 s on 30 July 2000

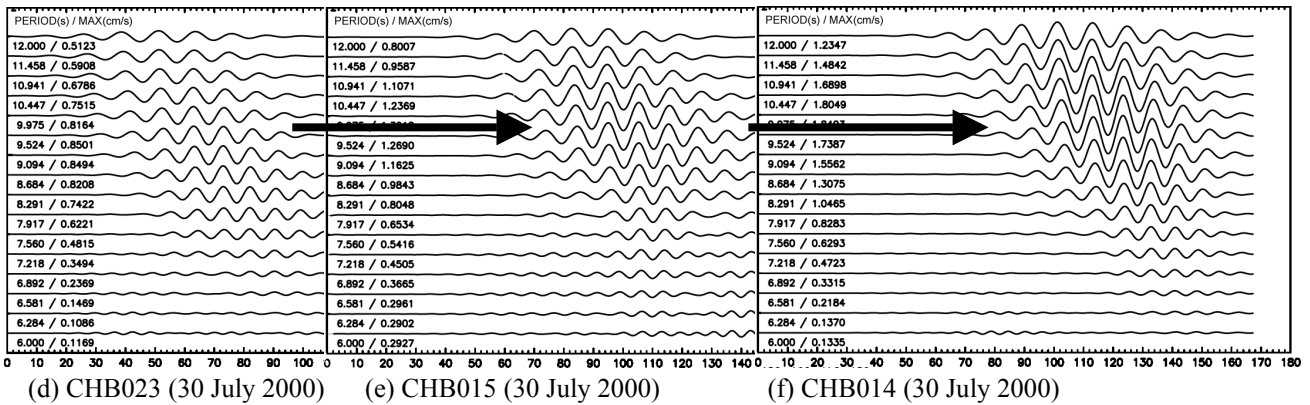
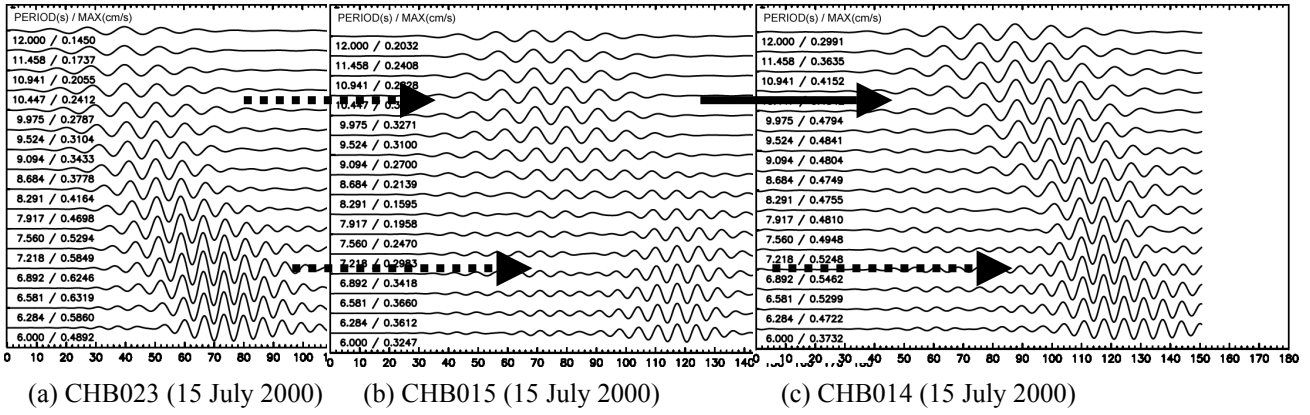


Figure 8 Observed ground motions with multiple filtered from 6 to 12 s at the CHB023, CHB015 and CHB014

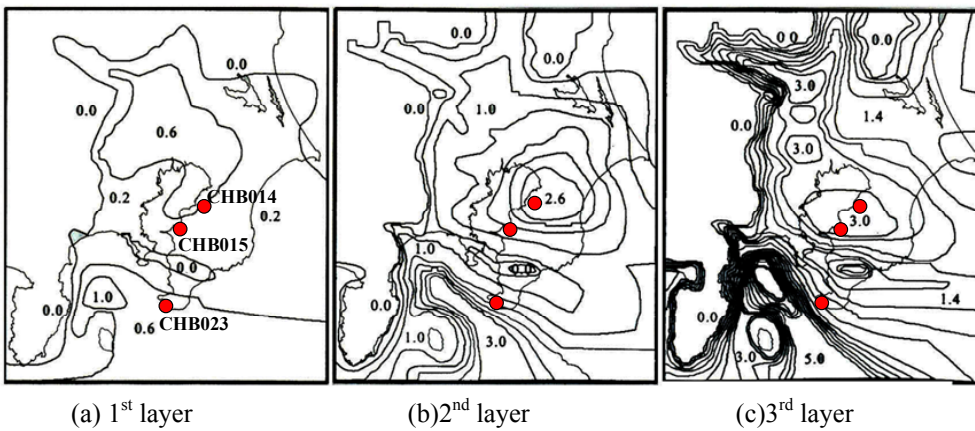


Figure 9 3D underground structural model in the Kanto basin by Yamada *et al.* (2003) and Location of strong motion sites, CHB023, CHB015 and CHB014. Each number shows the depth of km.

Table.1 Physical parameters at the CHB014 from Fig.9

Layer	Depth (km)	Vs(km/s)	$\rho(g/cm^3)$	Q
1	0.6	0.5	1.9	100
2	2.6	1.0	2.1	100
3	3.0	1.7	2.3	150
4	-	3.0	2.5	300

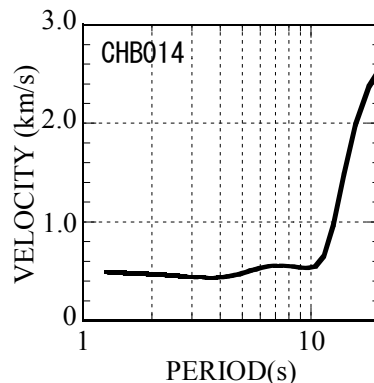


Figure 10 Dispersion curve of Love wave group velocity at CHB014

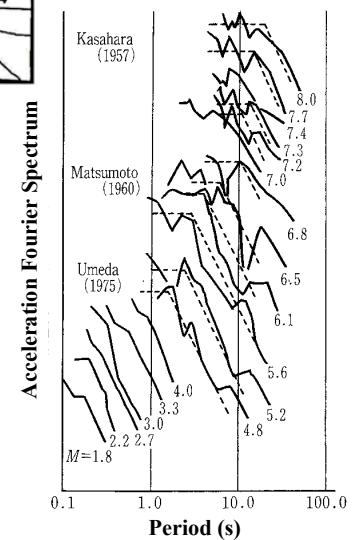


Figure 11 Observed acceleration spectrum on rock site by Ohta *et al.* (1976).