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A STUDY ON SURFACE WAVES GENERATED IN THICK SEDIMENTARY LAYERS DURING MAJOR EARTHQUAKES

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SUMMARY

In the Kanto basin, Japan, when we consider the case of next great earthquake, long period seismic motions will appear as the result of surface waves excited by thick 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 and Yamanaka (2003), we confirmed that this component was amplified by the thick sedimentary layers at the central Boso peninsula. These amplified surface waves have the potential to cause the disaster of huge fuel tanks during major earthquakes.

INTRODUCTION

In the Kanto basin including the Tokyo bay area, when we consider the case of next great earthquake, long period component will appear as the result of surface waves excited by thick 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 and Kikuchi (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 and Higashi (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 the1923 great Kanto earthquake are performed by Sato *et al.*(1999). Yamada and Yamanaka (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 of July 2000.

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DISTRIBUTION OF LARGE STRUCTURES AROUND TOKYO-BAYSIDE AREA AND THE RISK OF SURFACEWAVES EXCITED BY THICK SEDIMENTARY LAYERS

Earthquakes have never taken place larger than magnitude 7 after the 1923 great Kanto earthquake in the Kanto basin. Many large structures, high-rise, base-isolated buildings and fuel tanks, with long natural period have been constructed there in decades. Strong earthquake motions have not subjected such kind of large structures. Figure 1 shows the distribution of them in the Kanto basin. Especially, fuel tanks at the industrial zone around Tokyo-bay has the various natural periods based on the scale of tank and liquid volume. Taking the recent disaster, in 2003 Tokachi-oki earthquake (M8.0, Sep. 26, 2003), two fuel tanks with fundamental period of 7s burned for two days at Tomakomai. Figure 2 shows the wave plot with EW component from observation site of near fault to Tomakomai site. High amplitude with long period at the Tomakomai were amplified by around the ground characteristics. It has been proposed that thick sedimentary layers to seismic bedrock excited long period components. Thus, the 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.

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)

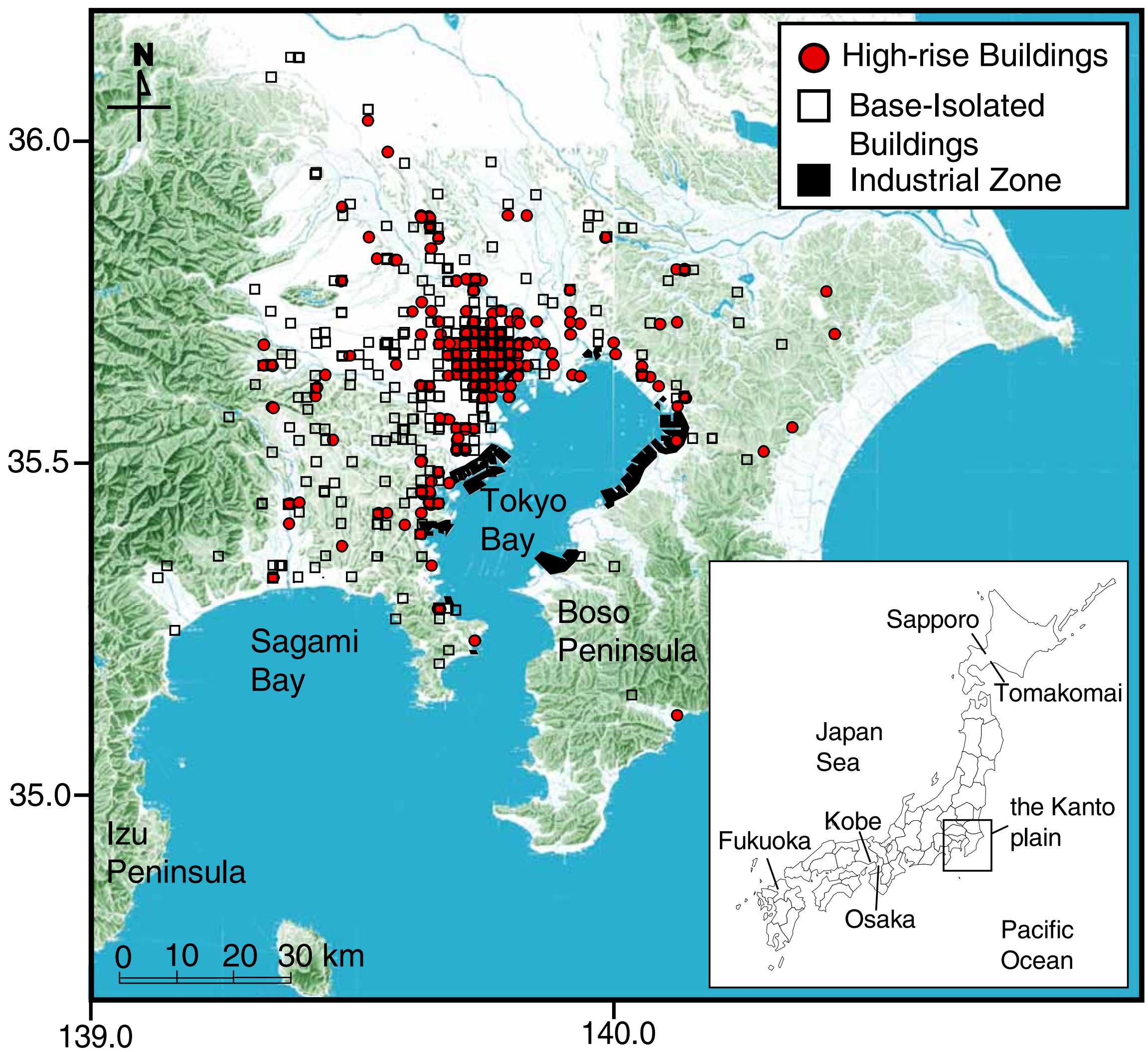


Figure 1 Distribution of large structures with long natural period, high-rise, seismically isolated buildings and industrial zone clouding fuel tanks in the Kanto basin, Japan.

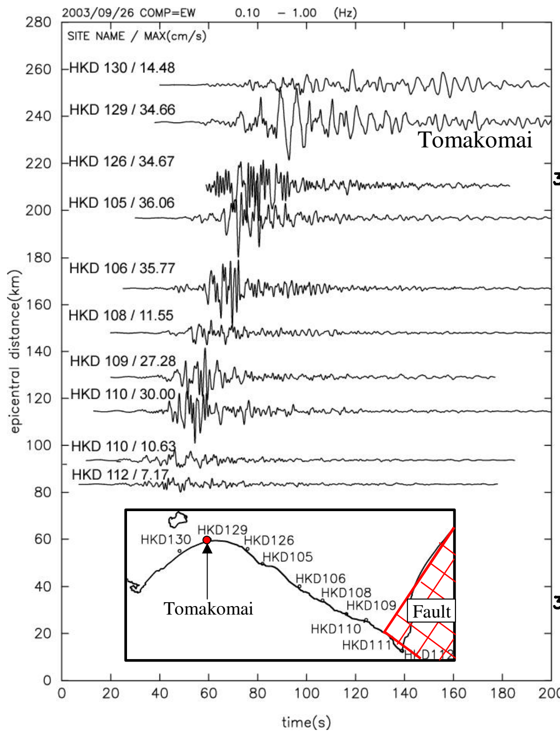


Figure 2 The velocity seismograms of E-W component with period of 1.0 to 10s from near fault site to Tomakomai on the 2003 Tokachi-oki earthquake (M8.0).

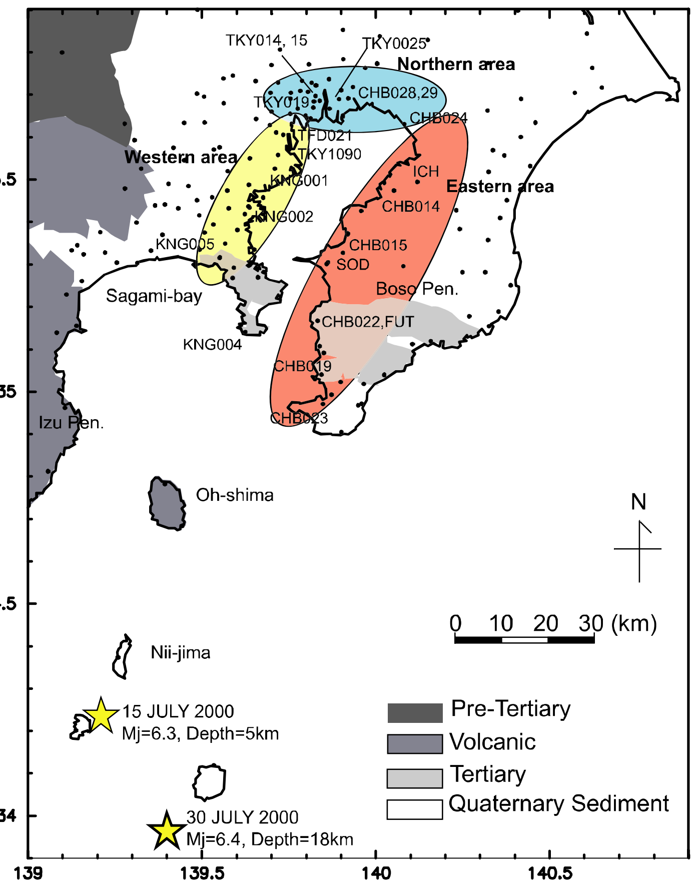


Figure 3 K-Net and SK-Net strong motion sites in the Kanto basin and epicenters of the July 2000 earthquakes.

SURFACE WAVES GENERATED IN THICK SEDIMENTARY LAYERS IN THA KANTO BASIN

Propagation of Surface Waves during the 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 after Koketsu and Kikuchi (2000). Similarly, we made the trajectories map including the Boso peninsula (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 phenomenon, 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 July 15, 2000 (EQ.1) and July 30, 2000 (EQ.2). And Fig.7 is the wave-plots of time histories filtered around dominant periods on EQ.2. Fourier spectra have the eminent peak with long period, but 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 periods longer than 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 from 9 to 12s. The Fourier 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.

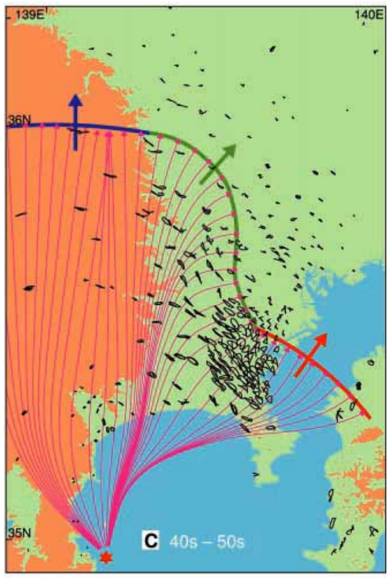
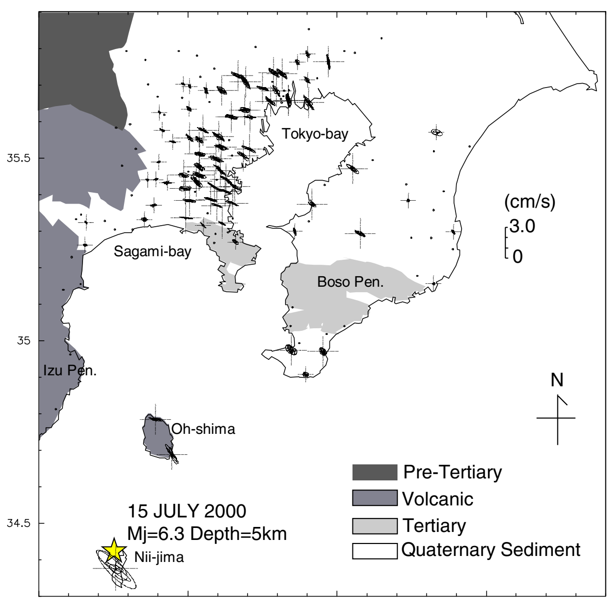
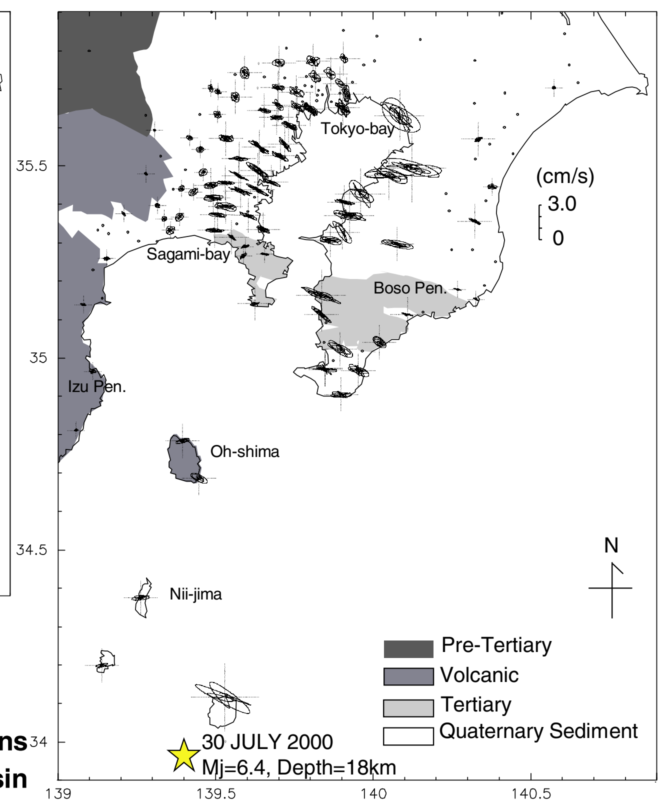


Figure 4 The trajectories of horizontal velocity motions in the southern part of Tokyo for the southwest of Tokyo earthquake of May 3, 1998 (M5.7) after Koketsu and Kikuchi.

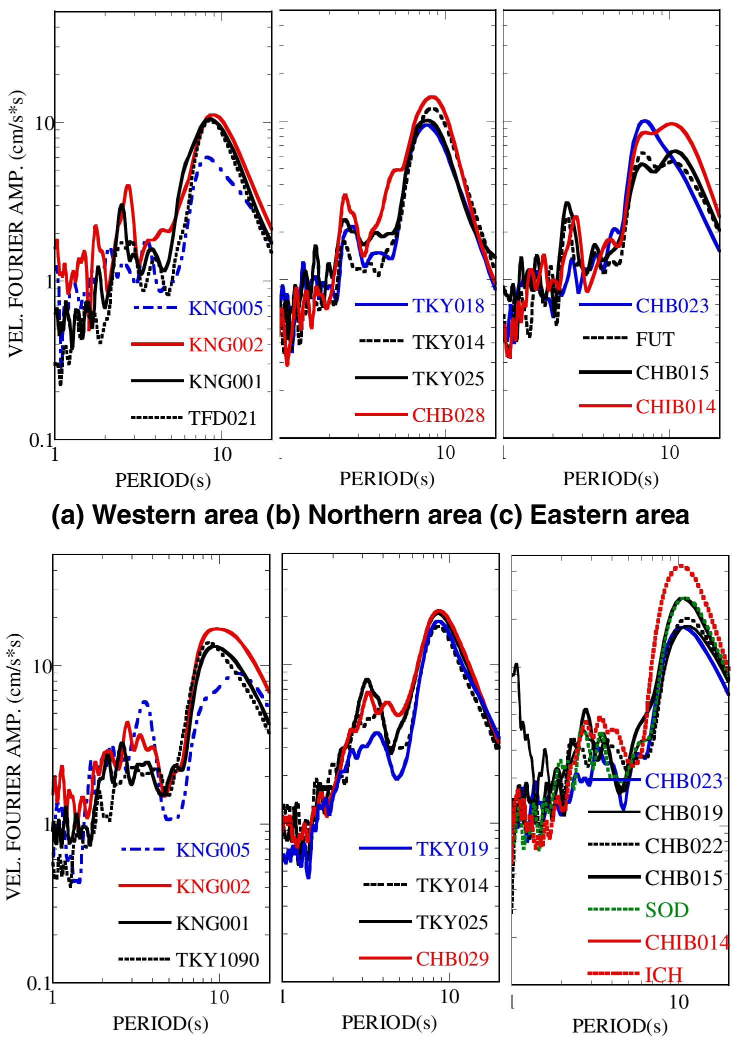


(a) July 15, 2000 (M6.3, Depth=5km)



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

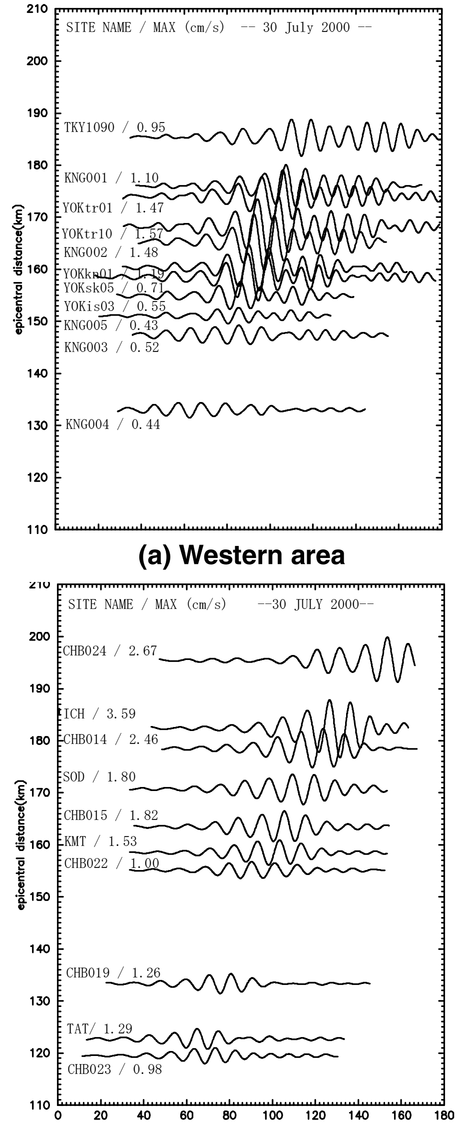
Figure 5 Trajectories map of velocity motions with long period from 6 to 12s in the Kanto basin by a series of Izu earthquakes of July 2000; (a) 15 July 2000, (b) 30 July 2000.



(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 for July 2000 earthquakes;
(a) – (c) : July 15, 2000 (d) – (f) : July 30, 2000



(a) Western area

(b) Eastern area

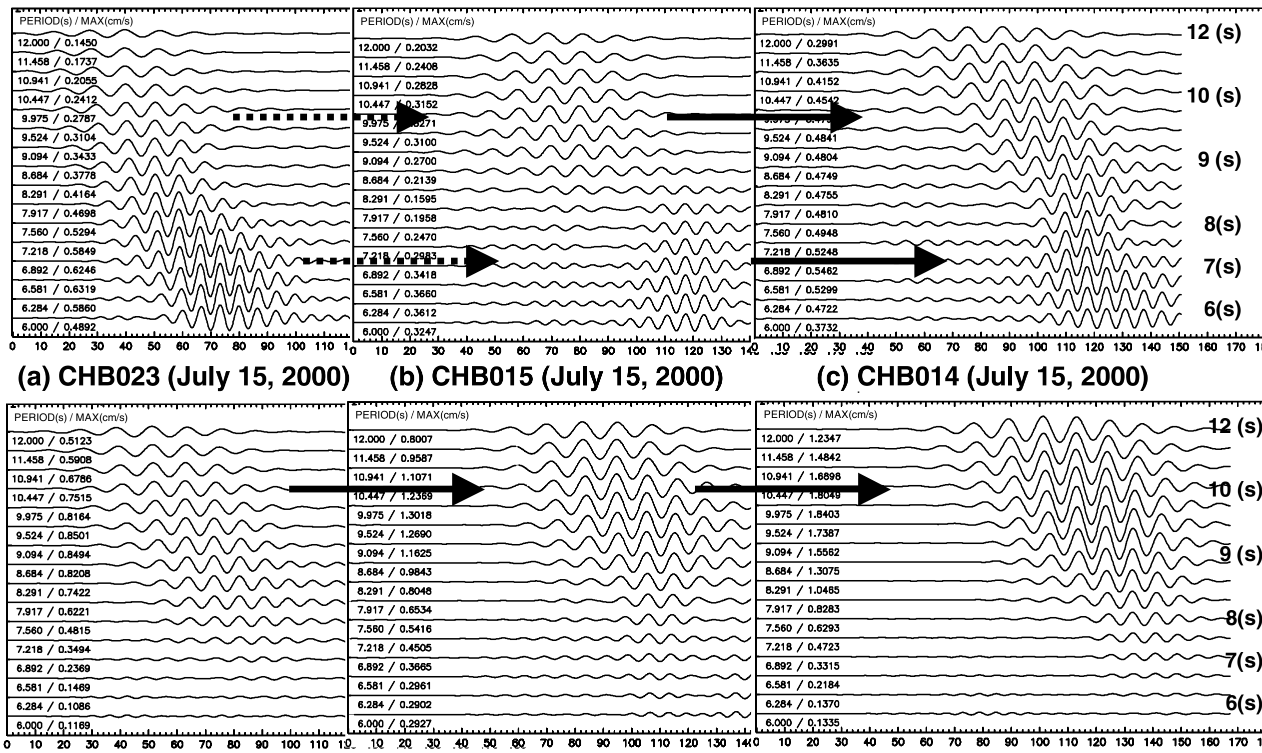
Figure 7 Velocity motions paste-up with period range from 7 to 12 s for the earthquake of July 30, 2000.

Amplification Characteristics in the Boso Peninsula (Eastern Part of Tokyo-bayside)

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

To consider about the different amplification between eastern and western area, we use the 3D underground structural model in the Kanto basin after Yamada and Yamanaka (2003) shown Fig.9. The central part of the Boso peninsula has the deepest to the seismic bedrock (Vs=3.0 km/s) in the Kanto basin.

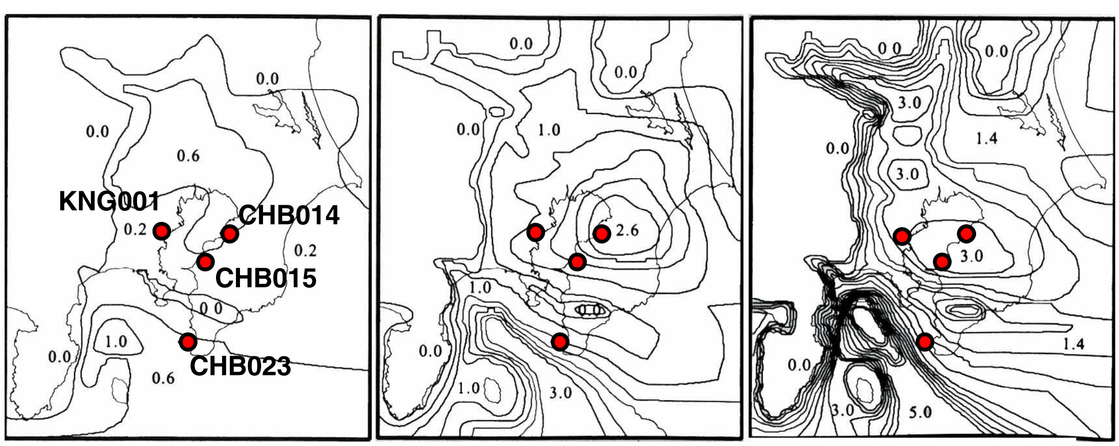
Other layers with an S-wave velocity of 1.7 km/s and 1.0 km/s are also deeper than other area. Table.1 is 1D underground structural model at KNG001 and CHB014 excerpted from Fig.9, and Fig.10 is the dispersion curve of Love wave. Airy phase in which surface waves are excited can be seen around 10s at CHB014. But then, Airy phase of KNG001 is around 7-8s. Therefore, Love waves with period of 10s are amplified highly by these thick sedimentary layers located at central the Boso peninsula. EQ2 (July 30, 2000) including the long period motions from 9 to 12s represented these amplification characteristics remarkably from observed strong motions.



(a) CHB023 (July 15, 2000) (b) CHB015 (July 15, 2000) (c) CHB014 (July 15, 2000)

(d) CHB023 (July 30, 2000) (e) CHB015 (July 30, 2000) (f) CHB014 (July 30, 2000)

Figure 8 Observed ground motions with multiple filtered from 6 to 12 s at the CHB023 CHB015 and CHB014; (a) – (c) : July 15, 2000 (EQ.1) (d) – (f) : July 30, 2000 (EQ.2)



(a) 1st layer (b)2nd layer (c)3rd layer

Figure 9 3D deep structural model in the Kanto basin by Yamada and Yamanaka (2003) and Location of strong motion sites, CHB023, CHB015, CHB014 and KNG001. Each number shows the depth in km.

Table 1 Physical parameters at CHB014 and KNG001.

				KNG001	CHB014
Layer	Vs(km/s)	ρ(g./cm3)	Q	Depth (km)	
1	0.5	1.9	100	0.2	0.6
2	1.0	2.1	100	1.4	2.6
3	1.7	2.3	150	3.0	3.0
4	3.0	2.5	300	-	-

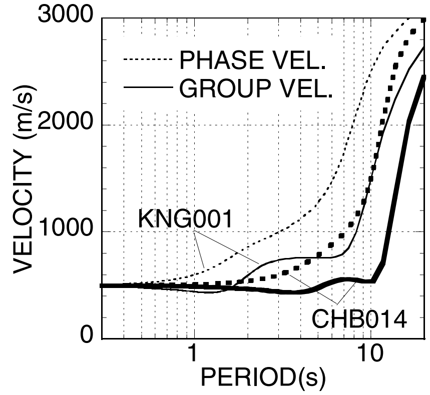


Figure 10 Dispersion curve of Love wave at CHB014 and KNG001.

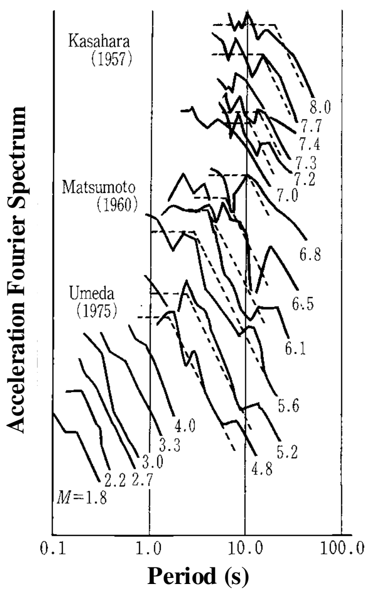


Figure 11 Observed acceleration spectra on rock site, after Ohta and Kagami (1976).

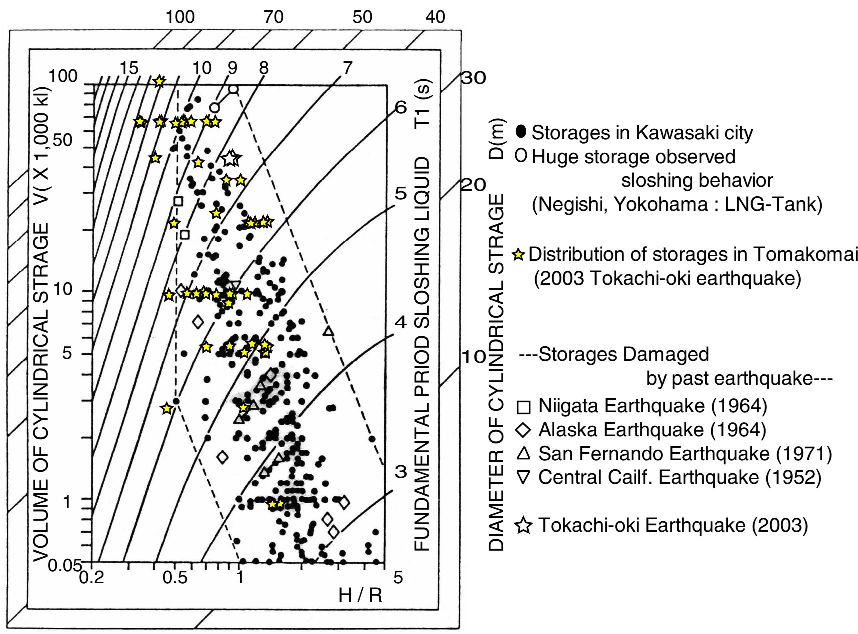


Figure 12 Relationship between scale of storages (fuel tanks) and sloshing fundamental period. (retouched in Seo(1982))

EXPECTATED SURFACE WAVES DURING MAJOR EARTHQUAKES

Predicted magnitude of next major earthquake at the Kanto basin is larger than 7. Figure 11 shows the observed spectral acceleration amplitude at bedrock after Ohta and Kagami (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 next Kanto earthquake or Tokai earthquake occurs, the earthquake motions with predominant period of 10s will be amplified at the central Boso peninsula. These long period motions have the potential to cause the disaster of large structures, e.g. fuel tank. Past major earthquakes have occurred the disaster of fuel tanks too. Figure.12 is the relationship between scale of storages and sloshing fundamental period by Seo (1984), and we were retouched the distribution of fuel tanks at Tomakomai on 2003 Tokachi-oki earthquake in this figure. Sloshing periods of damaged storages by past earthquake and storages in Kawasaki city (near KNG001) distribute throughout between 2.5s to 12s. This figure suggests that some fuel tanks will draw resonance phenomena even if any large earthquake will happens. There are fuel tanks with several periods at the industrial zone around Tokyo-bay. But if the target periods at the central Boso penisula are around 10s, we can point out the scale of tank with risk of sloshing phenomena during major earthquake from fig.11. In this case, volume of cylindrical storage is from 40,000 to 100,000 kl and ratio of liquid height and radius of cylindrical storage is from 0.3 to 0.8.

CONCLUSION

We examined the surface waves generated in Kanto basin during a series of Izu earthquake on July 15 and July 30, 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. To consider this phenomenon, we calculated the Love wave group velocity using the model of deep underground structure and confirmed that surface waves amplified by the thick sedimentary layers at the central Boso peninsula. These long period motions have the potential to cause the disaster of fuel tanks during major earthquakes.

ACKNOWLEDGMENTS

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