Examination of a Simple Ground Model to Estimate Local Seismic Waves in an Irregular Ground Area

Munetatsu Horiike[1], Shinsaku Tagawa[2] and Masayuki Kohiyama[3]

[1] *Student, Graduate School of Science and Technology, Keio University, Yokohama, Japan*
[2] *Formerly Student, Graduate School of Science and Technology, Keio University, Yokohama, Japan*
[3] *Associate Professor, Graduate School of Science and Technology, Keio University, Yokohama, Japan*
Email: horililo@yahoo.co.jp, kohiyama@sd.keio.ac.jp

ABSTRACT:

Accuracy of estimated seismic waves using a one-dimensional ground model is examined. Hiyoshi Area in Yokohama is focused, which has relatively complicated topography. First, two one-dimensional layered ground models are prepared: Model 1, a four-layered model based on a boring log and Model 2, a two-layered model based on airborne laser profiler and geological cross sections. Seismic records with peak ground acceleration 8 to 141 cm/s^2 are used for analysis, which were observed by six seismic stations in the study area. Incident waves at bedrock level of each observation point are calculated by one-dimensional equivalent linear analysis. Two ground models are compared with respect to acceleration response spectra. Then, acceleration response spectra at bedrock level at each observation point are compared in regard to each earthquake event. The results suggest that it is necessary to increase the spatial density of bedrock data to make an accurate ground model and to consider influence of surface waves and oblique incidence in regard to the studied area.

KEYWORDS: Simplified Ground Model, One-Dimensional Equivalent Linear Analysis, Irregular Ground

1. INTRODUCTION

In the 1995 Hyougo-ken Nanbu earthquake, information on the damage due to the earthquake was not transmitted accurately and promptly, and smooth response was not conducted sufficiently due to the lack of information. After this lesson, seismometer networks have been rapidly instrumented by national and local governments, and education and research entities. For example, Yokohama City has 150 seismic stations at 2 km intervals in mainly the fire station, and the city assesses and estimates earthquake damage using 50-meter-mesh ground model. Using this dense strong motion network and ground model, Yokohama City established Real-time Assessment of earthquake Disaster in Yokohama (READY) (Abe and Suzuki 2000). The data observed by the dense strong motion network show regional differences of JMA seismic intensity from 1 to 2 in the city area. Hence, in certain point which is distant from seismographs network, it is necessary to prepare appropriate ground model and to estimate local seismic wave for accurate estimation of damage or comprehending of damage after earthquake. Now using boring log and geological cross section surveyed by national and local governments, ground model is constructed to promote earthquake hazard map. But influence of different ground modeling is unclear. Therefore in this study, a certain area with relatively complicated topography in Yokohama is focused, and to examine influence of the modeling difference, estimated seismic waves is compared using two one-dimensional ground models.

2. STUDY AREA

In this study, Hiyoshi Area in Yokohama City is focused, which is shown in Figure 2.1. Yokohama City Government now deploys strong motion seismometers in 150 seismic stations and observed data has been publicized. However, in Yokohama, shape of the stratum composition of the ground is a complex in both subsurface and deep ground structures, and it is difficult to evaluate a local seismic ground motion in between seismometers. Moreover, a local seismic ground motion is influenced by the located ground that has such geotechnical features, and characteristics of seismic ground motion amplification changes in each area. Thus the ground models are constructed considering irregular ground condition as explained in the next section. Figure 2.1 shows six analysis points, Points A to F, at which the seismometers exists.

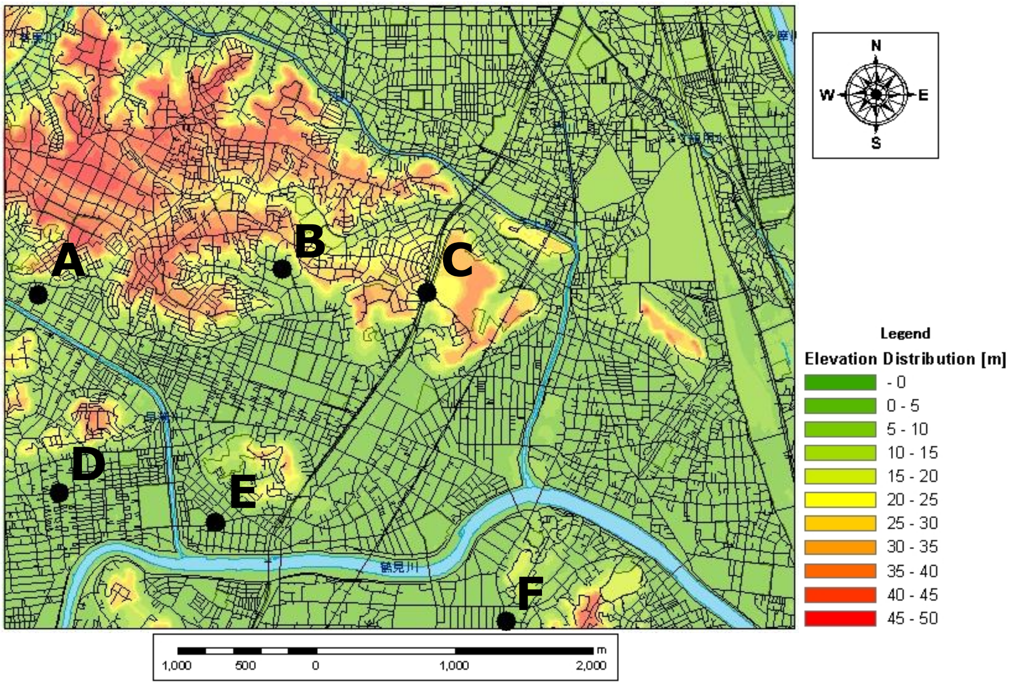
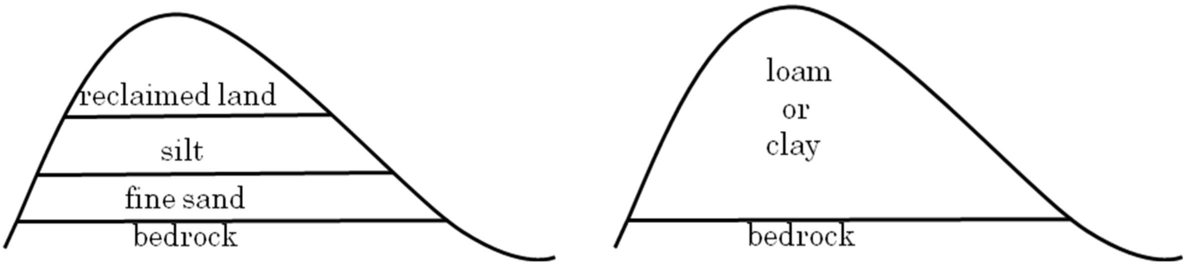


Figure 2.1 Elevation distribution of study area and locations of analysis points

3. MODELING OF GROUND

In this study, two one-dimensional layered ground models are compared; Model 1 (Figure 3.1a) is a detailed four-layered model based on a boring log at Point A to F, and Model 2 (Figure 3.2b) is a simplified two-layered based on geological cross section and boring log. The boring data of Kawasaki City is digitized based on geological maps (Environment Protection Bureau, Kawasaki City 1972 and 1983). The method to construct each ground model is described in the following sections.



a) Model 1 b) Model 2

Figure 3.1 Ground models

3.1. Model 1

Soil in an analysis point is classified into reclaimed land, silt, fine sand, and bedrock based on the borehole data at Point A to F (Institute of Environmental Sciences, Yokohama City 2003), and Model 1 has four ground layers. Moreover, the soil property of each layer is given based on the borehole data.

3.2. Model 2

Model 2 is constructed according to the following procedures: 1) Digital terrain model (5 m mesh) is made from a digital surface model acquired by an airborne laser profiler (PASCO Corporation. 2005). 2) Elevation data of tertiary deposit is extracted from boring log (Environment Protection Bureau, Kawasaki City 1972 and 1983; Institute of Environmental Sciences, Yokohama City 2003) and geological cross sections (Kawasaki City 1981; Office of Disaster Preparedness, General Affairs, City of Yokohama and OYO Corporation 1984) which is at 500 m intervals in both east-west and north-south directions. 3) These data are interpolated by the inverse distance weighted method using geographic information system. 4) From the above-mentioned data, ground model is classified into subsurface ground and bedrock. Furthermore, subsurface ground is classified into a loam layer or a clay layer. The soil property of each layer is set based on Koyamada et al. (2003) as shown in Table 3.1.

Table 3.1 Soil property of Model 2

Soil Type	Density [g/cm^3]	Shear Wave Velocity [m/s]	Basis Deformation [%]	Maximum Damping Ratio [%]
Loam	1.6	200	0.19	14
Clay	1.4	100	0.19	16
Bedrock	2.0	400	—	—

4. ANALYSIS METHOD

The seismic records of five earthquake events observed by the six seismic stations in Yokohama are used in this study as shown in Table 4.1. Removing amplification characteristics of subsurface ground from seismic record at ground surface, Incident wave at bedrock level of each point is calculated by one-dimensional equivalent linear analysis using the ground response analysis program, DYNEQ (Yoshida and Suetomi 1996) in regard to Models 1 and 2. Two ground models are compared with respect to relation between depth and shear wave velocity as well as acceleration response spectra at outcropped bedrock level.

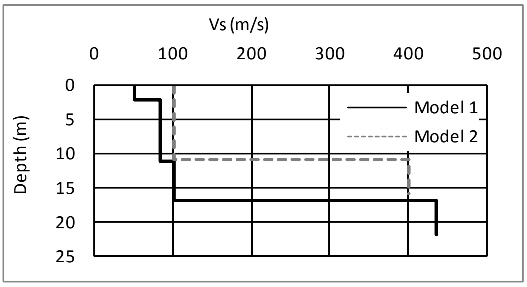
Table 4.1 Earthquake events of seismic record used in this study

No.	Date [Day Month Year]	Location	Epicentral Distance [km]	Depth [km]	Magnitude
1	11 04 2005	Northeast Chiba-ken	103	52	6.1
2	23 07 2005	Northwest Chiba-ken	57	73	6.0
3	20 06 2006	Northwest Chiba-ken	64	66	4.6
4	04 02 2007	Northwest Chiba-ken	58	67	4.3
5	16 07 2007	Offing Niigata-ken	242	17	6.8

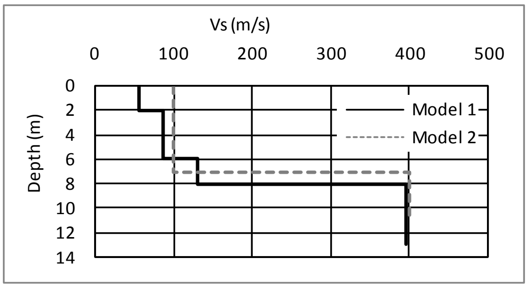
5. ANALYSIS RESULTS AND DISCUSSIONS

5.1. Shear Wave Velocity

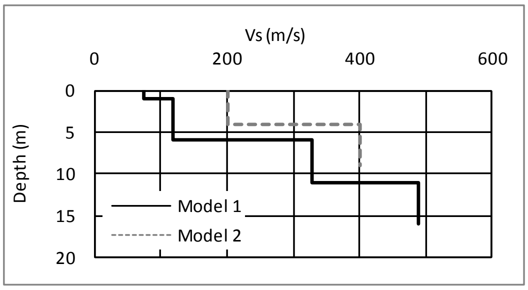
Relation between depth and shear wave velocity is shown for each model in Figure 5.1. The shear wave profile is not much different between two models at Point D. But at Point C, elevation of bedrock in Model 2 is higher than that in Model 1 and shear wave velocity is longer. This reason is due to the limited bedrock data and the difference is large especially in the center of 500 m mesh enclosed by geological cross sections. Thus, it is necessary to increase the spatial density of bedrock data to construct an accurate ground model. In addition, it is difficult to interpolate shape of rise or decline in complicated topography. Therefore interpolating method should be improved. The soil property of models cannot be applicable completely. Thus, it is necessary to use regional value for some analysis points.



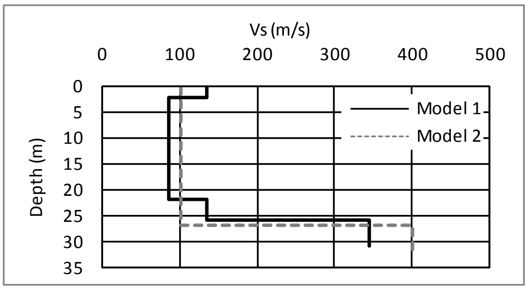
a) Point A



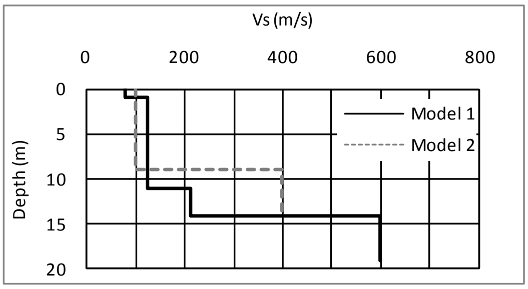
b) Point B



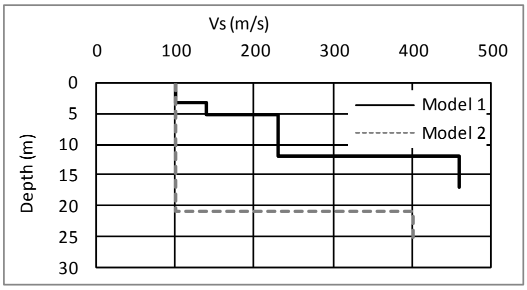
c) Point C



d) Point D



e) Point E

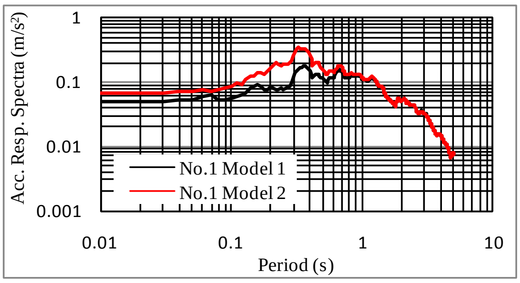


f) Point F

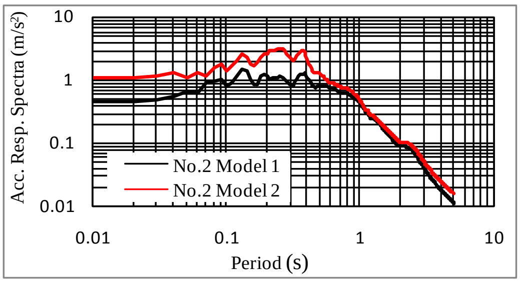
Figure 5.1 Relation between depth and shear wave velocity

5.2 Comparison of Acceleration Response Spectra between Two Models

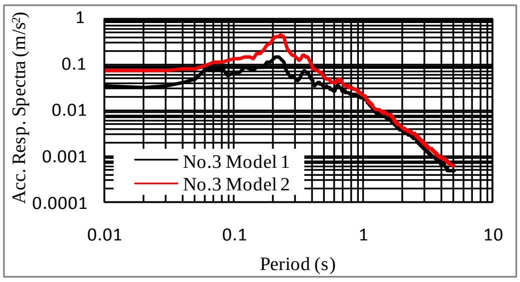
Regarding five earthquake events No. 1 to 5, acceleration response spectra (component of NS) of incident wave at outcropped bedrock level are calculated by one-dimensional equivalent linear analysis. The response spectra are compared between Models 1 and 2 as shown in Figure 5.2; as an example, results of Points C and D are shown. From Figure 5.2, in the long period range from 2 to 5 s, the response spectra are very close, but in the short period range, differences were observed at some analysis points as observed in Point C. At Point C, the peak value of Model 2 is about twice of that of Model 1. At these points, there are large differences in layer thickness and shear wave velocity between two models. In addition, the differences depend much on an earthquake which have long period component as the earthquake event No. 5. In other points, the response spectra is very close as observed Point D, but still a little difference is observed in regard to peak value. At these points, layer thickness and shear wave velocity of two models are relatively close. Hence it is obvious that layer thickness and shear wave velocity is very important to calculate the incident wave.



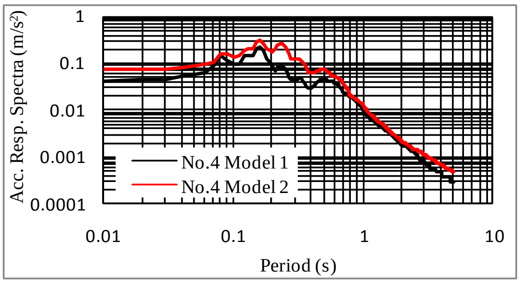
a) Point C, Event No. 1



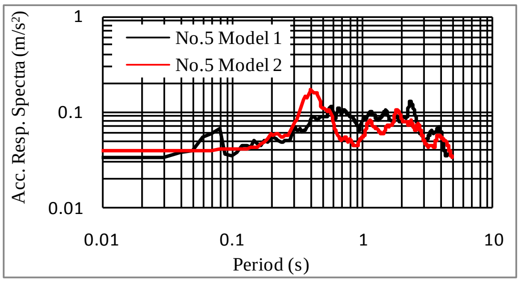
b) Point C, Event No. 2



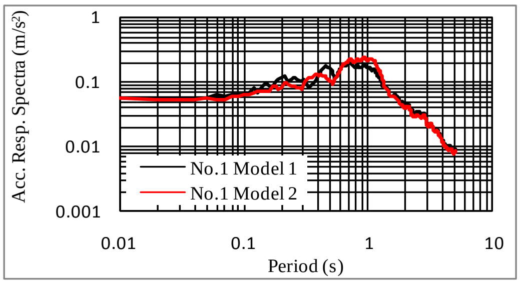
c) Point C, Event No. 3



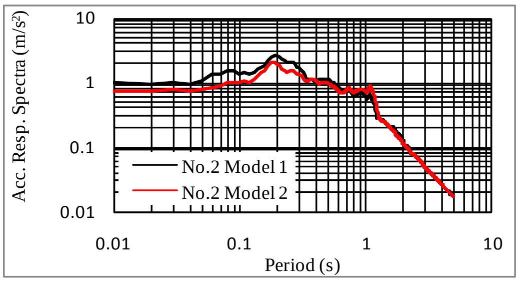
d) Point C, Event No. 4



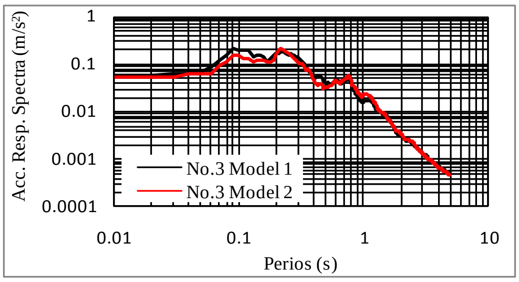
e) Point C, Event No. 5



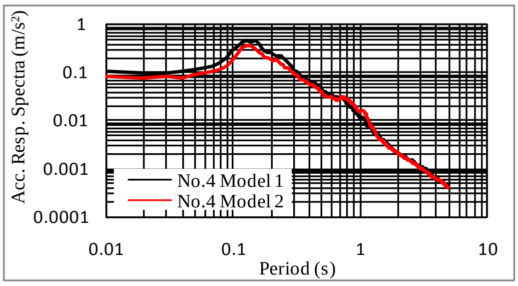
f) Point D, Event No. 1



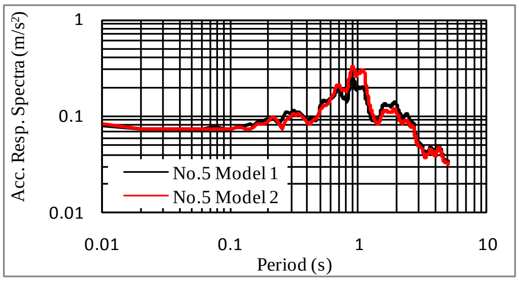
g) Point D, Event No. 2



h) Point D, Event No. 3



i) Point D, Event No. 4



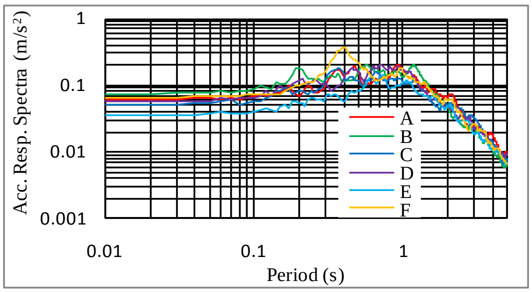
j) Point D, Event No. 5

Figure 5.2 Acceleration response spectra at outcropped bedrock level

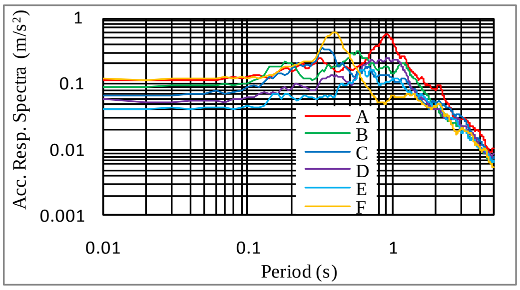
In whole, regarding Model 2, there are trends toward that the response spectra are overvalued compared with Model 1. Therefore, in Model 1, amplification characteristics of subsurface ground were successfully removed from seismic record at ground surface compared with Model 2.

5.3 Comparison of Acceleration Response Spectra among Analysis Points

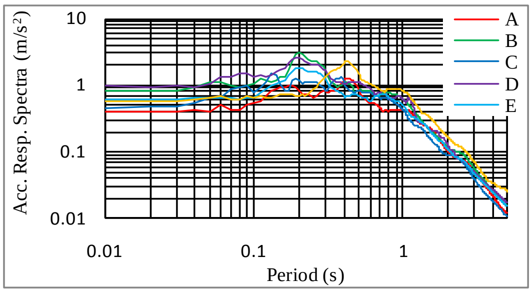
Then, acceleration response spectra (component of NS) at outcropped bedrock level at each observation point are compared in regard to all the earthquakes as shown in Figure 5.3. In this case, both models do not accord in the response spectra at any earthquake case. Especially in the short period range, peak values are much different. Neither ground model represents accurate seismic amplification characteristics of subsurface ground. For example, in regard to the earthquake events No. 2, 3, and 4, which occurred in almost the same region, the peak values at the Point B are overvalued compared with the other point. Because Point B is located at bottom of the narrow long valley and enclosed by cliff or steep slope, there are greater influence of an oblique incident wave, a refracted wave and a reflected wave by seismic ground motion from a certain direction. On the other hand, the difference of the response spectra is observed among analysis points in the case of the earthquake event No. 5 at not only short period range but also long period range. Because hypocentral distance is quite father than other earthquake, there is greater influence of a surface wave which include prominent long period component. Therefore it is necessary to consider influence of a surface wave and oblique incident wave in regard to the studied area.



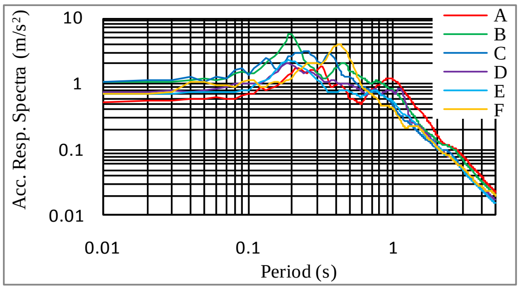
a) Model 1, Event No. 1



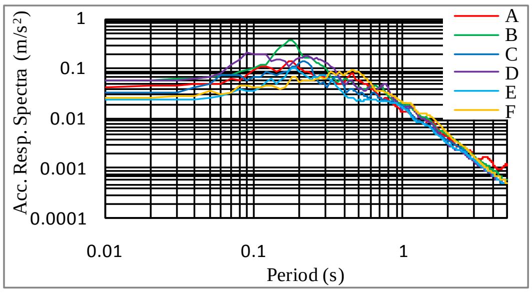
f) Model 2, Event No. 1



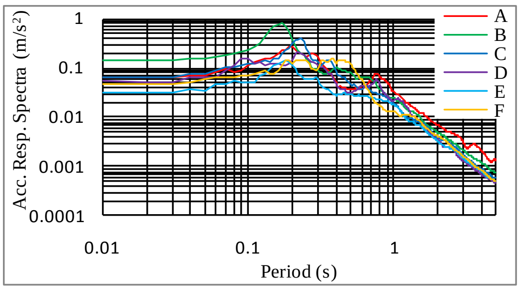
b) Model 1, Event No. 2



g) Model 2, Event No. 2

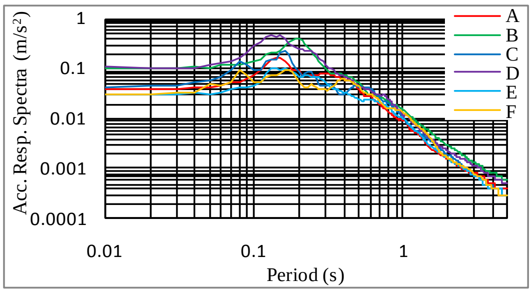


c) Model 1, Event No. 3

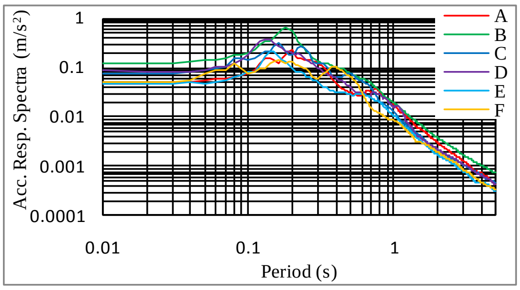


h) Model 2, Event No. 3

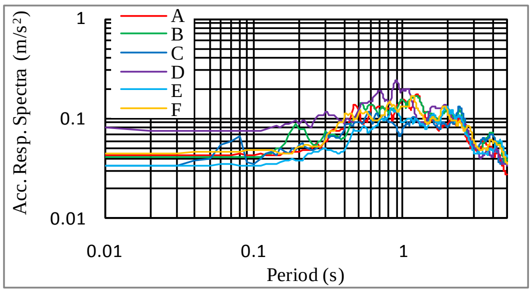
Figure 5.3 Acceleration response spectra at outcropped bedrock level



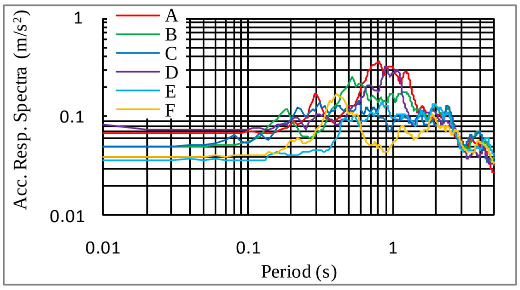
d) Model 1, Event No. 4



i) Model 2, Event No. 4



e) Model 1, Event No. 5



j) Model 2, Event No. 5

Figure 5.3 Acceleration response spectra at bedrock level (continued)

6. CONCLUSIONS

In this study, Hiyoshi Area in Yokohama City, which has irregular ground profile, was focused, and ground structure is modeled into a detailed model (Model 1) and a simplified model (Model 2). Using observed seismic records at ground surface, acceleration response spectra of incident wave at bedrock level were calculated by one-dimensional equivalent linear analysis. By comparing these acceleration response spectra of Models 1 and 2, the difference of modeling was examined. The following findings are observed:

Difference of modeling brought much effect on estimation of incident seismic wave at bedrock. The effect was prominent in short period range possibly because there were large difference in layer thickness and shear wave velocity. On other hand, long period range did not have large difference between Models 1 and 2. The results suggest that it is necessary to increase the spatial density of bedrock data to make an accurate ground model and to consider influence of surface waves and oblique incidence in regard to the studied area.

ACKNOWLEDGMENTS

This work is conducted as a part of a research project, Keio Leading Amenity & Security Infrastructure starting in 2008 (KLASI 2008). The authors thank supporting companies of the project. The boring data used in the study were provided by Kawasaki and Yokohama Cities, and the seismic records were provided by Yokohama City. The authors are also grateful to them.

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