Earthquake Engineering, Tenth World Conference © 1992 Balkema, Rotterdam. ISBN 90 5410 060 5

Effects of geological irregularities on ground motion characteristics

Ken-ichi Tokida, Keiichi Tamura & Hidemi Fukada
Public Works Research Institute, Ministry of Construction, Tsukuba, Japan

ABSTRACT : Two dimensional soil response analyses are conducted to study ground motion characteristics on the irregular soil profiles. A computer program FLUSH is employed in numerical calculations. Two kinds of geometric irregularities are considered; the inclined base layer and the basin, and the dimensions of irregularities are parametrically changed. The relationship between the maximum acceleration amplification ratio and soil profile irregularities is studied.

1. INTRODUCTION

The ground motion characteristics in the surface strata were mainly studied by one dimensional approaches, assuming vertical propagation of shear waves. However, it has been well recognized that the ground motions are strongly affected by two or three dimensional ground irregularities with the recent accumulation of strong motion records and development of analytical procedure. For example, it was reported that the ground motion in the Mexico City from the Mexico Earthquake of 1985 was much amplified by the soft basin sediment (e.g., Sanchez-Sesma et al., 1988).

From this point of view, two dimensional response analyses of ground are conducted to study the effects of geometric irregularities on the ground motion characteristics. The amplification ratio of the maximum acceleration is defined, and the relationship between this ratio and irregularities is studied.

2. GROUND MODELS

The two models shown in Figure 1, the Inclined Base Model and the Basin Model, are considered for two dimensional response analysis of ground. They are designated to simulate typical alluvial soil profiles with geometric irregularities. The Ac, Ds and Dg represent the alluvial clay, diluvial sand and diluvial gravel layers, respectively. The inclination angle θ is changed for three cases in the Inclined Base Model, i.e., $\tan\theta = 1/5$, $1/2$ and ∞. In the Basin Model, the inclination angle θ is changed same with the case of the Inclined Base Model, and the width of central horizontal part L is changed for two cases, i.e., L=150 and 300 m. The Dg layer is considered the base layer for earthquake response analysis, and the viscous boundary is attached between the Ds and Dg layers. Vertical moving is restrained for the nodal points on the lateral boundaries. The soil properties assumed are listed in Table 1.

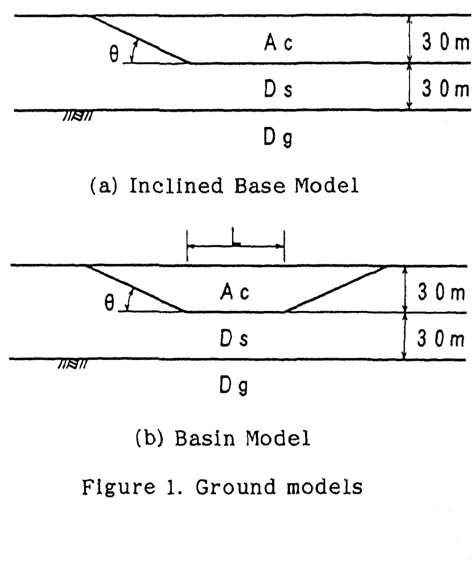
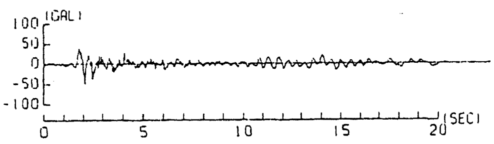


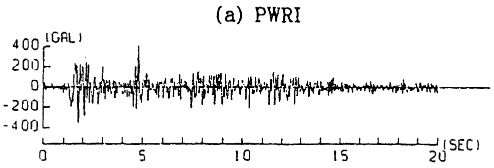
Figure 1. Ground models

Table 1. Soil properties

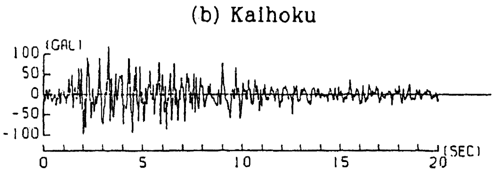
Layer	Unit Weight [gf/cm^3]	Shear Wave Velocity [m/s]	Poisson Ratio
Ac	1.60	150	0.45
Ds	1.85	270	0.40
Dg	2.10	500	0.40



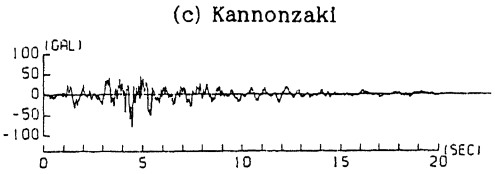
(a) PWRI



(b) Kaihoku



(c) Kannonzaki



(d) Rincon Hill

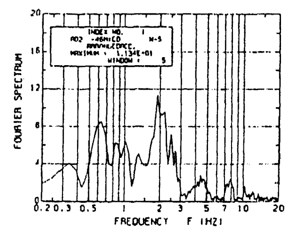
Figure 2. Input ground motions

Table 2. Input ground motions

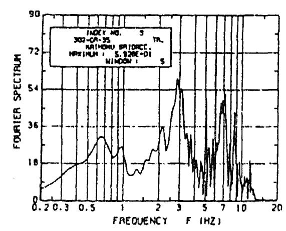
Record	Earthquake	Date	Magni -tude	Distance [km]
PWRI	Ibaraki-ken Nanbu	2/27/83	6.0	22
Kaihoku	Miyagiken-Oki	6/12/78	7.4	83
Kannon-zaki	Chiba-ken Toho-Oki	12/17/87	6.7	69
Rincon Hill	Loma Prieta	10/17/89	7.1	95

3. INPUT GROUND MOTIONS

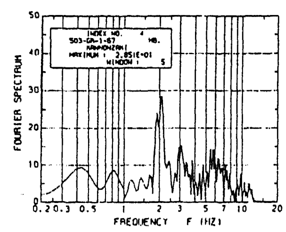
The four recorded ground motion data shown in Table 2 are employed as input motions. The PWRI record was obtained in the diluvial gravel layer at the depth of 46 m from the ground surface (Tokida et al., 1991), and the other three records were obtained on the rock sites (Iwasaki et al., 1978; Sasaki et al., 1989; Shakal et al., 1989). Figures 2 and 3 show acceleration time histories and Fourier spectra of these four records, respectively. As seen from these figures, strong motion records with different predominant frequencies are selected for input motions. In the following response analyses, the maximum peak acceleration of input ground motions is modified so that the peak acceleration at the bottom of Ds layer is 100 gals.



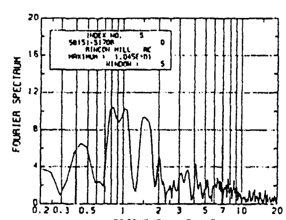
(a) PWRI



(b) Kaihoku



(c) Kannonzaki



(d) Rincon Hill

Figure 3. Fourier spectra of input ground motions

4. RESPONSE ANALYSIS OF GROUND

A computer program FLUSH (Lysmer et al., 1975) is employed for response analysis of ground. Nonlinear behavior of soils are considered by the equivalent linear method. Figure 4 shows an example of the shear modulus reduction and damping ratio relationships with shear strain (Iwasaki et al., 1980).

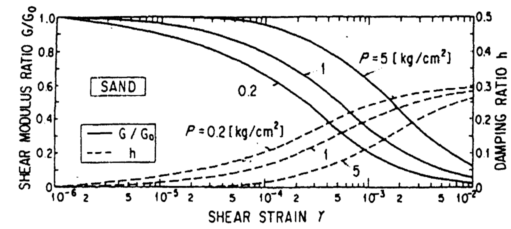
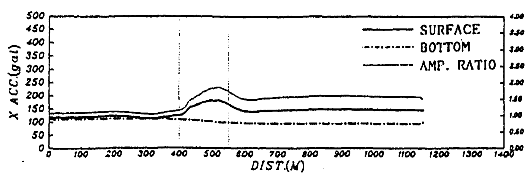
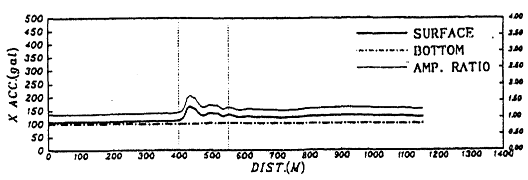


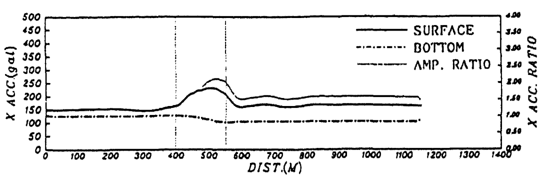
Figure 4. Assumed dynamic property of Ds layer



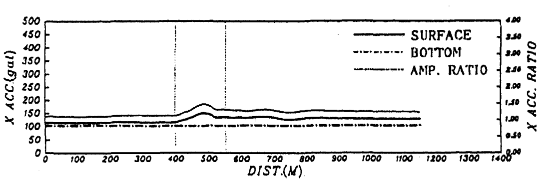
(a) PWRI



(b) Kaihoku



(c) Kannonzaki



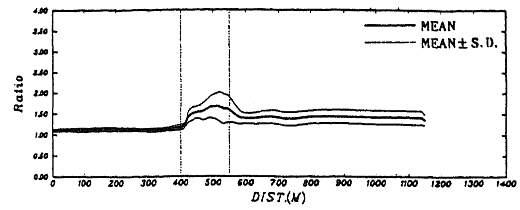
(d) Rincon Hill

Figure 5. Distribution of maximum acceleration and amplification ratio for Inclined Base Model

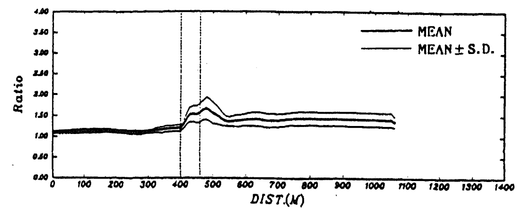
5. DISTRIBUTION OF MAXIMUM ACCELERATION

5.1 Inclined Base Model

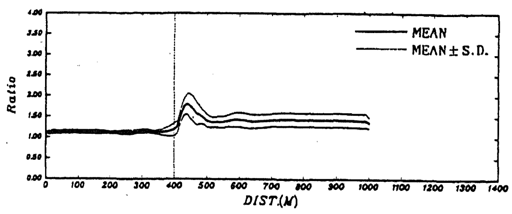
An acceleration amplification ratio is defined as the ratio of the maximum acceleration on the ground surface to that on the bottom of Ds layer. Figure 5 shows an example of the distributions of the maximum accelerations on the surface and bottom, and



(a) $\tan\theta = 1/5$



(b) $\tan\theta = 1/2$



(c) $\tan\theta = \infty$

Figure 6. Amplification ratio for Inclined Base Model

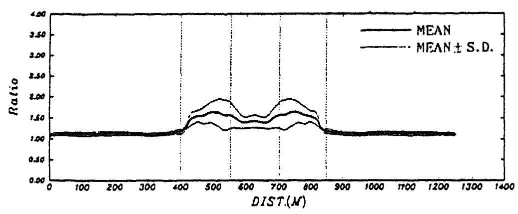
the acceleration amplification ratio calculated for the Inclined Base Model with $\tan\theta = 1/5$.

Figure 6 shows the mean value and standard deviation of amplification ratios calculated from the four input ground motions for the Inclined Base Model. The maximum amplification ratio arises on the soil profile changing area or near the end of deep soft soil deposits. The peak value of the mean amplification ratio becomes larger as the inclination angle becomes large.

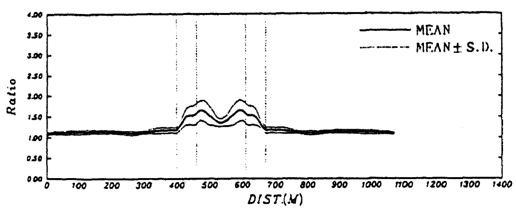
5.2 Basin Model

Figure 7 shows the amplification ratio of the Basin Model, where the central width L is taken as L=150 m. The amplification ratio takes its largest value on the ground condition changing area, whereas it is a little small on the central part where the thickness of the soft soil is deepest.

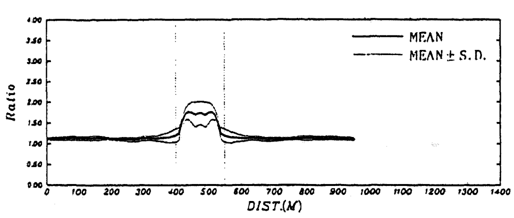
The amplification ratio for L=300 m is shown in Figure 8. When the central width is taken as 300 m, the change of the mean amplification ratio becomes gentle, however the peak value of the ratio is almost same with the case of L=150 m for each inclination angle.



(a) $\tan\theta$ =1/5

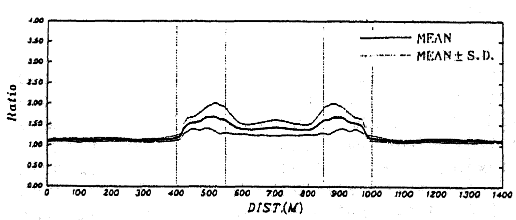


(b) $\tan\theta$ =1/2

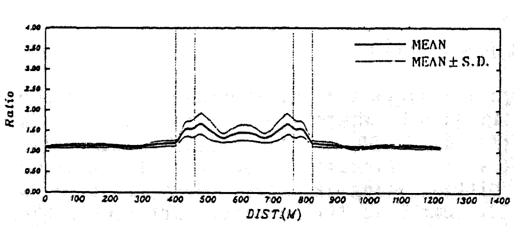


(c) $\tan\theta$ =∞

Figure 7. Amplification ratio for Basin Model (L=150 m)

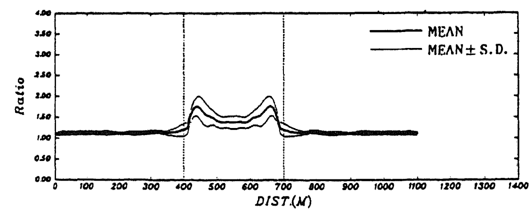


(a) $\tan\theta$ =1/5



(b) $\tan\theta$ =1/2

Figure 8.(1) Amplification ratio for Basin Model (L=300 m)



(c) $\tan\theta$ =∞

Figure 8.(2) Amplification ratio for Basin Model (L=300 m)

6. CONCLUDING REMARKS

The effects of geological irregularities on the ground motion characteristics are studied by two dimensional analyses. The magnitudes and affecting extents of seismic response due to geometric soil irregularities are estimated. The acceleration on the ground surface takes its maximum value on the soil profile changing area or near the end of soft soil deposits, and this maximum value becomes large as the inclination angle of ground irregularity becomes steep.

REFERENCES

Iwasaki, T. et al. 1978. Strong-motion records from public works in Japan (No.2), Technical Note of Public Works Research Institute, Vol.33.

Iwasaki, T. et al. 1980. Experimental study on dynamic deformation characteristics of soils, Report of Public Works Research Institute, No.153. (in Japanese)

Lysmer, J. et al. 1975. FLUSH - A computer program for approximate 3-D analysis of soil-structure interaction problems, Earthquake Engineering Research Center Report, No.EERC 75-30.

Sanchez-Sesma, F. J. et al. 1988. The Mexico earthquake of September 19, 1985 - On the seismic response of the valley of Mexico, Earthquake Spectra, Vol.4

Sasaki, Y. et al. 1989. Strong-motion records from public works in Japan (No.15), Technical Note of Public Works Research Institute, Vol.52.

Shakal A. et al. 1989. CSMIP Strong-motion records from the Santa Cruz Mountains (Loma Prieta), California Earthquake of 17 October 1989, Report No.OSMS 89-06

Tokida, T. et al. 1991. Attenuation characteristics of ground strains induced during earthquake, Proc. of Second International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics.