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STUDY ON DYNAMIC BEHAVIORS OF IRREGULAR TOPOGRAPHY

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SUMMARY

The nature of surface motion of alluvial valleys or sedimentary basins are investigated for the case of incident plane SH waves. Boundary Element Method is applied to the two dimensional wave propagation problem. The rapid changes in the ground motion amplification along the surface of the valley and significant dependence of motion on the incidence angle of SH waves, are explained qualitatively by the steady state response and random earthquake response.

INTRODUCTION

Recently, many earthquake damages on irregular topographical sites, especially on alluvial valleys or sedimentary basins have been reported. Since many human settlements are founded on alluvial valleys, it is important for the design of earthquake resistant structures to study the mechanism of these amplification effects.

The surficial soil and sedimentary deposit may affect significantly the amplitudes of incident seismic waves. And the seismic response of them becomes very complex, because of diffraction, refraction, reflection and conversion phenomena that occur when seismic waves interact with an attenuation soil structure. Several researchers have investigated the dynamic behaviors of such irregular topographical sites. But most of them treated very restricted deposit geometries,e.g., plane SH waves incident on the horizontally stratified surface layers overlying a half-space or on semi-elliptical basins excavated in a half-space. In this report we investigated qualitatively the seismic response of sedimentary deposit in fairy complex shaped basin as the elasto-dynamic problem in which SH body wave as well as SH surface wave incident upon two dimensional models.

ANALYTICAL MODEL

The analytical models are three types of basin as shown in Fig-1. The two media are perfectly elastic, isotropic, and homogeneous, with material properties given by shear wave velocity Vs unit weight per cubic volume ρ , and poisson's ratio ν . The subscript 1 on Vs, ρ , ν , indicates values for the valley material and the subscript 2 indicates values for the half-space. The material contact is assumed to be welded.

The parameters of models are the dimensions of valley, and the impedance ratio α between basin and half-space ($\alpha = V_{S1} \cdot \rho_1 / V_{S2} \cdot \rho_2$) as tabulated in Table-1. The width and depth of valley,unit weight per cubic volume and poisson's ratio are fixed in this analysis (2B=2km,D=50m, ρ =2.0 t/m, ν =0.4). The material damping is neglected in the analysis because it is difficult to assume the adequate damping value.

The half-space is assumed to be subjected by the incident motion which represents a plane SH wave traveling upward at an angle θ to the vertical as shown in Fig-2. All motion is in the Z direction only and is the same for all Z.

CALCULATION OF SEISMIC RESPONSE

Surface displacement spectra for unit incident SH wave is calculated by two dimensional boundary element method. The frequency range analyzed in this paper is below 4.0 Hz. In order to investigate the time-domain behavior of surficial soil, the Foureir transform $F_\theta(f)$ of Hachinohe EW 1968, X(t),(modified that the higher frequencies more than 4 Hz are cut off by the low pass filter and normalized that the maximum acceleration is 10 gal) is multiplied by the transfer function A(f), according to the analyzing frequencies. Foureir transform F(f) of the surface response are obtained.

$$F(f)=A(f)*F_\theta(f) \tag{1}$$

and then inverse-transformed into the time domain are done, we can get the response time histories X(t).

$$X(t)= \int_{-\infty}^{\infty} F(f)e^{i\omega t}df \tag{2}$$

SURFACE RESPONSE SPECTRA

Dependence of displacement spectra on the shapes of valley and the incidence angle Fig-3 gives the envelopes of surface displacement of valley for four kinds of incidence (θ =0° ,30° ,60° ,90°) of SH waves whose amplitude is one. Two horizontal axes in figures are X/B and frequency f. The point X/B = ± 1 corresponds to the edge of the valley, and X/B = 0, to the center of the valley. The height of the curves is the surface displacement amplitude that corresponds to amplification factor. The maximum peak values are shown in each figure. There are many sections along the surface of the valley where significantly high local amplification take place. These regions are not necessarily confined to the deepest part of the valley. The region of such high amplification is mainly concentrated toward the place where the discontinuity of the bottom lines of the valley takes place.

For increasing θ , the maximum peak values increase for all models, and the pattern of the surface amplification changes so that the motion in the region of negative X/B increase and in the positive region X/B decrease relative to the symmetric incidence with θ =0° ,except the pattern of model-c. This may be interpreted by the following analogy. All incident waves enter the valley from the left. The waves reflected into the valley, predominantly from the left interface are partly or completely reflected from the right interface back into the valley. The amplification caused by focusing of these waves is apparently greater for negative X/B in case of model-a and model-b , and for positive in case of model-c . The pattern of surface amplification depends upon the shear wave velocity in the valley and also the size and shape of the valley .

Earthquake response Fig-4 shows the surface response acceleration time histories of the several points of valley of model-a and model-c in case of incident angle $\theta = 0°$, $\theta = 90°$ for impedance ratio $\alpha = 0.1$. The wave form of each point and response values are quite different from each other. The vibration period becomes longer and the maximum response values become larger compared to those of input wave or outcrop wave . Fig-5 shows the envelope of maximum acceleration which is normalized by the maximum response of free field without valley. Three lines corresponds to the impedance ratio 0.1, 0.2, 0.5 respectively. If the sedimentary deposit is soft (in this analysis $\alpha = 0.1$, 0.2), the amplification of surface motion becomes fairly larger than those of free field or outside of valley and those amplification pattern are very much affected by the incident angle θ . Otherwise ,in case of fairly hard deposit (in this analysis $\alpha = 0.5$), the amplification of motion is not so large and it is less affected by the incident angle and also the shape of basin.

CONCLUSIONS

The analysis of the amplification effects on incident plane SH waves in three types of valley may qualitatively explain several ground amplification phenomena. From the engineering point of view, the results of the present analysis may be summarized as follows:

1. The surface-displacement amplification for the sedimentary deposit may change rapidly over short distances. The degree of complexity of the amplification pattern increases with decrease of impedance ratio and with increase of complexity of the shape of cross sectional shape of valley.
2. If the shear-wave velocity in the sedimentary deposit decreases, other model properties being fixed, the over-all amplification in the valley increases.
3. The pattern of spectral amplification at a given point on the surface of the valley significantly depends on the angle of incidence of SH wave.
4. The earthquake response at a given point on the surface dose not necessary resemble to the steady state response. The frequency content of earthquake motion affects on the response. But we can know general the tendency of the amplification for earthquake motion from the steady state response.
5. The SV response, which dose not appear in this paper, is similar to the SH response.

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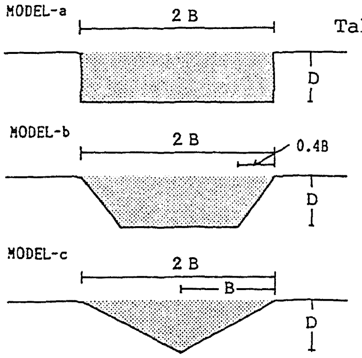

Fig-1 Analitical model

Table-1 Shear wave velocities and impedance ratios

TYPE	V_{s1} (m/s)	V_{s2} (m/s)	α
(a)	500	1000	1/2
(b)	200	1000	1/5
(c)	100	1000	1/10

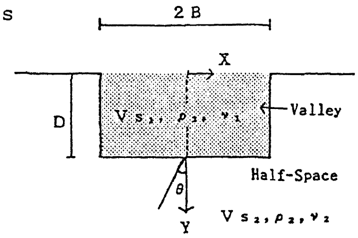

Fig-2 Valley and the surroundig half-space

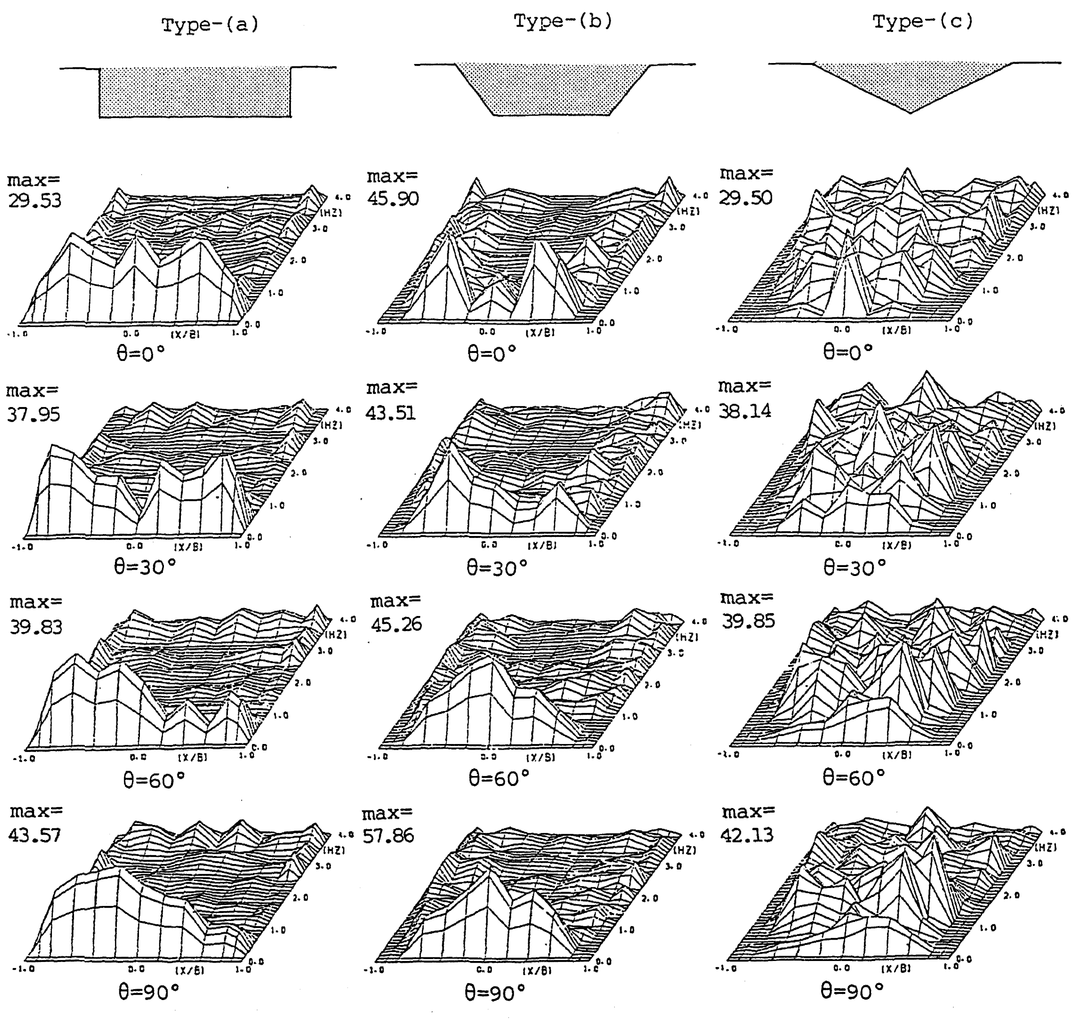

Fig-3 Displacement response spectra for unit harmanic SH incident waves

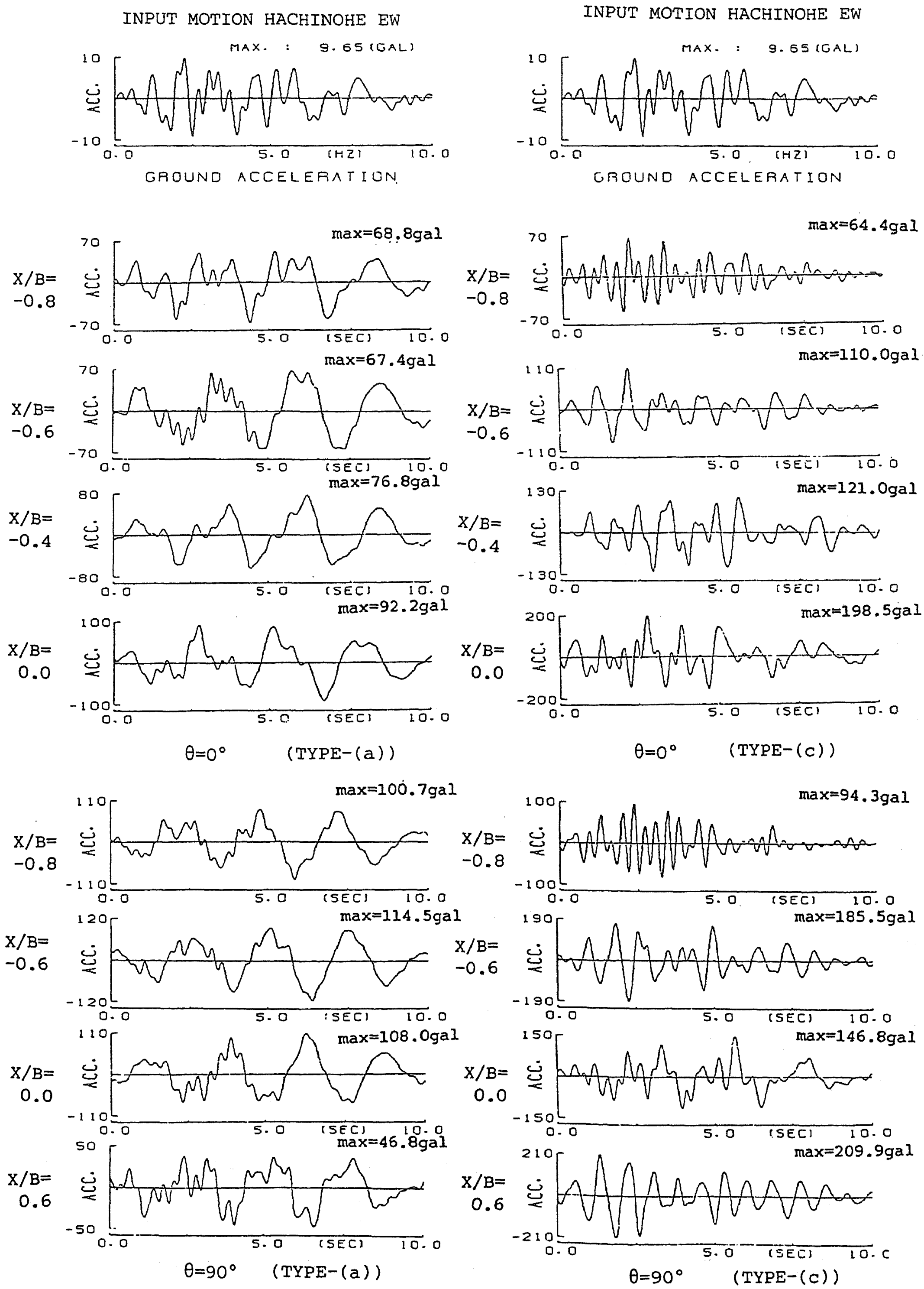

Fig-4 Response acceleration time histories on the surface

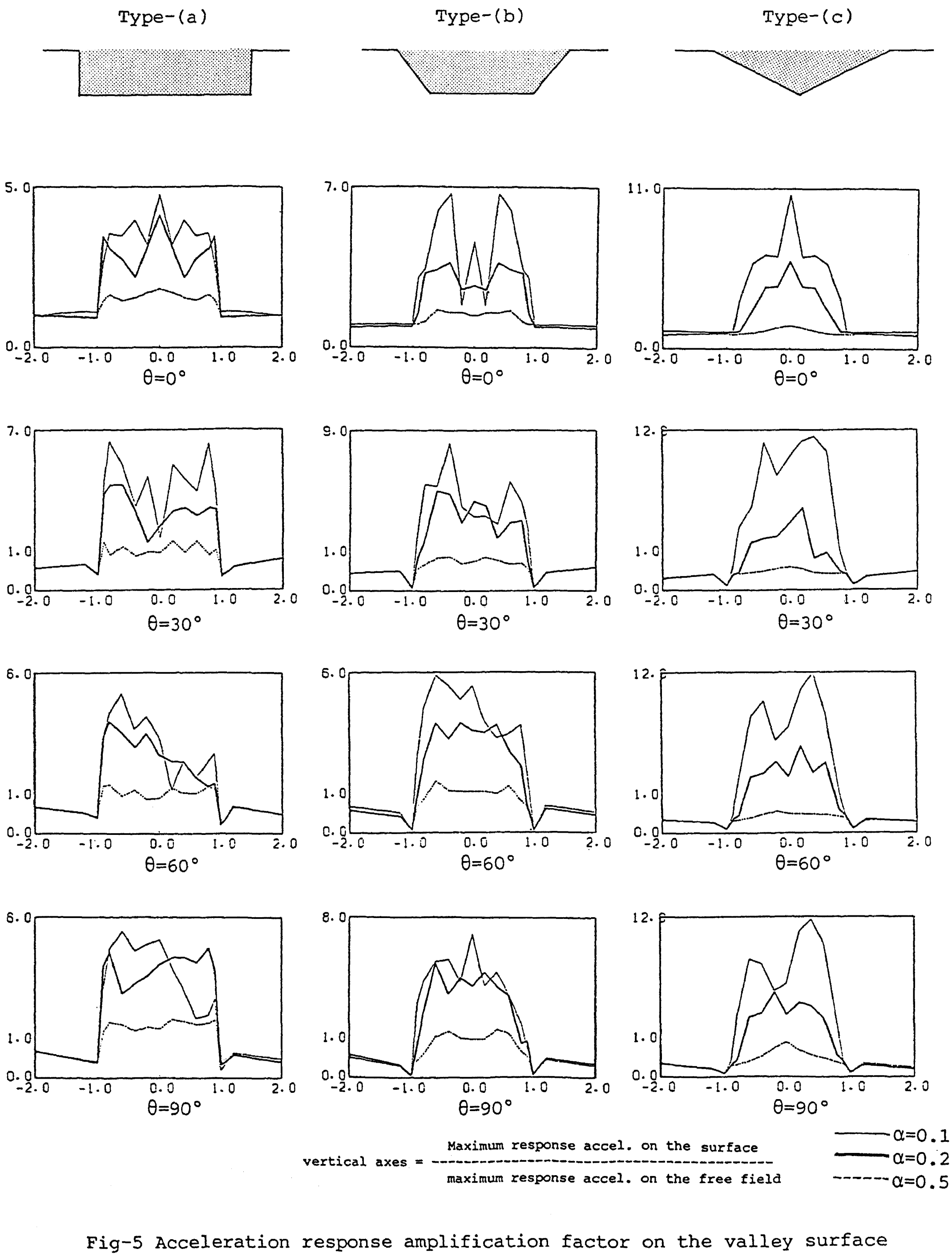

Fig-5 Acceleration response amplification factor on the valley surface