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BEHAVIORS OF ALLUVIAL PLAIN WITH IRREGULAR TOPOGRAPHY BY THE WAVE PROPAGATION (PART 2)

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SUMMARY

The surface wave transmitted from the surrounding bedrock and propagates transversely to the alluvial plain is analyzed and revealed by the earthquake observation. To analyze this phenomenon, we made a simple model taking into consideration the irregularity on the bedrock surfaces and executed numerical calculation by the potential method with the P wave and S wave which have been developed by us. The qualitative properties of surface wave in the alluvial *plain with irregular topography have been discussed based on the results of* analysis of the wave propagation diagrams, time-histories of surface displacement, surface displacement amplitude ratio, stress and displacement potential of alluvial stratum.

INTRODUCTION

The wave enters from a side of the bedrocks of peripheral mountains into the alluvial stratum adjacent thereto. This is the surface wave of alluvial stratum. Its upper part and lower part spread transversely on the free surface and at the bedrock boundary, respectively[1]. (Refer to Fig. 1.) This surface wave of alluvial stratum appears later than the main motion and has a simple wave form, and its acceleration rate is considerably high. Therefore, it can not be ignored from the seismological viewpoint. To make clearer this phenomenon, numerical calculation was made by the potential method. This method allows separation of displacement potential of body waves. Namely it is step-by-step explicit analysis. It is useful for explaining and representation of wave motion[2].

The model calculation for the case where the bedrock of lower face of alluvial stratum is horizontal has been described in the references 3, in this report the plain with irregular topography on bedrock is discussed mainly.

CALCULATION MODELS AND BEHAVIORS OF ALLUVIAL PLAIN WITH IRREGURAL TOPOGRAPHY

Fig. 2 shows the simplified analysis models. The models A, B, and C shown in the figure are topography having a protrusion on the rigid bedrock, topography having a dent, and regular topography, respectively. In all these models, the vertical sine wave is inputted from a left upper point on the surface. Basically, the thickness of alluvial plain H is set to 2.0 λS (where λS is distortional wave length), and with the irregular models A and B a protrusion and a dent having width WB = 1.5 λS and height (depth) of HP (HD) = 1.0 λS is provided, respectively, at 2.0 λS from the source.

Fig. 3 a, b and c are the displacement propagation diagrams of the models A, B and C when a vertical sine wave (20 steps) is applied to the asterisked point on the surface. Fig. 3 a shows the distribution of displacement after 60, 90, 120, and 150 steps. Figs. 3 b and c show the displacement after 60 and 120 steps. The results of consideration of these figures are as follows;

(1) On the alluvial plain having a protrusion or a dent, the wave propagation is significantly different from that on the regular topography. Especially, the protrusion greatly affects the wave propagation. The plain having a dent propagates the wave relatively similarly to that with regular topography.
(2) As the time elapses, the waves reflected by the bedrock and the protrusion or dent are multiplied upon the direct surface wave. Especially, on the topography having a protrusion, the surface wave and reflected waves are remarkably complicated.
(3) Though depending on the thickness of irregular area, with this models, the surface wave is propagated, being affected not so notably by the irregular topography.
(4) On the plain having a protrusion, the wave is stored in the stratum at the source side where the wave power does not decay.
(5) On the plain with irregular topography the corners significantly affect the wave.

Figs. 4 a and b show the displacement distribution after 120 step of time lapse in the plain having a different protrusion and dent. Even a slight protrusion (HP=0.5 λS) and dent (HD=0.5 λS) diversify significantly the wave behaviors as compared to the plain with regular topography. If the length (WB) of irregular area is increased to WB = 3 λS, the wave behaviors are changed minutely. However, the surface wave proceeds, not being influenced directly. Fig. 4 c indicates the distribution of displacement of the model C when the input period is doubled. The detailed description is given in the reference 6. As shown in this figure, when the alluvial stratum thickness H = λS, a vortex affecting the entire thickness is formed. If H > λS, as shown in Fig. 3 c, a vortex is generated, however, it does not cover the entire thickness; its scale is near the λS. Accordingly, if the plain has a bedrock on its bottom, the wave propagation is characterized by a vortex formed in the alluvial stratum.

TIME-HISTORIES AND STRESS OF ALLUVIAL PLAIN WITH IRREGULAR TOPOGRAPHY

Fig. 5 shows the vertical and horizontal displacement (W, U) time-histories in respect to the representative three points (.) on the surface shown in Fig. 1. These time histories make clearer the above-mentioned results (1) to (5).

Fig. 6 shows the max. amplitude ratio of surface displacement of irregular topography models (A) and (B) to the regular topography model (C). To facilitate comparison of these models, we examined the viscoelastic alluvial plain. As a result of examination of Fig. 6, the following items were evidenced.

(1) The vertical amplitude ratio is changed significantly just above the corner part of the irregular topography. On the plain having a protrusion, the ratio is increased at the both corners, and especially, the ratio at the source side is high, 1.2. On the plain having a dent, a high ratio, 1.2, is observed at the source side, whereas at the opposite side the ratio is

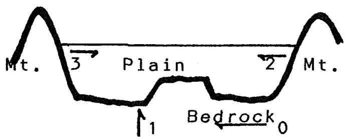


Fig. 1 Travelling Course of Earthquake Wave to Plain

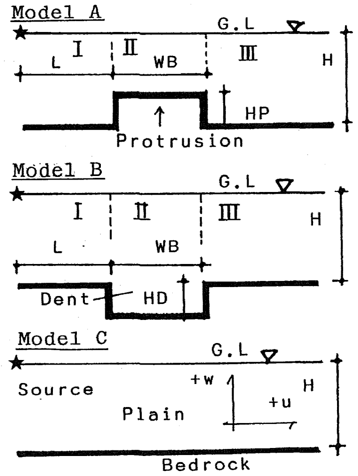
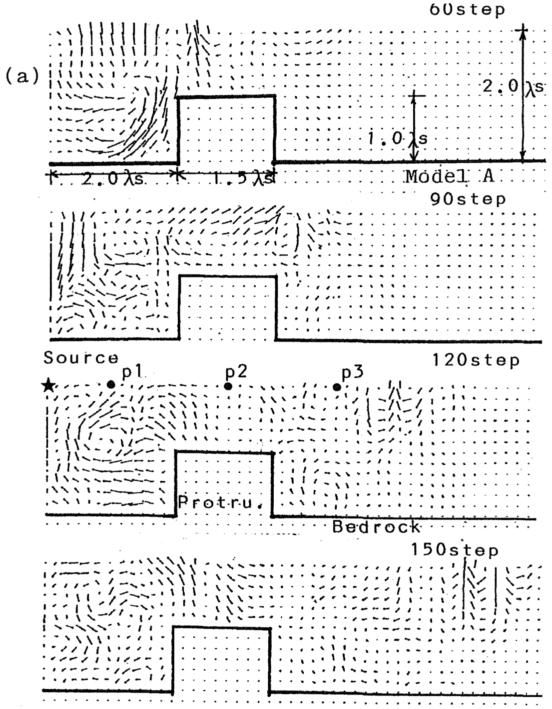


Fig. 2 Simplified Analysis Models



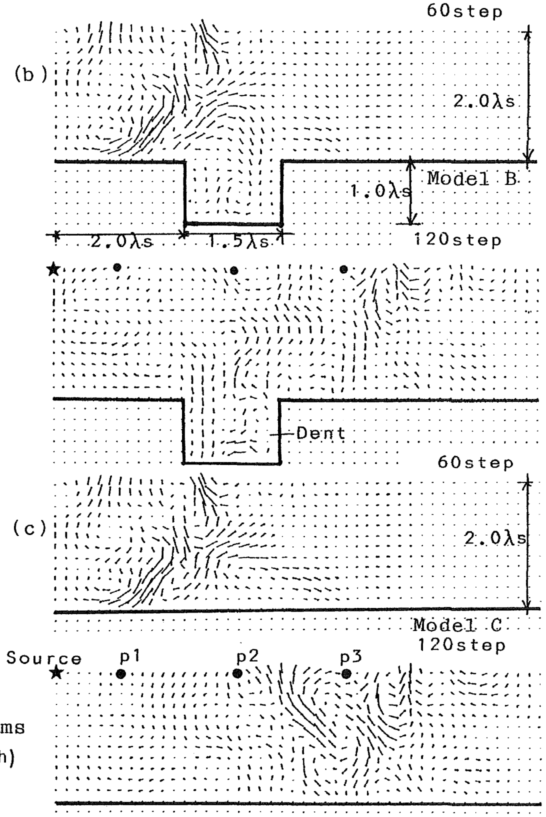
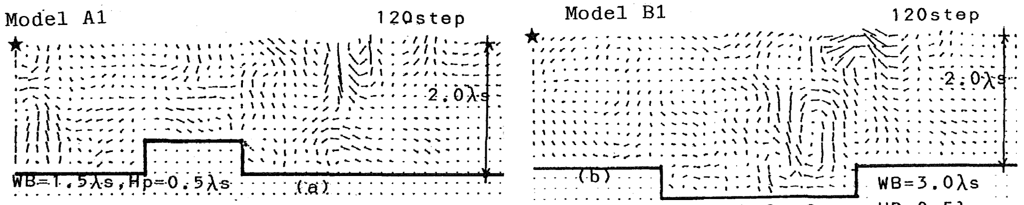


Fig. 3 Displacement Propagation Diagrams of Models (λs is S Wave Length)



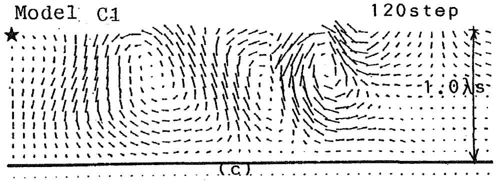


Fig. 4 Displacement Distributions when Bedrock Surface Shape of Model are changed.

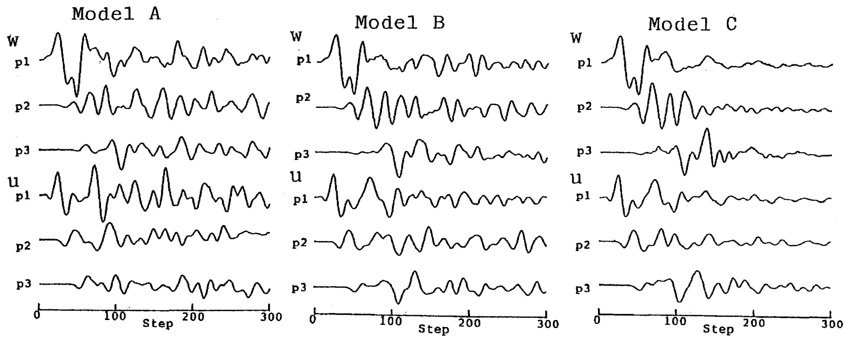


Fig. 5 Displacement Time-Histories on Surface of Models

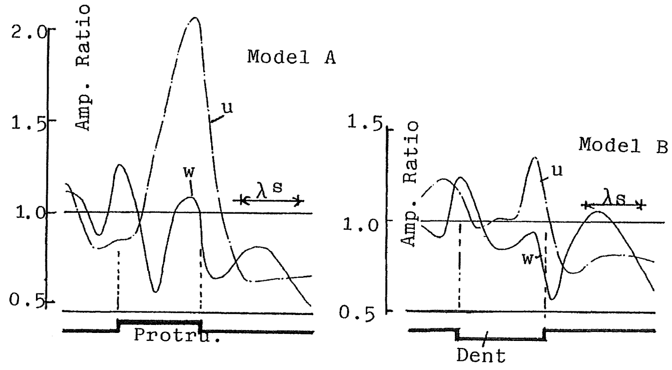


Fig. 6 Amplitude Ratios of Surface Displacement to Model C.
(λs is S Wave Length)

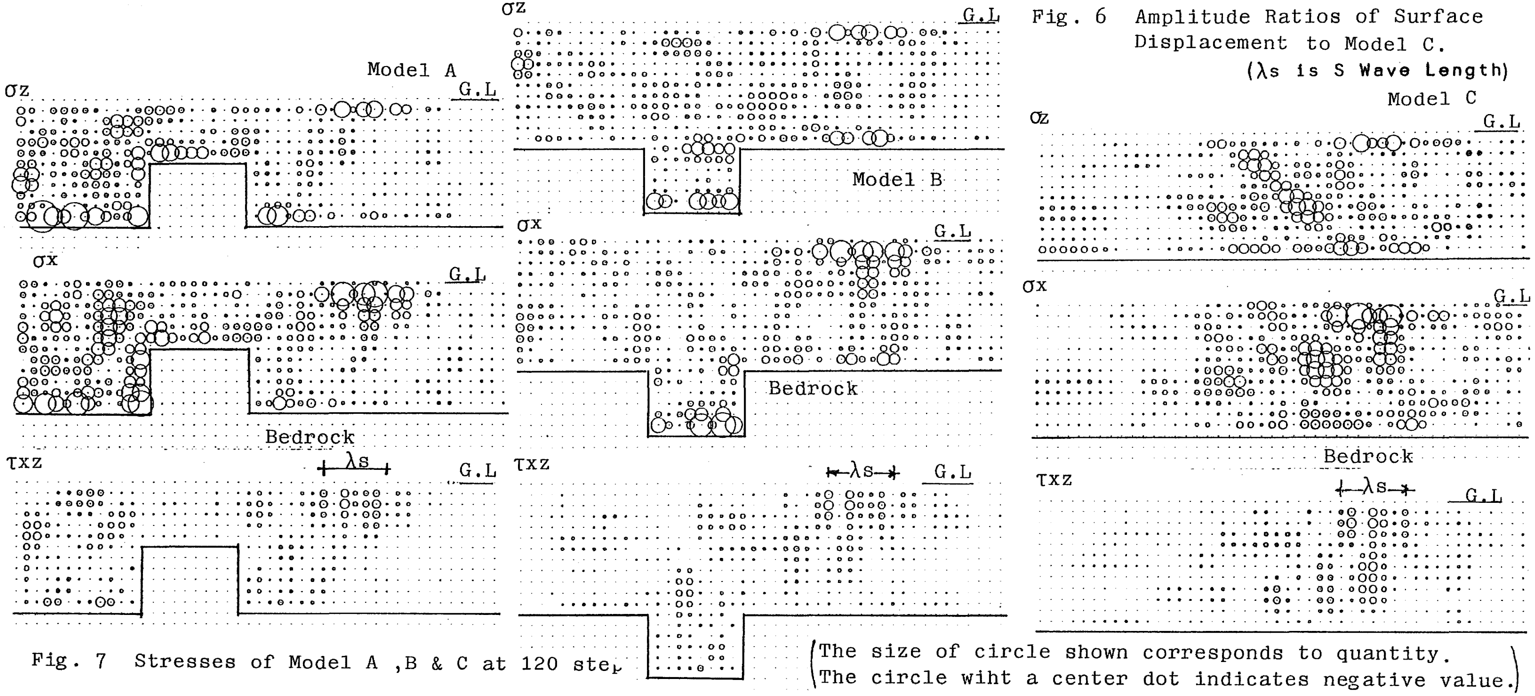


Fig. 7 Stresses of Model A ,B & C at 120 step

(The size of circle shown corresponds to quantity.
The circle wiht a center dot indicates negative value.)

significantly low, 0.6.

(2) The horizontal amplitude ratio increases rapidly up to max. 2.0 at the stratum (area II) whose thickness is thinly changed on the plain having a protrusion. On the plain having a dent, the ratio is not so significant (it is approx. 1.0) even at such a stratum (II), however, the ratio is increased at the both corners.

(3) At the stratum (area III) apart from the source at the right side of the irregular stratum (protrusion or dent), both the vertical and horizontal amplitude ratios are decreased. The ratios are decreased remarkably on the plain having a protrusion.

Fig. 7 shows the relations between stress σz, σx and τxz at 120 step in the models (A), (B) and (C). On all the three models, great stress occurs near the plain surface in the front of the direct surface wave. In particular, in the model (C) there is a following considerable stress field. In the models (A) and (B) there is large stress field near the corner at the source side and near the corner at the opposite side, respectively. However, the stress σz and σx are relatively larger than τxz unlike horizontal input from the lower bedrock reported in the reference 4. Moreover, the stress τxz of the model (C) forms vertical positive and negative arragnement whereas it forms horizontal positive and negative arrangement when inputted horizontally from the bedrock.

RESOLUTION BY DISPLACEMENT POTENTIALS

The finite difference method of wave propagation which has been developed by us considers the propagation of the wave by dividing it into displacement potentials (P wave and S wave). These resolved potentials spread at the P wave and S wave velocities, respectively, and integrated as displacement or stress, if necessary, at the boundary. The distribution of displacement at 120 step of the models (A) and (C) shown in Fig. 3 is resolved into vertical and horizontal displacements of the P wave and S wave. Fig. 8 represents the obtained result. As is evident from this figure;

(1) Regardless of existence of irregularity, the displacement potentials of the P wave and S wave are gathered near the surface stratum where the direct surface wave exists.

(2) The displacement phase of these P wave and S wave potentials is inverse. This causes displacement.

(3) The displacement components resolved by the P wave and S wave potentials are not always large at an area where considerable displacement appears.

CONCLUSION

As a result of the above-mentioned examinations the qualitative properties of surface wave in alluvial plain which is transmitted from the peripheral mountains are cleared to some extent.

(1) This calculation method is effective to know visually the generation of surface wave, and process of disturbance by reflection against bedrock.

(2) Even insignificant irregularity causes behaviors quite different from those on the regular alluvial plain. On the topography having a protrusion the wave spreads more irregularly than on that having a dent.

(3) On the alluvial plain a vortex occurs, and it has an influence later. Particularly, if the plain thickness is approximately equal to distortional wave length of entered wave, the vortex is so intensive that it covers the entire plain.

(4) The surface amplitude ratio to the regular alluvial plain is changed

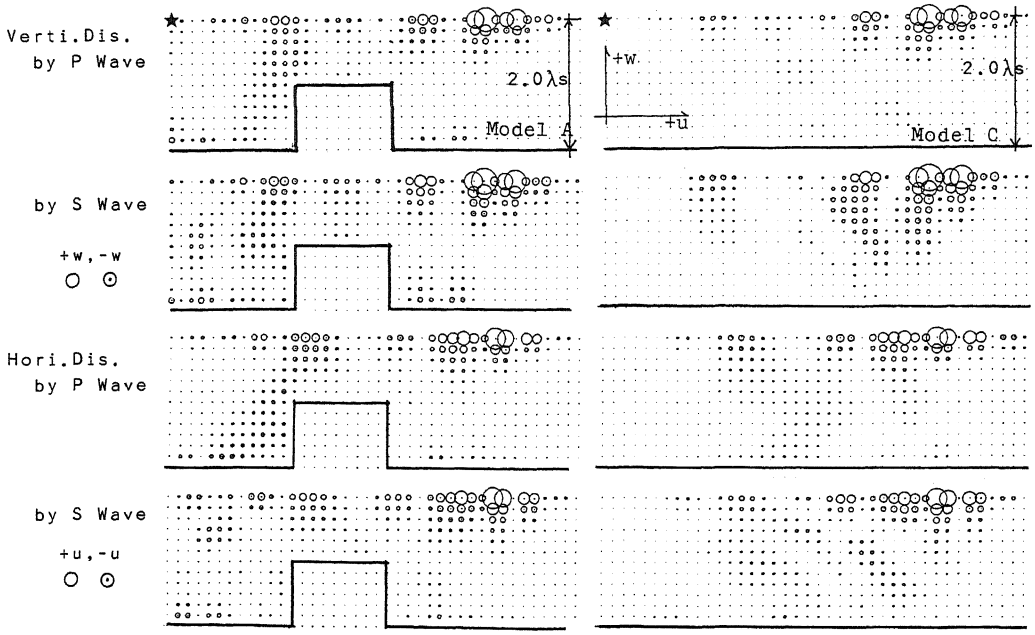


Fig. 8 Displacements of P & S Wave Potentials of Models at 120 step (★;Source,λs is S Wave Length)

rapidly near the irregular stratum. After passing through it, the ratio is reduced.

(5) A great stress occurs near the front surface of the direct surface wave and irregular area corner. The shear stress causes vertical positive and negative arrangement.

(6) Near the surface where the surface wave exists the potentials of the P wave and S wave are gathered. The displacement components caused by these waves have inverse phase.

We are examining the underground velocity structure by blasting experiments on the alluvial plain where we continue the earthquake observation. Applying the result to the models, we intend to investigate further the wave propagation mechanism of irregular alluvial plain and various changes of it depending on protrusion or dent shapes, and examine the seismological problems when earthquake occurs.

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