Amplification of seismic movement in adjacent non-curved valleys

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ABSTRACT

Two dimensional (2D) non-curved adjacent configurations valleys under incidence of vertically propagating SV waves is modelled with HYBRID program which combining finite elements in the near field and boundary elements in the far field in various topographical conditions. This paper presents the non-curved adjacent valleys modelling in order to invest the effects of depth ratios and distance between the different forms of irregularities on the ground amplification at various points. In this study, the irregularities are characterized by their depth (H), half width at the surface (L) and distance between two adjacent valleys (D). Analyses are made for different depth ratios (H/L=0.2, 0.4, 0.6, 1) and distance between two adjacent valleys (D=L, 2L, 3L). Finally, practical criteria are proposed for engineering applications to assess the spectral response at the surface of non-curved adjacent irregularities.

Keywords: Non-curved Adjacent Valleys, Site Effect, Seismic response, Hybrid Numerical Method, Topographic effects.

1 INTRODUCTION

It has been recognized that effects of geometrical of a site can significantly affect the nature of strong ground motion during earthquakes. The modification of the seismic movement due to local topographical and geotechnical conditions is called site effect. Certainly in the recent past, there have been numerous cases of recorded motions and observed earthquake damage pointing towards geometrical and geotechnical amplification as an important effect. Thus study of site effects is one of the most important topics in earthquake engineering. Geometrical of a site modify the nature of seismic waves in transition from depth to the surface. The majority of seismic codes rest on seismic site effects by using one-dimensional (1D) model. The purpose of this paper is study of site effects in two-dimensional (2D) non-curve adjacent valleys in a building code. The 2D wave scattering is studied with a hybrid numerical method, combining finite elements in the near field and boundary elements in the far field (FEM/BEM). This program has been developed by Gatmiri and his coworkers [1, 2, 3, and 4]

2 SUMMARY OF PREVIOUS STUDY

Gatmiri et al have performed several parametric analyses of site effects. In order to better clarify the usage of HYBRID program, some of these studies are mentioned in the following. It should be noted, that sediments are modeled by finite elements and substratum is represented by boundary elements, which is adapted to the study in the far field. Gatmiri et al., studied various configurations and considered the influence of configuration of irregularities, slope angle of irregularities and dimensionless frequency of incident wave. The several salient features of topographic effects obtained are as follows [3, 4]:
The seismic ground motion was amplified at the crest of ridges, at the upper corner of slopes and at the edges of canyons; it was systematically attenuated at the base of these reliefs. This conclusion was normally verified for the cases of low dimensionless frequency. The ground motion as not homogeneous as in case of the half-space, but it strongly varied on the free field. There were successive regions that movements of round ere attenuated. The magnitude of response at a location on the top surface was dependent on the distance from this location on the relief. This distance was a function of the frequency content of the relief itself.

The effects of topography were also influenced by the slope angle of the relief. Generally, the stiffer the slope of the relief was, the more the effects of topography due to this relief were accentuated. The topographic effects of a relief on the seismic response of that relief strongly depended on the frequency content of the excitation. In general, the higher the excited frequency was the more significant and complex were the site effects due to relief, and the wider the region influenced by the presence of the relief was, especially for the wavelengths comparable to or lower than the characteristic dimension of the relief.

Gatmiri and Arson, studied several parametric analysis in order to characterize the combined effects of topographical irregularities and sedimentary filling on ground motion under seismic solicitation due to vertically incident SV Ricker wave [4].

Indeed, the horizontal displacement in a canyon tend to be attenuated at the center and slightly amplified at the edge but in an alluvial basin, horizontal displacements are amplified at the center and can be locally attenuated near the edge if depth is large enough. A qualitative comparison between seismic response of the filled and empty was carried out suggesting that 2D geotechnical effects increase with depth and steep sidedness.

Gatmiri et al., studied acceleration response spectra of different empty valleys. Curves were collected on a unique figure, which characterized topographical effects in a quantitative and qualitative way in the spectral domain. The results showed that maximum amplification was reached at the edge point of valleys. The spectral acceleration responses were classified according to a unique geometrical criterion except for elliptical valleys: the “S/A” ratio (where S is the area of the valley opening, and A indicates the angle between the horizontal line and slope in the above corner) (Fig. 1). The spectral response increased by increasing the parameter of S/A, in elliptical valleys for each depth ratio [5, 6].

Figure 1. Definition of parameters S, A [5, 6]

New criteria were offered in order to develop simple methods to incorporate 2D combined site effects in building codes. Filling ratio effects of Non-curved alluvial valleys and the influence of the changes in impedance ratio between sediments and the bedrock were investigated. The derived conclusions are presented briefly as follows [7]:

Existence of sediments could smooth valley’s response at the edge and amplify it at the Centre. When combining the depth and shape effects, two geometrical parameters S/A and sin (A) were presented; by increasing S/A, SR*sin (A) increased (S and A are similar to prior work).In order to combine filling ratio and depth ratio effects, the two geometrical parameters S1/A and H/L were considered. As increasing the S1/A, SR*H/L increased (S1, the area which was occupied by sediment, and H/L was the valley’s depth ratio) (Fig. 2). Spectral ratio had an inverse relation to impedance ratio. By sediment softening in comparison to rocky bed, the spectral ratio increased and the seismic response of a configuration became more and more complicated and the data sequencing became more and more difficult. Finally, variation S1/A n1/ß as a function of dimensionless parameter SR*sin (A)* H1/L (H1 was sediments depth) was plotted as a linear trend.

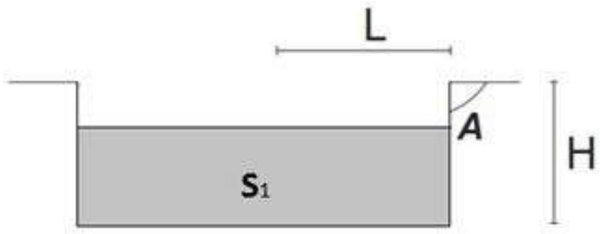

Figure 2. Definition of parameters S1, H/L [7]

2.1 PROBLEM PARAMETERS

2.1.1. GEOMETRICAL PARAMETERS

In order to evaluation of influence of shapes of empty non-curved adjacent valleys on the site effects the shapes of rectangular valleys was modelled. Valleys are characterized by their depth, H and their half width at the surface, L (Fig. 3). Simulations are carried out with depth ratios, H/L, equal to 0.2, 0.4, 0.6, 1. The value of L for all of the valleys is kept equal to100m.

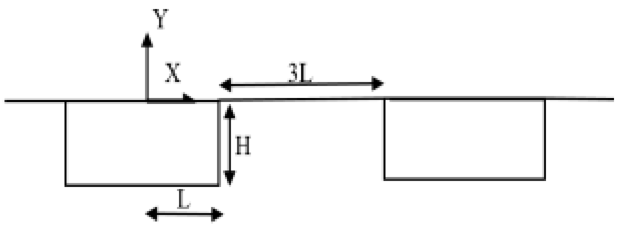

Figure 3. Adjacent rectangular valley

2.1.2 MECHANICAL PARAMETERS OF THE MATERIAL

In adopted models, the rocky bed are assumed to be homogeneous linear elastic materials. The main parameters of the bedrock are given in Table 1. The data used as input in this research are the digits and numbers considered for simulation in this program and their practical application calls for assessment of the extent by which they are factual and statistical as well as their sensitivity of results to these parameters, an assessment which is beyond the scope of objectives of this study.

Table 1. Mechanical characteristics of bedrock

E(MPa)	ν	ρ(kg/m³)	C(m/s)
6720	0.4	2450	1000

2.2. INCIDENT WAVE CHARACTERISTICS

The main focus of this work is the study of the effect of 2D geometrical irregularities on modification of seismic response and this study relies on simplified geometrical conditions as seismic loading is considered to be the simplest one; vertically incident SV Ricker wave. Imposed displacements are therefore expressed as [8];

$$u(t) = A_o(a^2 - 0.5)\exp(-a^2)$$

Were

$$a = \pi\frac{t - T_s}{T_p}$$

Amplification A0 is constant value of 1; predominant frequency (f) is thus equal to 2 Hz; and TP = TS = 0.5s. The incident signal lasts 3s, but it can be seen from Fig. 2 that amplitude is nearly zero as soon as it reaches t = 1s. That is why the window has been defined from t=0 to t=3s (Fig. 4). It should be noted, in all the models above, vibration is applied to the base of the left valley (Fig. 5).

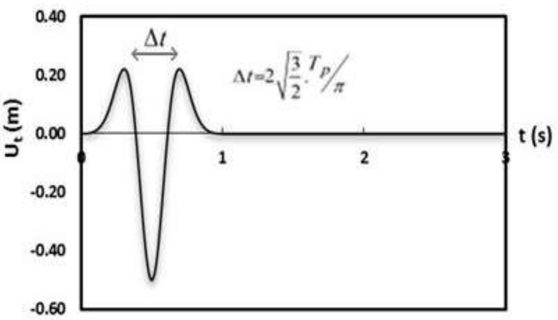

Figure 4. Incident Ricker signal [8]

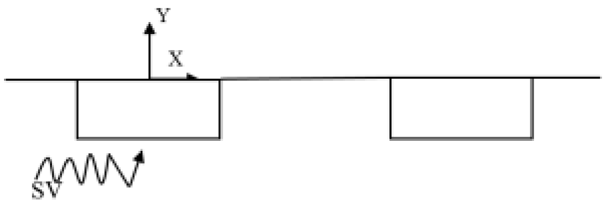

Figure 5. Point of the wave diffusion

2.3. 2D SITE EFFECTS IN NON-CURVED ADJACENT VALLEYS

The aim of this section is compare of influence of non-curved adjacent valleys on the seismic response of valleys with different ratios of H/L. The geometrical characteristics of valleys are displayed in Figure 1. In rectangular valley, L is half of the width of the valley and is equals to 100 m for all the valleys, as well as the distance between the adjacent valleys was determined 3L and the depth of valleys are H. In the present work, simulations are carried out with a depth (H) equal to 20, 40, 60, and 100 m and for different ratios (H/L) equal to 0.2, 0.4, 0.6, and 1. The spectral ratio in rectangular valleys in depth 6 is show in figure 6. According to the following graph, the results of non-curved adjacent rectangular valleys show a general trend that spectral ratio is increased with increasing H/L ratio, and this increase is more evident in the inner edge of the valleys. The spectral ratio at the inner edge of rectangular valleys in depth 1 is more critical than spectral ratio at the inner edge of depth 0.2, 0.4, 0.6. (Fig. 7).

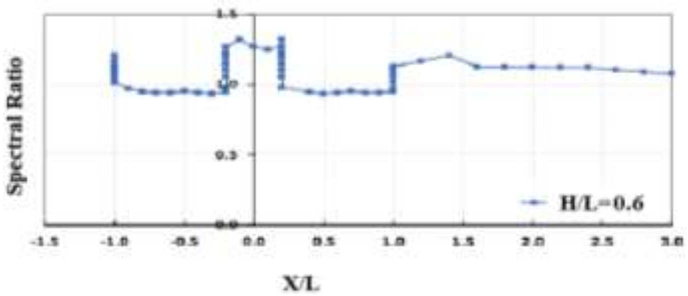

Figure 6. The results of Rectangular model in 0.6 depth

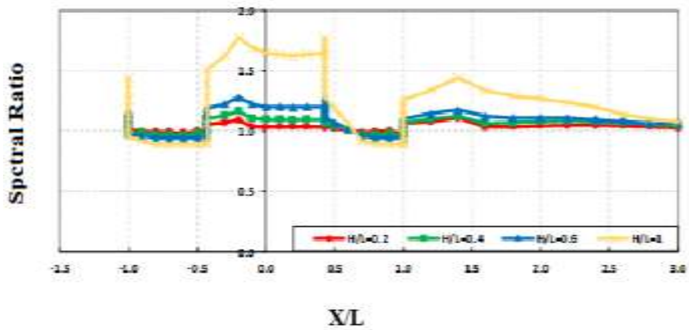

Figure 7. The results of Rectangular model in different depth

3 CONCLUSION

Site effects in non-curve adjacent valleys are studied by means of a hybrid numerical technique. The main results of this study are:

- Spectral ratio is increased with increasing H/L ratio.
- In the constant H/L ratio, spectral ratio at the adjacent rectangular valleys in H/L=1 is more than spectral ratio at the H/L=0.2, 0.4, 0.6.
- According to the results, the spectral ratio at the inner edge of all valleys is more critical and the value of that is nearly uniform, between two adjacent valleys.

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