SURFACE MOTION OF AN EARTH DAM ON LAYERED HALF-SPACE FOR INCIDENT PLANE SH WAVES

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ABSTRACT:

Surface motion of an earth dam with a core wall on layered half-space for incident plane SH waves is presented by indirect boundary element method (IBEM). The free-field response is calculated for the surface displacements, the displacements and stresses at the interface between the dam and the layered half-space. The fictitious distributed loads are applied on the interface and the surface of the dam to calculate the Green's functions for the surface displacements of the half-space, the displacements and stresses at the interface, and the displacements and stresses at the surface of the dam. The amplitudes of the fictitious distributed loads are determined by the boundary conditions. The surface motions due to the free field and due to the fictitious distributed loads are added to obtain the whole solution. The numerical results are performed for an earth dam with a core wall on one single soil layer over half-space, and the effects of incident frequency and angle, height of dam, thickness of soil layer, and stiffness ratio among the core wall, the dam, the soil layer, and the bedrock, etc. on the surface motion are discussed. It is shown that the surface motion depend on both the scattering of incident waves by the dam and the resonance characteristics of layered half-space, and there are interaction between the scattering of waves by the dam and the dynamic characteristics of layered half-space.

KEYWORDS: Earth dam, layered half-space, plane waves, scattering, amplification, IBEM

1. INTRODUCTION

Both earthquake investigations and theoretical studies indicate the large amplification of ground motion by a hill or an earth dam due to multiple reflections of waves inside the hill or dam (e.g., Geli et al, 1988). Seismic response of earth dams has been paid great attention in recent years (e.g., Niwa et al, 1984; Gazetas, 1987; Abouseeda and Dakoulas, 1996; Abouseeda and Dakoulas, 1998; Bardet and Davis, 1998; Chen and Harichandran, 2001; Cascone and Rampello, 2003).

Liang and Ba (2008) presented a solution for surface motion of a hill in layered half-space subjected to incident plane SH waves in frequency domain by indirect boundary element method (IBEM), and found that soil layers significantly affect both the amplitudes and frequency spectrum of the surface motion. This paper further extended to an earth dam with core wall, and it is shown that the surface motion depend on both the amplification of incident waves by the dam and the dynamic characteristics of layered half-space.

2. METHOD

Figure 1 shows the model for surface motion of an earth dam with core wall on layered half-space for incident SH waves. The indirect boundary element method (IBEM) in frequency domain is applied.

The free-field response is calculated to determine the displacements and stresses on the interfaces S_3 and S_4, and then the Green's functions for the layered half-space, core wall and dam are calculated. The Green's functions are the displacement response and stress response when the fictitious distributed loads are applied on interface S_3, S_4 and S_2 and surface S_1. The amplitudes of the fictitious distributed loads are then determined by the boundary conditions. These conditions can be satisfied in an average sense by using the method of weighted

residuals. The response arising from the waves in the free field and from the fictitious distributed loads are summed up to obtain the whole solution. The details can be found in Liang and Ba (2008).

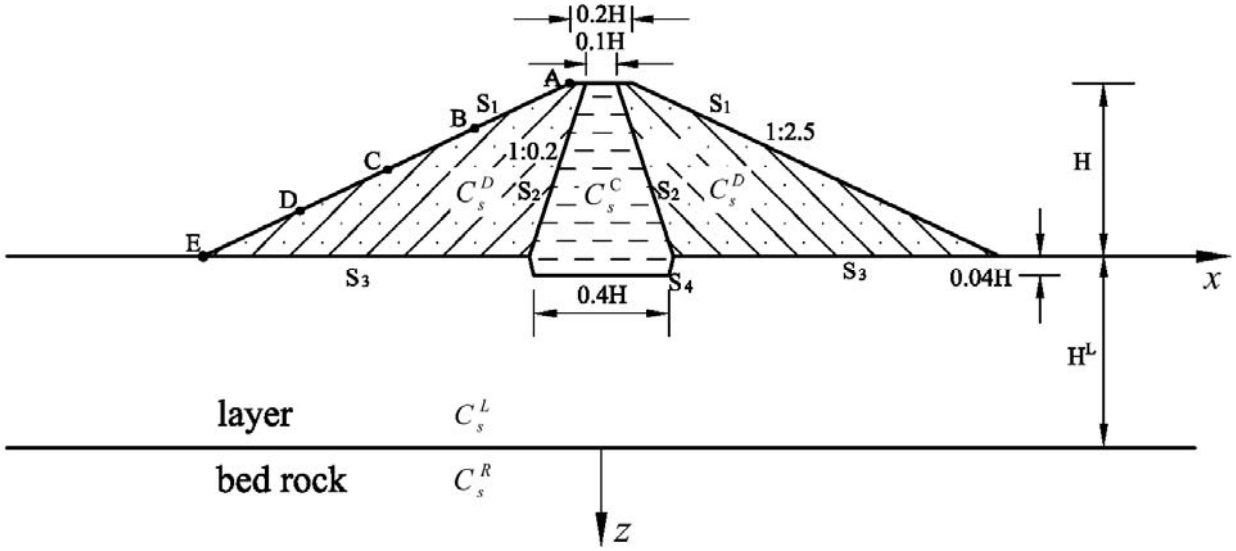

Figure 1 The model

3. VERIFICATIONS

To verify the precision of the method, Figure 2 shows the surface displacement amplitudes of a triangle hill on homogeneous half-space compared with the results in Sanchez-Sesma et al (1982) and Qiu and Liu (2005). The results of the present study agree well with know results.

4. NUMERICAL RESULTS

An earth dam with core wall on one single soil layer over half-space is studied for simplicity. The parameters are defined as follows: dam height is H, layer thickness is H^L; the shear velocity, mass density and damping ratio for bedrock, soil layer, dam and core wall are C_s^R, ρ^R, ζ^R; C_s^L, ρ^L, ζ^L; C_s^D, ρ^D, ζ^D and C_s^C, ρ^C, ζ^C, respectively. The dimensionless frequency is defined as $\eta = H/\lambda^L$, where λ^L is the wavelength of the shear waves of soil layer.

Figure 3 illustrates the surface displacement amplitudes of the dam on homogeneous half-space for the purpose of comparison. Figure 4 illustrates the surface displacement amplitudes of the dam on layered half-space, and the parameters are defined as: H^L/H =0.5, 1.0 and 2, C_s^R/C_s^L =2.0, 5.0 and ∞, respectively; C_s^D/C_s^L=0.5, C_s^C/C_s^L =0.5, $\rho^R=\rho^L=\rho^D=\rho^C$, ζ^R =0.02, $\zeta^L=\zeta^D=\zeta^C$ =0.05; incident angle θ =5°, 30°, 60° and 90°, incident frequency η =0.125, 0.25, 0.5, 0.75 and 1.0, respectively. Figure 5 illustrates the spectral amplification at surface positions A, B, C, D and E of the dam on layered half-space. It is shown from these figures that there are significant differences between the surface motion of the dam on the homogeneous and that on layered half-space; the surface displacement amplitudes of the dam on the layered half-space also highly depend on the shear velocity and thickness of the soil layer, or, the resonance characteristics of the layered half-space, besides the incident frequency. In other words, the surface displacement amplitudes depend on both the scattering of incident waves by the dam and the dynamic characteristics of the layered half-space. It is also shown that there are interaction between the scattering of waves by the dam and the dynamic characteristics of layered half-space, and surface motion at different positions may differ significantly.

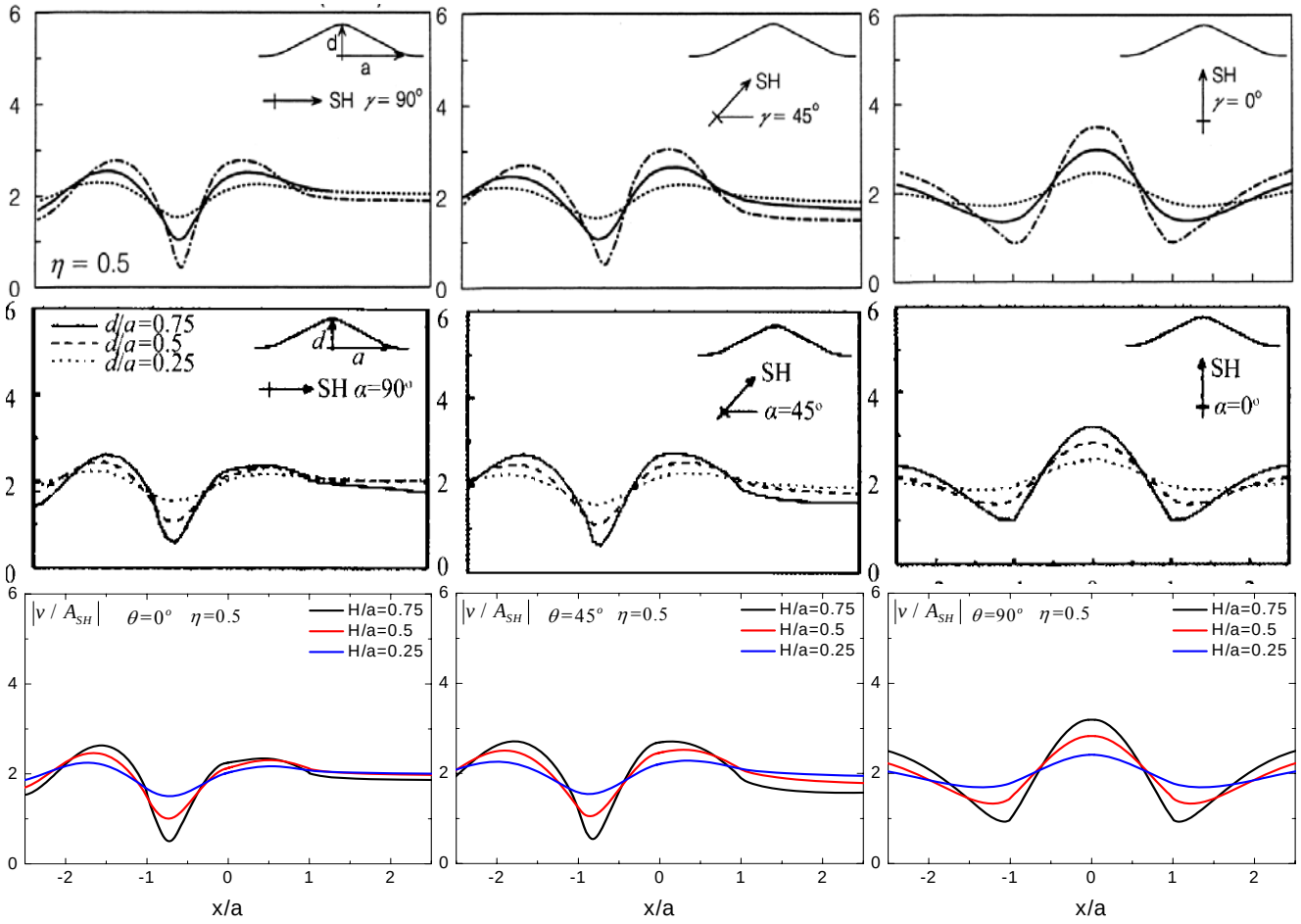

Figure 2 Verification of present study

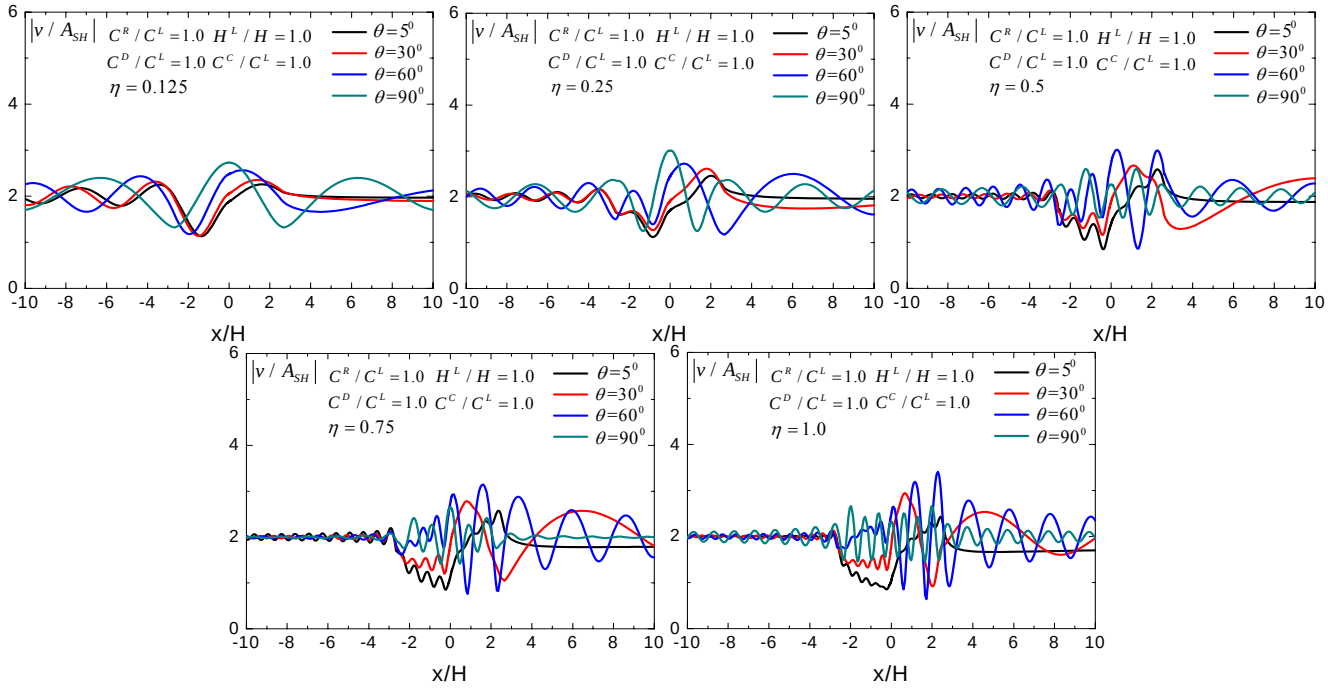

Figure 3 Surface displacement amplitudes of dam on homogeneous half-space

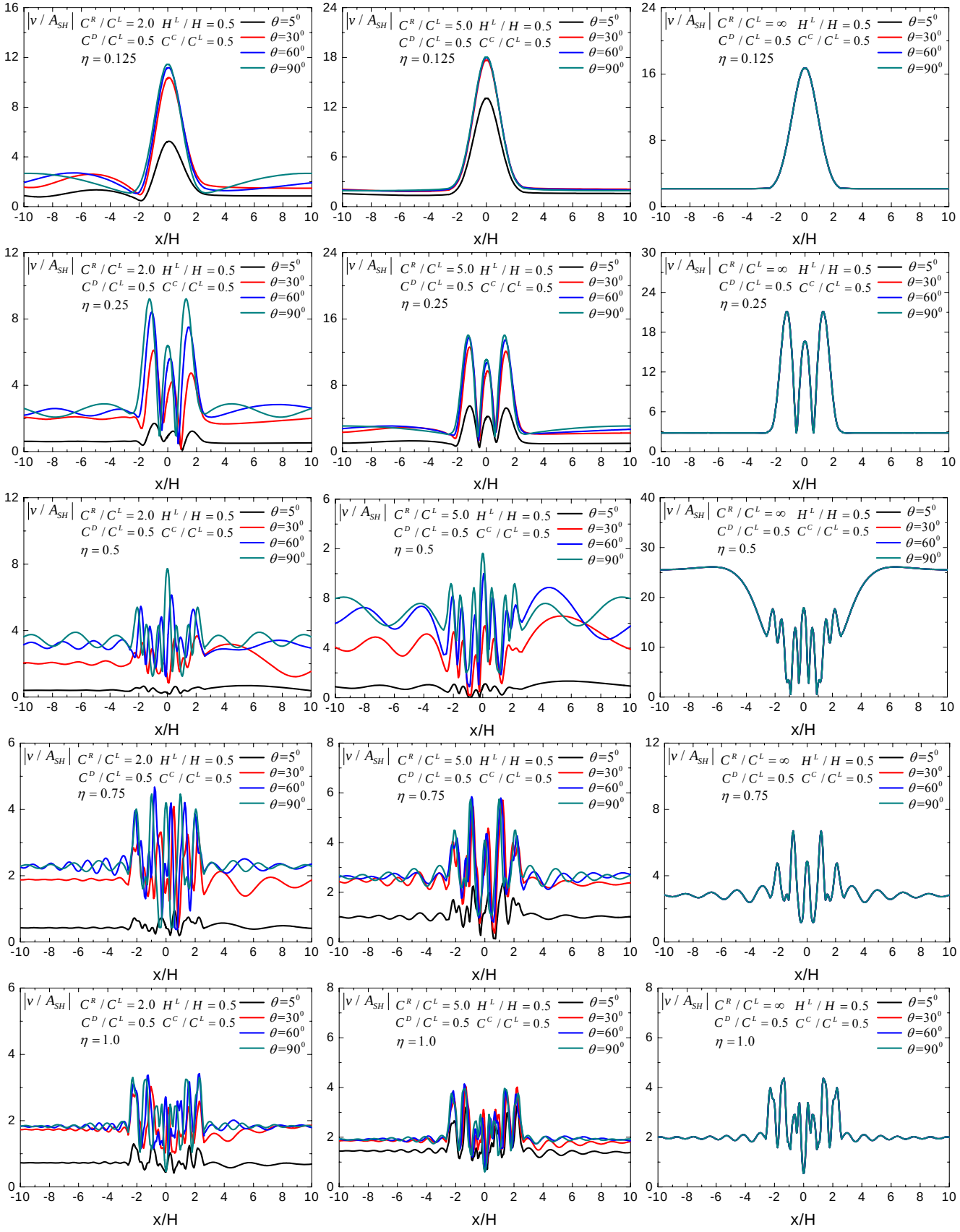

Figure 4 Surface displacement amplitudes of dam on layered half-space

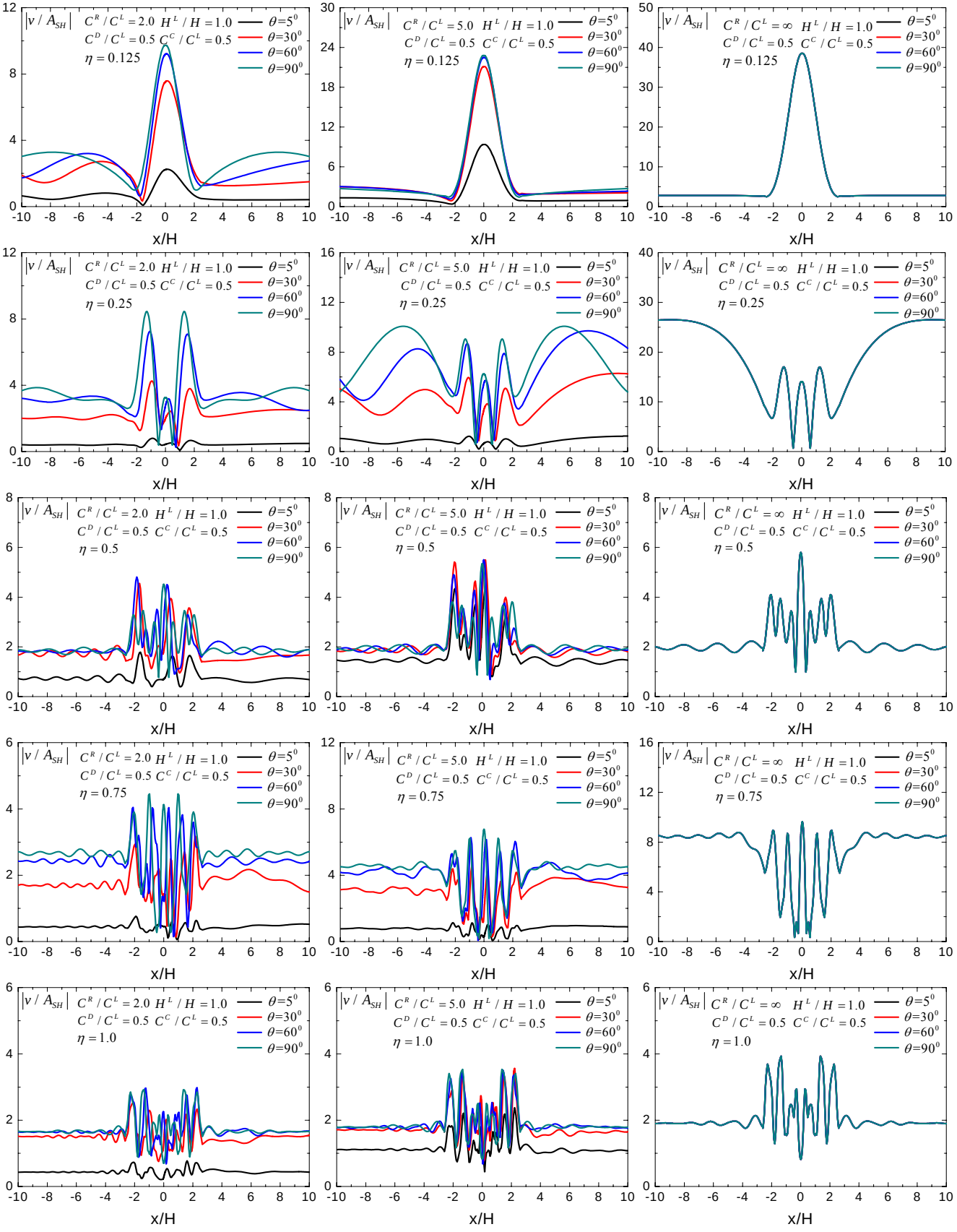

Figure 4 (Continued)

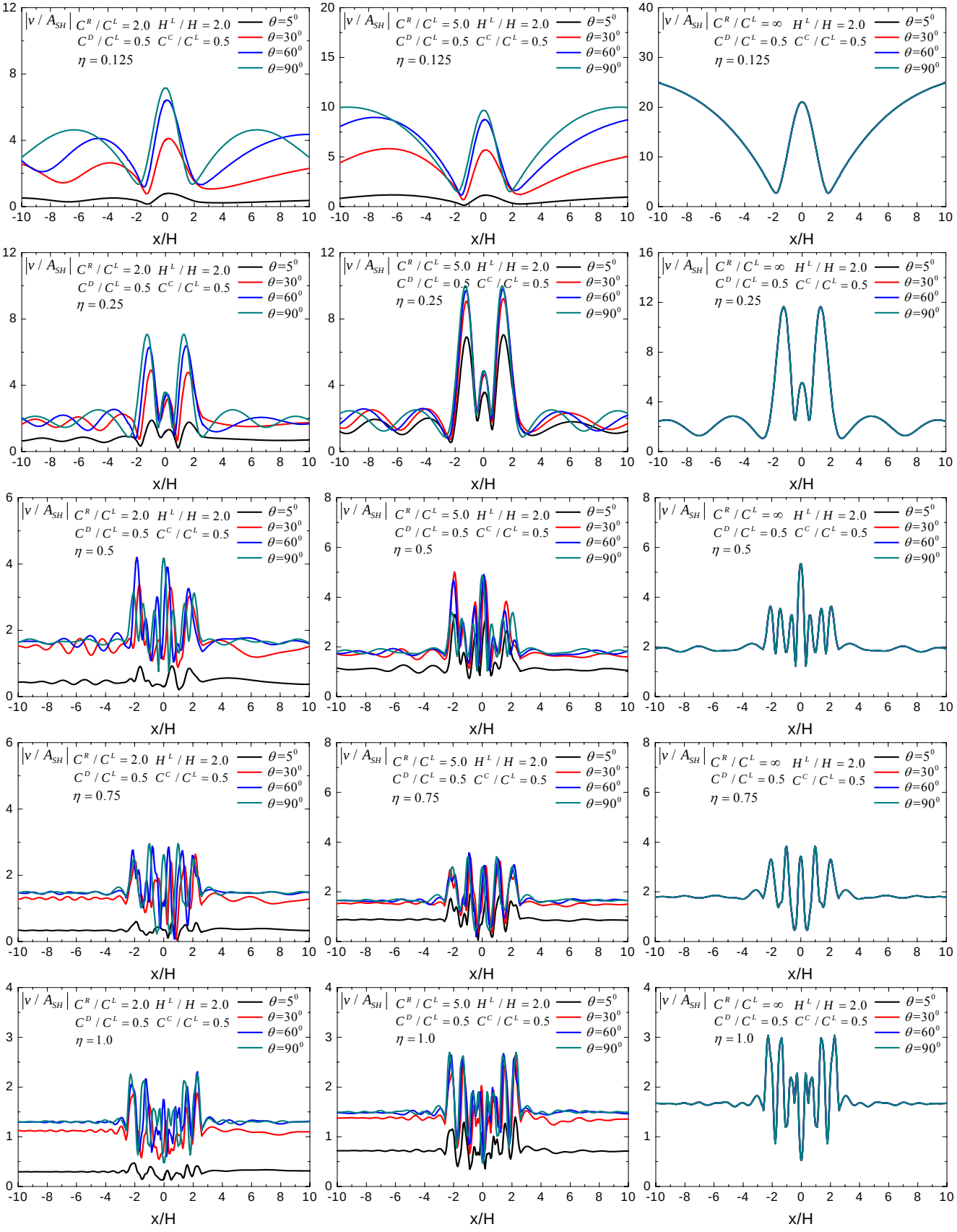

Figure 4 (Continued)

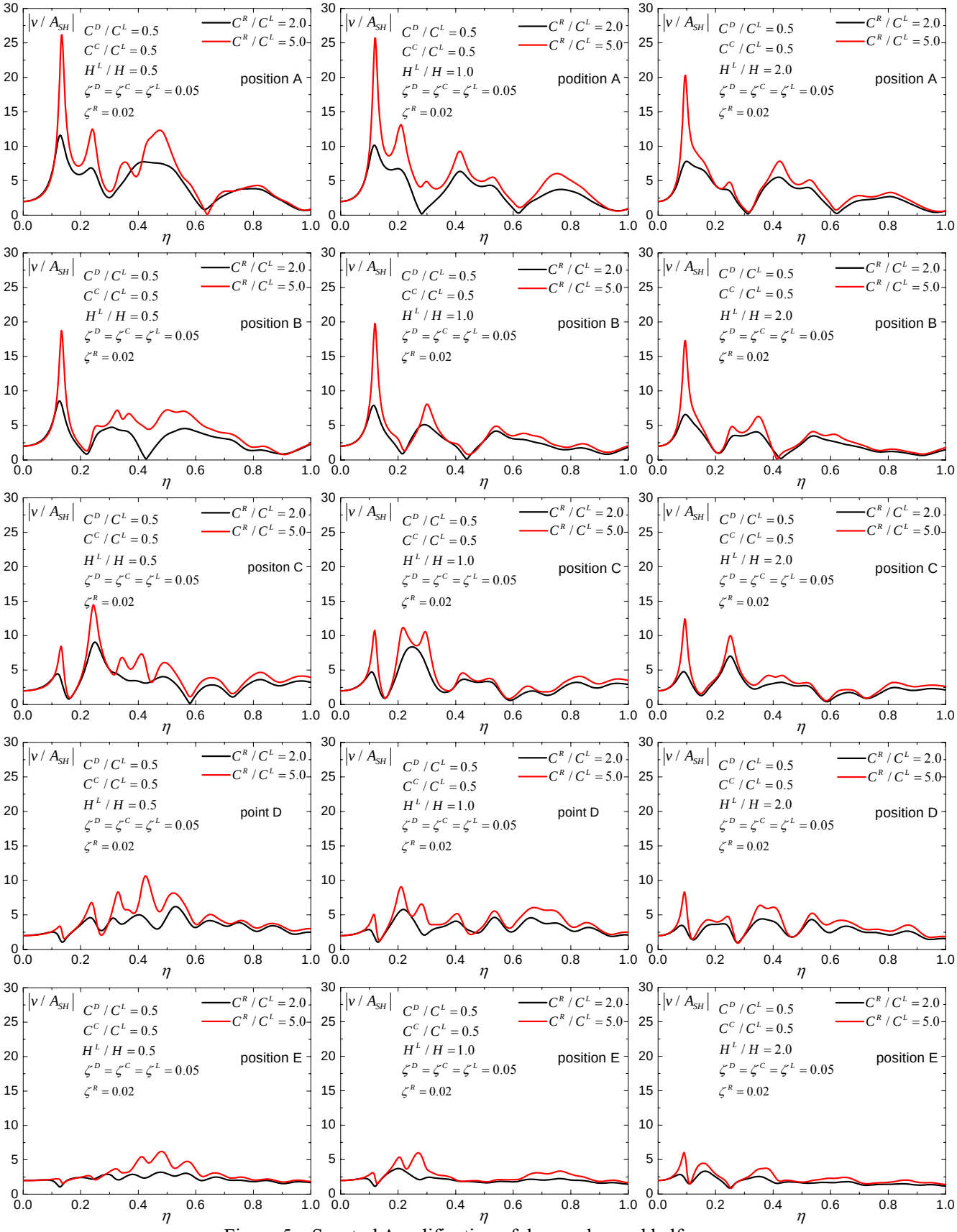

Figure 5 Spectral Amplification of dam on layered half-space

5. CONCLUSIONS

This paper presents a solution for surface motion of an earth dam with a core wall on layered half-space for incident plane SH waves by indirect boundary element method (IBEM). The numerical results are performed for an earth dam with a core wall on one single soil layer over half-space. It is shown that there are significant differences between the surface motion of the dam on homogeneous half-space and that on layered half-space; the surface motion of the dam on layered half-space also highly depends on the resonance characteristics of the layered half-space; there are interactions between the scattering of waves by the dam and dynamic characteristics of the layered half-space; and surface motion at different positions may differ significantly.

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