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BOUNDARY ELEMENT METHOD APPLIED TO SIMULATE THE SEISMIC RESPONSE OF SLOPE TOPOGRAPHIES ON UNDERGROUND CAVITIES FOR INCIDENT P, SV WAVES

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This paper presents results of numerical analyses for the seismic response of slope type topographies in an elastic medium, under vertically incident SV and P seismic waves by Boundary Element Method (BEM). Due to the complexity of this matter, few studies have been performed in this field. In this regard, a 2-D scattering and diffraction of plane P and SV waves induced by slopes above underground cavities and slope-cavity interaction are proposed. To show the interaction between them, a parametric analysis is carried out in the time-domain by BE approach.

Problems related to wave scattering and diffraction by surface and subsurface topographies, such as slopes, valleys, canyons, the foundation of structures, cavities, pipes, subways, and tunnels are of great importance in civil Engineering (Liu et al., 2019). Moreover, underground cavities are common feature in a mountainous area, especially in the karstic regions. Therefore, a comprehensive study of the topographic-cavity interaction effects on wave scattering has great theoretical significance in the estimation of the seismic responses (Alielahi and Adampira, 2018).

For this, an efficient formulation was implemented in a computer code named as SAMBE (Seismic Analysis of Multiple Boundary Element) was developed by Alielahi (2013) based on time-domain boundary element method. The parametric study was performed by solving the following well known transient boundary integral equation, which is governing the dynamic equilibrium of isotropic elastic media:

$$c_{ij}(\xi)u_i(\xi,t)=\int_{\Gamma}[\int_{0}^{t}(U_{ij}^{*}(X,t,\xi,\tau)t_i(X,\tau)-T_{ij}^{*}(X,t,\xi,\tau)u_i(X,\tau))d\tau]d\Gamma+u_j^{inc.}(\xi,t) \tag{1}$$

where U_{ij}^{*} and T_{ij}^{*} are time-domain displacement and traction fundamental solutions at position X and time t due to a unit point force applied in ξ position and preceding time $\tau < t$, respectively. u_i and t_i are displacement and tractions of boundary element. c_{ij} is the well-known discontinuity term resulting from the singularity of traction fundamental solution kernel.

To do this, the important parameters considered in this parametric study include: the ratio of the slope edge distance from the underground cavity; the cavity depth; radios of cavity and influence of slope walls inclination. The results indicate the following: (1) different incident waves caused different amplification pattern; (2) the presence of underground cavities may significantly change the surface motion field.

Figure 1 shows the geometry and variable parameters of the slope and underground cavity subjected to vertically propagating SV and P waves. In this figure, d, a, H and h represent the horizontal distance between the slope crest and the center of the cavity, the cavity radius, the slope height, buried depth of the cavity, respectively. Following that, in the parametric study, the influence of some parameters like slope walls inclination (θ), Cavity radius ratio ($WR=a/H$), Cavity Depth Ratio ($HR=h/H$) and Cavity location ratio ($SR=d/h$) are considered.

The study identified topographic effects as seen in previous numerical studies such as modification of the free-field horizontal motion, generation of parasitic vertical motion, zones of alternating amplification and de-amplification on the ground surface.

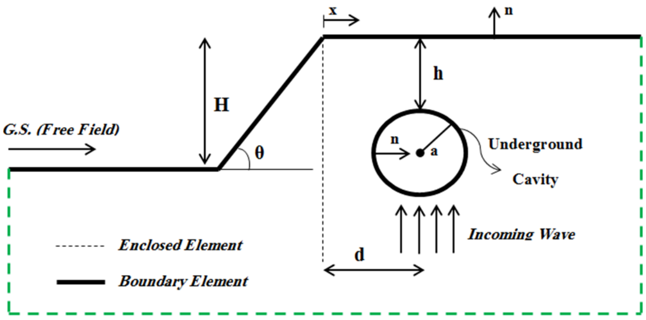

Figure 1. Geometry of Slope with Underground Cavity.

Eventually, Introducing simple preliminary ideas for modification of the standard design spectra for structures to be located on slopes by underground structures such as metro stations, underground parking stations, subway tunnels, and cavities is the purpose of this research. The results encourage a step forward for site response analysis and microzonation of topographical areas by distinguishing the amplification patterns of slope topography and free-field half-space. Results of this paper can be used in building codes and seismic microzonation guidelines.

Clear representations of the amplification pattern of 2D slope topography subjected to vertically propagating SV and P waves were obtained by extensive numerical parametric analysis using the time domain boundary element method. This study shows that the amplification potential of the crest of slope was strongly influenced by the incident wavelength, slope walls inclination, cavity depth ratio, cavity radius ratio and location of the cavity.

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