Amirkabir University of Technology
(Tehran Polytechnic)
Vol. 47, No.1, Summer 2015, pp. 9- 11

Amirkabir Journal of Science & Research (Civil & Environmental Engineering)
(AJSR - CEE)

Comparison of Dynamic Behavior Prismatic and non-Prismatic Canyons using Three- Dimensional Boundary Element Method

R. Tarinejad[1*], M. Isari[2]

1-Assistant Professor, Department of Civil Engineering, University of Tabriz, Tabriz, Iran
2-MSc Student, Department of Civil Engineering, University of Tabriz, Tabriz, Iran

(Received 12 Jun 2012, Accepted 15 Oct 2014)

ABSTRACT

Experiencing several earthquakes around the world indicate that, for a specific earthquake, the amount of structural damages, with almost identical features, is highly influenced by the condition of the site, which is called as the site effects. In fact, something which exists in reality and practice is, in most cases, the non-prismatic canyons in line with the longitudinal axis of the valley so that narrowing parts of the canyons are usually selected as the appropriate sites for a variety of structures, and then studied .In this study, the dynamic behavior of prismatic and non-prismatic canyons, using three-dimensional boundary element method in triangular, trapezoidal, and semi-circular forms under the SH waves, are studied.The Results indicate that the movement of non-prismatic canyons, which have narrowing in the middle and opening in two ends of the canyon, based on the frequency and wave angle, are in some cases more than prismatic canyon. Therefore, to obtain accurate values of site effects, it is necessary to do a realistic and three-dimensional modeling of the canyon.

KEYWORDS

Non-Prismatic Canyons, Boundary Element Method, Site Effects, Prismatic Canyons.

* Corresponding Author, Email: r_tarinejad@tabrizu.ac.ir

1- BRIFE INTRODUCTION

Topographic amplification plays an important role on the modification of seismic ground motion. This effect may become crucial in the selection or simulation of ground motion to use in the structural seismic response analysis. The effects of surface topography can greatly enlarge the site response exerting an important influence on the distribution of damage observed during the earthquakes. The analytical methods are restricted to media with simple geometries as well as scalar wave components. On the other hand , the numerical techniques can be used for real-world geometries and vector wave components but they need much computational time and memory. For the infinite problems, we need to model a large part of the media with huge degrees of freedom especially using the domain methods such as the finite element. However, the boundary element method (*BEM*) is very effective when dealing with wave propagation problems in infinite media with geometrical irregularities [1]. The main advantage of this method is that discretization is only applied at the boundaries of the physical domain, thus reducing the number of unknown variables significantly in comparison to the other methods such as finite element and finite difference techniques. On the other hand, since the fundamental solutions automatically satisfy the far-field conditions, the *BEM* is especially well suited to the problems involving infinite domains such as a canyon located on a half-space. Issues such as the reduction of dimensionality, the fulfillment of radiation conditions at infinity, and higher accuracy in the results, make the boundary element method quite attractive in engineering seismology and especially in the evaluation of topographic effects.

2- METHODOLOGY, DISCUSSION, RESULTS

The governing wave equation in frequency domain for elastic, isotropic and homogeneous body is:

$$c_1^2\nabla(\nabla.\bar{u}) - c_2^2\nabla\times\nabla\times\bar{u} + \omega^2\bar{u} = -b \qquad (1)$$

in which $\bar{u}$ denotes the displacement amplitude vector, b denotes the body force vector, ω denotes the circular frequency and $c1$ and $c2$ are the propagation velocities of compression (*P*) and shear (*S*)waves, respectively. The velocities are related to the properties of the medium through:

$$c_2 = (\mu/\rho)^{0.5}, c_1 = (\lambda + 2\mu/\rho)^{0.5} \qquad (2)$$

Where λ and μ are the Lame constants and ρ is the mass density [2-3].The corresponding governing boundary equation for an elastic, isotropic, homogenous body can be obtained using the well-known dynamic reciprocal theorem as:

$$c^i u^i + \int_\Gamma p^* u d\Gamma = \int_\Gamma u^* p d\Gamma \qquad (3)$$

Where *ci* is the jump tensor and dependent on the local geometry, *p** and *u ** are the fundamental solution for traction and displacement respectively, at a point *x* when a unit Dirac Delta load is applied at point *i*. In the *BEM*, the variables *u* and *p* are discretized into the values at the so-called *collocation nodes*. The displacement and traction fields are interpolated over each element using a set of shape functions. The same shape functions are also used to approximate the geometry, i.e. the elements are isoperimetric. Discretization of Eq. (3) yields:

$$c^i u^i + \sum_{j=1}^{ne}\left\{\int_{\Gamma_j} p^*\Phi d\Gamma\right\}u^j = \sum_{j=1}^{ne}\left\{\int_{\Gamma_j} u^*\Phi d\Gamma\right\}p^j \qquad (4)$$

According to Eq. (4) the surface integral is exchanged with a sum of integrals over *ne* elements. It should be noted that the *BEM* allows the use of *constant* elements, where the displacements and tractions are assumed to be constant over the entire element leading to discontinuities at the element edges. However, this kind of element is inadequate for most wave propagation problems as the convergence is very slowly compared to that of higher-order elements [4]. *Quadratic* elements are used in this research. After assembling all equations, the Following set of equations is obtained:

$$HU=GP \qquad (5)$$

In which , *H* is a 3*n* x 3*n* matrix, *U* is a 3*n* x 1 displacement vector, *G* is a 3*n* x 3*nne* matrix, and *P* is a 3*nne* x 1 traction vector, and *nne* is the product of the number of elements and number of nodes. The Problem has 3*n* unknowns that should be obtained by solving Eq. (5). A special-purpose 3-*D* computer program was developed to implement the boundary element procedures for an incident plane wave with circular frequency ω. The propagation direction of the wave was defined by angles θ*h* and θϖ corresponding to the angle of the ray (normal to wave front) from the horizontal *x*- and vertical *z*-axes, see Figure (1). The program can be used for canyons of arbitrary shape. The numerical examples of this section are designed to demonstrate the accuracy and efficiency of the method for different cases.

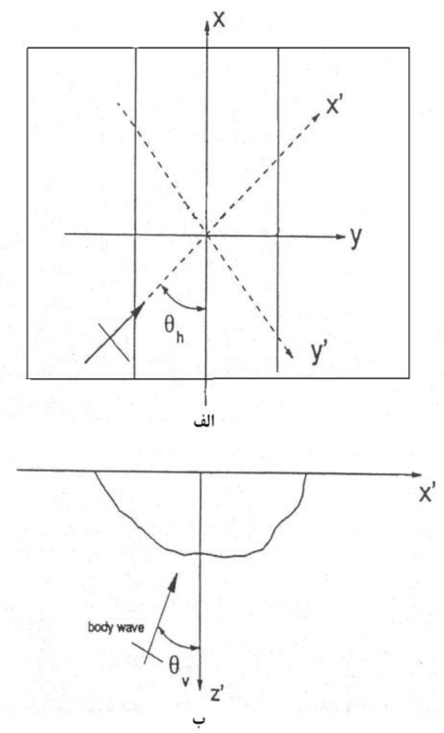

Fig. 1- Topographic system considered is an arbitrarily shaped canyon of finite length with the incident waves arriving from an arbitrary direction.

An arbitrarily shaped canyon of finite length located in homogenous, elastic and isotropic half space is considered as illustrated in Figure (1). Seismic body waves arrive from an arbitrary direction with angles of θ*h* and θ*v* with respect to the horizontal *x* and the vertical *z*-axes, respectively. The half-space is characterized by the *P* and *S* wave velocities *cp* and *cs*, respectively. In order to obtain the accurate results, the discretization should be fine enough and the 3D boundary element model should be large. The authors' studies lead to the fact that in order to obtain accurate results, the element size should be smaller than one-fourth of the shear wavelength. To establish the numerical accuracy of the method, problems involving the scattering of a harmonic plane *SH*-wave, for which the results are available from previous works, are solved using the proposed method. In all cases, a semi-circular cross section of radius *R* cut in a homogenous half space is considered. The semi cylindrical canyon and a length 1.5*R* of the free field on each side of the canyon are discretized. The model has 180 nine-node boundary elements with 777 nodes along the main boundary. A length 1.5*R* of the free field on each side of the canyon and a length 5*R* along the canyon axis are modeled. The results show that along the length of the valley where the two ends are wider, increasing displacement is greater than the prismatic.

3- CONCLUSIONS

In the last two decades , the use of boundary element method is increased . Such algorithms are used for solving the discrete boundary conditions for the wave equation is used. This method of introducing the imaginary boundaries that regional approaches are needed to avoid. The results of three-dimensional models of prismatic and non-prismatic valley show that due to the changes in the canyon section of the site and may be changed depending on the frequency of the incoming wave. The general conclusion that can be removed from the study is that, it can be said prismatic models are not realistic calculations to examine more closely the phenomenon of resonance three-dimensional topographic model is highly recommended.

4- MAIN REFERENCES

[1] Tarinejad R, "Seismic loading Of canyon site structures", Phd Thesis by guidance Mohammad T.Ahmadi.School of Engineering, Tarbiat Modares Univesity, 2008.

[2] Dominguez, J, "Boundary Elements in Dynamics", Elsevier, 1993.

[3] Manolis, G.D., Beskos, D.E, "Boundary Element Methods in Elasto dynamics", Unwin Hyman Ltd, ISBN: 004- 620019- 3, 1988.

[4] Tarinejad, R., Ahmadi, M.T., and Harichanran, R.S, "Effect of non-prismatic 3D-canyon on the scattering of seismic P-and SV-waves", 4ICEGE, Tessalonki, Greece, 2007.