Soil Dynamics and Earthquake Engineering 31 (2011) 729–736

Contents lists available at ScienceDirect

Soil Dynamics and Earthquake Engineering

journal homepage: www.elsevier.com/locate/soildyn

SH-wave diffraction by a semi-circular hill revisited: A null-field boundary integral equation method using degenerate kernels

Jeng-Tzong Chen [a,b,*], Jia-Wei Lee [a], Chine-Feng Wu [a], I-Lin Chen [c]

[a] *Department of Harbor and River Engineering, National Taiwan Ocean University, Keelung, Taiwan*
[b] *Department of Mechanical and Mechatronic Engineering, National Taiwan Ocean University, Keelung, Taiwan*
[c] *Department of Naval Architecture, National Kaohsiung Marine University, Kaohsiung, Taiwan*

ARTICLE INFO

Article history:
Received 8 September 2010
Received in revised form
28 November 2010
Accepted 1 December 2010
Available online 26 January 2011

Keywords:
SH-wave
Diffraction
Semi-circular hill
Null-field BIEM
Degenerate kernel

ABSTRACT

Following the success of seismic analysis of a canyon [1], the problem of SH-wave diffraction by a semi-circular hill is revisited using the null-field boundary integral equation method (BIEM). To fully utilize the analytical property in the null-field boundary integral equation approach in conjunction with degenerate kernels for solving the semi-circular hill scattering problem, the problem is decomposed into two regions to produce circular boundaries using the technique of taking free body. One is the half-plane problem containing a semi-circular boundary. This semi-infinite problem is imbedded in an infinite plane with an artificial full circular boundary such that degenerate kernel can be fully applied. The other is an interior problem bounded by a circular boundary. The degenerate kernel in the polar coordinates for two subdomains is utilized for the closed-form fundamental solution. The semi-analytical formulation along with matching boundary conditions yields six constraint equations. Instead of finding admissible wave expansion bases, our null-field BIEM approach in conjunction with degenerate kernels have five features over the conventional BIEM/BEM: (1) free from calculating principal values, (2) exponential convergence, (3) elimination of boundary-layer effect, (4) meshless and (5) well-posed system. All the numerical results are comparing well with the available results in the literature. It is interesting to find that a focusing phenomenon is also observed in this study.

1. Introduction

Taiwan is located in the Pacific Ring of Fire, which is an area with a large number of earthquakes and volcanic eruptions. It results in significant displacement amplitude on the canyon, hill, and ground surface due to scattering and diffraction of seismic waves. Studying the vibrational response of the soil due to earthquakes is an important issue in this area. Based on assumptions of linear elastic, isotropic and homogenous medium for the soil, problems of SH-wave diffraction can be formulated to the two-dimensional Helmholtz equation.

Regarding problems of SH-wave diffraction and scattering by the alluvial valley and canyon, Trifunac derived analytical solutions for semi-circular cases with alluvial and without alluvial in 1971 [2] and 1973 [3], respectively. Later, Yuan and Liao [4] employed the approach of wave function expansion to deal with problems of SH-waves scattered by a cylindrical canyon of circular-arc cross-section. For the multi-layers problems, Vogt et al. [5] have employed the indirect-boundary element method (BEM) to solve the canyon problem of arbitrary shape in a layered half-space. The reflection waves caused by a hill are more complex than by a canyon from the point of wave physics. Mathematically speaking, hill scattering is more difficult than the canyon case due to not only its convex geometry but also its solution space. It means that the closed-form or analytical solution is not easy to derive. Therefore, numerical methods are required.

Numerical methods were used to solve this kind of problems including wave function expansion method [6–8], BIEM/BEM [1], hybrid method [9] and spectral-element method (SEM) [10]. For the boundary element methods (BEM), direct [11,12] and indirect formulations [13] have been employed. Regarding the fundamental solution, Kawase [14] used the discrete wave number Green's function in BEM. For the conventional BEM, the closed-form fundamental solutions is utilized. Chen and his coworkers employed the degenerate kernel for the fundamental solution and proposed the null-field integral equation approach. To consider the complex shape of canyon or hill, hybrid method and SEM are flexible to solve this problem. The main point to care about for the wave function expansion method is the selection of completeness of the wave function base. As quoted by Tsaur and Chang [6] "Unfortunately, their series solution for such a problem is in error due to unsuitable connection between the domain decomposition and the expression of corresponding wavefield."; this

* Corresponding author at: Department of Harbor and River Engineering, National Taiwan Ocean University, Keelung, Taiwan. Tel.: +886 2 24622192x6177; fax: +886 2 24632375.
E-mail address: jtchen@mail.ntou.edu.tw (J.-T. Chen).

0267-7261/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.soildyn.2010.12.001