Advances in Applied Mathematics and Mechanics
Adv. Appl. Math. Mech., Vol. **10**, No. 4, pp. 912-924

DOI: 10.4208/aamm.OA-2017-0301
August 2018

Singular Boundary Method to Simulate Scattering of SH Wave by the Canyon Topography

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Received 18 November 2017; Accepted (in revised version) 22 February 2018

Abstract. This study presents an alternative meshless boundary collocation approach, the singular boundary method (SBM), in conjunction with the image concept for simulating SH wave scattering by the canyon topography. First the image concept is implemented to extend the original semi-infinite domain problems to infinite domain problems. Then the SBM has been used to solve the infinite domain problems. In the SBM it employs the singular fundamental solutions as basis functions and introduces the concept of source intensity factor to regularize the singularities of the related fundamental solutions, which avoids singular numerical integrals in the boundary element method. To demonstrate the effectiveness of the proposed approach for SH wave scattering by the canyon topography, several benchmark examples are considered. The present results are compared with the analytical solutions, the null-field boundary integral equation method.

AMS subject classifications: 65N80, 65N35, 65N38, 86-08

Key words: Singular boundary method, image concept, SH wave scattering, canyon topography.

1 Introduction

Despite active research of many decades, efficient numerical simulation of the seismic wave propagation under soil medium is still a great challenge in civil engineering. According to the engineering experience from earthquake damages, it shows that surface

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ground motions generated from earthquake are influenced by the three main factors such as the source, the propagation medium and the local site topography.

In this study the fundamental and simplest seismic wave propagation problems, plane shear horizontal (SH) wave scattering by the canyon topography under 2D homogeneous medium, are considered. Trifunac [1,2] has derived the closed-form solutions of SH wave propagation by a canyon with semi-circular shape and semi-elliptical shape. Pao and Mow [3] have published a book on scattering and diffraction of elastic waves. However, the aforementioned analytical solutions are only limited for simple cases with simple geometries. In 1991, Liu and his coworkers [4] have derived a new analytical solution based on complex function and conformal mapping for SH wave propagation by the canyon of arbitrary shapes. However, it encounters troublesome and expensive conformal mapping computation in the solution of irregular-shape canyon.

Therefore, numerical methods have been used to simulate this kind of SH wave scattering problems. The popular finite element method (FEM) [5,6] needs to be coupled with some effective special treatments for handling infinite or semi-infinite domain problems, which are often tricky and largely based on trial-error experiences. Unlike the FEM, the boundary element method (BEM) [7] appears attractive to infinite or semi-infinite domain problems, because the fundamental solutions in the BEM satisfy the governing equation and Sommerfeld radiation condition at infinity in advance. However, the BEM encounters sophisticated mathematical and time-consuming numerical integration of singular fundamental solutions. Recently, Chen and his coworkers [8,9] have proposed a null-field boundary integral equation method (BIEM) to simulate SH wave scattering by 2D topographies of canyon, valley and hill, which inherits the benefits of the standard BEM and introduces degenerate kernels to avoid the numerical calculation of singular integrals. However, the degenerate kernels are only available for several simple geometries.

To avoid these drawbacks in the BEM, several numerical approaches have been proposed, for example, the method of fundamental solutions, the boundary knot method [10, 11], the boundary particle method [12], the modified collocation Trefftz method [13], the regularized meshless method [14–16], the modified method of fundamental solutions [17], the singular boundary method (SBM) [18] and the boundary distributed source method [19], just to mention a few.

This paper focuses on the singular boundary method (SBM), which is a novel meshless boundary collocation method proposed by Chen in 2009 [18]. It employs the singular fundamental solutions as basis functions and introduces the concept of source intensity factors (also called origin intensity factor in some literatures [20–22]) to regularize the singularities of the related fundamental solutions, which avoids singular numerical integrals in the BEM.

The key issue of the SBM is to efficiently determine the related source intensity factors (SIFs). Until now, four approaches, the inverse interpolation technique (IIT) [18], the subtracting and adding-back technique (SABT) [23], the integral mean value technique (IMVT) [24,25] and the empirical formulation (EF) [21], have been proposed to determine