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Seismic response of an embedded pile in a transversely isotropic half-space under incident P-wave excitations

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ABSTRACT

A rigorous mathematical formulation is presented for the analysis of a thin cylindrical shell embedded in a transversely isotropic half-space under vertically incident P-wave excitation. By virtue of a set of ring-loads Green's functions for the shell and a group of dynamic fundamental solutions for the half-space under arbitrary interfacial dynamic loads, the problem is shown to be reducible to a pair of Fredholm integral equations. By utilizing an adaptive-gradient family capable of capturing regular-to-singular solution transitions smoothly, an accurate numerical procedure is developed. To assess the effect of material anisotropy on the dynamic load-transfer process, a set of comprehensive numerical results presented for various material and geometrical conditions. The accuracy of the proposed numerical scheme is confirmed by its comparison with a benchmark solution for the corresponding isotropic problem.

1. Introduction

Analytical and numerical methods adopted to study soil–structure interactions have expanded greatly during the last decades. For a review of such analysis and their development one can refer to Kausel [1].

By increasing the use of composite materials and the recognition of anisotropic behavior of rocks and deposited soils, the study of stress-transfer in transversely isotropic solids have gained the focus of researchers from several areas. This kind of solutions are valuable in analysis of crack, inclusion, and interaction problems which has a great appeal in offshore engineering, geomechanics, geophysics and material science. Scattering problems in transversely isotropic media is a kind of this investigations and studied broadly. Incident wave scattering and diffraction problem on cracks studied by Kunda and Bostrom [2], Bostrom et al. [3], Brock and Hanson [4], Wu [5], Tan et al. [6] and Gautesen et al. [7]. Study of wave scattering problem around the inclusions and cavities presented by Gatmiri and Eslami [8]. Analysis of wave–seabed interaction studied by Jeng and Liu [9] by regarding the effect of seabed anisotropy effect. Hirose et al. [10] used BEM to analyze wave propagation in a water-filled borehole in an anisotropic solid. Scattering problem by an infinite transversely isotropic cylinder in a transversely isotropic medium studied by Niklasson and Datta [11]. By the method of potential functions, Eskandari and Sattar [12] presented solution for transient wave propagation in transversely isotropic medium.

To the best of authors' knowledge, in contrast to the need for rigorous treatments to study of seismic soil–pile interaction in transversely isotropic solids, these solutions are not presented in the literature. However, approximate analytical or numerical solutions of dynamic soil–structure interaction problems in transversely isotropic solids are studied widely. Liu and Novak [13] and later Zheng [14] studied dynamic-response of a single pile embedded in transversely isotropic layered media using the finite element method combined with dynamic stiffness matrices of the soil. Barros [15] studied axial soil–pile interaction under dynamic excitation, in which pile modeled by means of FEM while for soil half-space BEM is adopted. Dynamic interaction of rigid foundations embedded in transversely isotropic solids studied by using BEM by Gazetas [16], Kirkner [17], Wang and Rajapakse [18] and Barros [19]. Dynamic response of a pile in a transversely isotropic saturated soil to transient torsional loading can be found in Chen et al. [20] and for a cylindrical pile placed on a rigid bedrock under time-harmonic torsion in Wang et al. [21].

Their contributions to a difficult problem notwithstanding, these formulations are less than rigorous in enforcing the full mechanical interaction conditions between the pile and the soil. The lack of serious recognition and treatment of the singular nature of the load-transfer procedure at the end sections of the pile and the elementary treatment of the pile medium are some examples.

For the case of dynamic soil–pile interaction in isotropic materials the most rigorous analytical treatments can be found in

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