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Rocking vibrations of a rigid circular foundation on poroelastic half-space to elastic waves

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ABSTRACT

A study is carefully conducted for the rocking response of a rigid circular foundation resting on a poroelastic half-space when subjected to seismic waves under the framework of Biot's theory. The free-field waves, rigid-body scattering field waves and radiation scattering field waves are introduced to consider the complex behavior of the soil owing to the scattering phenomena caused by the existence of the foundation. The contact surface between the soil and the foundation is supposed to be perfectly bonded and fully permeable. Combining with the divided wave fields, two sets of dual integral equations elaborating the mixed boundary-value conditions are established, and then reduced to Fredholm integral equations. Therefore, with a semi-analytical method, the expressions of the rocking displacements are obtained. The numerical results of the rocking vibration of the foundation for incident P, SV and Rayleigh waves are presented. The influences of certain parameters, such as the permeability of the soil, the incident angle, Poisson's ratio and the mass of the foundation, on the rocking vibration of the foundation are explored and studied. Different reactions are found when the foundation is excited by different waves.

1. Introduction

Foundation vibration often brings about adverse effects on buildings and precision machinery, and may even cause damages. Various factors have contributed to foundation vibration, such as construction work, machinery in factories and seismic waves propagating through the soil.

There are many researches dealing with foundation vibration excited by seismic waves in single phased elastic soil. Based on the Bubnov–Galerkin method, Oien [1] developed an approximate solution for the diffraction of harmonic waves by a movable rigid strip bonded to the surface of an elastic half-space. The response of a rigid circular disk to incident waves was studied by Kobori et al. [2,3] (translational, rocking and torsional vibrations). They also examined the coupling effects between rocking and translation vibrations. Iguchi [4] presented an approximate analysis of input motions for a rigid embedded foundation. Pais and Kausel [5] extended the work by Iguchi [4] to obtain the motion of embedded cylindrical and rectangular foundations in response to seismic excitations. Luco [6] studied the torsional response of an elastic structure subjected to the obliquely incident SH waves, which was placed on a rigid circular foundation supported by elastic soil. The mixed boundary-value problems were formulated in terms of dual integral equations to be solved. Luco and Mita [7] investigated the translational and rotational components of the vibration of the circular foundation for non-vertically incident P, SV, SH and Rayleigh waves. Tham et al. [8] analyzed the dynamic response of a group of flexible foundations to incident Rayleigh and SH waves using a combined procedure of the boundary element method and the finite element method. The influence of the foundation stiffness on the dynamic response was discussed.

It is noted that most of the former theoretical studies are based on the assumption that the foundation rests on a single-phase linear elastic material. Generally speaking, due to the existence of underground water in soil medium, the coupling between the fluid and solid may affect the wave propagation and foundation vibration to some extent. Therefore, the fully saturated soil model superior to the elastic one would be a good choice for analyzing the vibration of the foundation excited by seismic waves.

Biot [9,10] established the theory governing wave propagation in the fluid-filled poroelastic medium. Since then, strong interest has been expressed in studying soil–foundation interaction based on Biot's poroelastodynamic theory. Halpern and Christiano [11,12] obtained the solution of poroelastic half-space to steady-state harmonic surface tractions and studied the response of a rigid rectangular foundation on the poroelastic half-space firstly. The Fourier transform was employed in their analysis process. Philippacopoulos [13] presented an analytical study of the vertical response of a rigid circular foundation on saturated layered soil. By employing Biot's theory and wave function expansion,

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