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Transient dynamic response of fluid-saturated soil under a moving cyclic loading

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ABSTRACT

Based on the Theory of Porous Media (TPM), a mathematical model of a two-dimensional incompressible fluid-saturated elastic soil is established, and the periodic boundary conditions are presented to analyze the transient dynamic response of this soil under a moving cyclic loading. The differential quadrature method (DQM) and the second-order backward difference scheme are applied to discretize the governing equations on the spatial and temporal domains, respectively. As application, a typical two-dimensional wave-induced transient problem with a seabed of finite thickness is analyzed, and the numerical results are compared with the analytical results presented in the present work. In addition, a transient dynamic response of fluid-saturated soil under limit moving vehicle loadings is studied. The effects of the velocity of vehicle and the volume fraction on the settlement and the pore water pressure are studied.

1. Introduction

The investigation of porous media plays an important role in its classical application fields, such as soil mechanics, hydrology, etc.; furthermore, it is essential to the development of emerging sciences and technologies as well, such as, mechanical characteristic of skin, soft tissue and articular cartilage in biology, etc. Hence, it is important to provide the relevant theoretical analyses and numerical simulation methods. In addition, the transient response of a saturated soil is also essential to understand the deformations as well as the pore water pressures generated by ground motion. This response is a key factor to the analysis of foundation of buildings, offshore structures, and wave propagation in geological medium due to blast or earthquake.

There are some theories describing the characteristics of porous media, for example, Biot Theory [1,2], Porous Media Theory [3–5] and Hybrid Mixture Theory [6], etc. Detailed comments on these theories can be found in Ref. [7] presented by Schanz. In 2005, de Boer [5] established a complete porous elastic theory based on the continuous media mixture laws and the concept of volume fraction, in which several micro-mechanical characteristics can be directly applied to describe the macro-mechanical characteristics. Thus, the Porous Media Theory may be an alternative method to study the mechanical properties of porous media.

Most of the transient response studies for porous media are solved by numerical methods, such as finite element method (FEM) [8–11], boundary integral–boundary element method (BEM) [12–15],etc. Ghaboussi and Wilson [8] seem to be the first to have formulated a FEM for dynamical processes in poroelastic media based on the Biot's theory. Zienkiewicz and Shiomi [9] published the most complete FEM presentation for poroelastodynamics. Chen [12,13] introduced the Green's functions of saturated porous media and applied BEM to study the dynamic response of porous media. Khalili and Yazdchi [16] used the finite element–infinite element method to study the wave propagation in saturated soil. Karim et al. [17] applied the element-free Galerkin method (EFGM) to study the transient response and obtained the stable numerical results. Korsawe et al. [18] used the Galerkin finite element method (GFEM) and the least-squares mixed finite element method (LS-MFEM) to analyze the consolidation in porous media, and thoroughly compared the effect of the two different numerical approaches on the numerical results. Breuer and Jagering [19] used a standard FEM to investigate elastic and plastic dynamical problems of saturated porous media based on TPM. Hu et al. [20] applied the DQM to analyze the dynamic response of fluid-saturated visco-elastic porous media.

In this investigation, based on TPM, a mathematical model of a two-dimensional incompressible saturated elastic soil is established, and the periodic boundary conditions are presented for analyzing the transient dynamic response of the saturated soil under a moving cyclic loading. The differential quadrature method (DQM) and the second-order backward difference scheme are applied to discretize the governing equations on the spatial and

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