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Effects of inner soil on the vertical dynamic response of a pipe pile embedded in inhomogeneous soil

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Abstract: This paper is concerned with the effects of inner soil on the vertical dynamic response of a pipe pile embedded in a vertically multilayered and radially inhomogeneous soil. The soil is considered a three-dimensional axisymmetric medium, the radial inhomogeneity of which (due to the construction disturbance effect) is simulated by gradually varying the soil parameters in the radial direction. The pipe pile is treated as a vertical, hollow, viscoelastic, one-dimensional bar. The velocity admittance and reflected signal at the pile head are derived by solving the equilibrium equations for the pile and soil. They are then used to obtain an insight into the coupled effects of the inner soil and several related factors, such as the pile parameters, construction disturbance effect and pile defect characteristics, on the vertical dynamic response of the pipe pile concerned in pile integrity testing. A comparison with the measured data is also presented to verify the reliability of the proposed solution.

Keywords: pipe pile; inner soil; velocity admittance; reflected signal; construction disturbance effect

1. Introduction

The pipe pile, known for its good adaptability, high bearing capacity and reliable quality assurance, has been increasingly employed to support various civil engineering structures worldwide. During the installation of open-ended pipe piles, soil enters the inside of the pile and forms a soil column (known as the soil plug). The existence of the inner soil complicates the behavior of the pipe pile compared to that of a solid pile. Previous studies have shown that both the static bearing capacity and the driving response of pipe piles are closely related to the properties of the inner soil [1–5]. Beyond that, the effects of the inner soil on the dynamic response of a pipe pile are also worth studying to provide references for the integrity testing of this type of pile.

The crux of the problem lies in the simulation of the dynamic interaction between the inner soil and the pile shaft. Many researchers have devoted their attention to this field and have obtained significant results. For instance, Ding et al. [6] simulated the inner soil using the Voigt model and on this basis derived an analytical solution to study the high-frequency interference observed in the low-strain integrity detection of large-diameter pipe piles. In another study, Ding et al. [7] introduced a simple Winkler model to obtain a time-domain analytical solution for a pipe pile under axial point loading. Although the Voigt and Winkler