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Nonlinear Kinematic Response of Piles Subjected to Vertical P-Wave

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Abstract

A numerical solution of kinematic pile response to vertically propagating p-waves due to seismic excitation is developed using finite element method (FEM). Dynamic equation of motion for the soil-pile system is solved by means of newmark's time integration method in time domain. The effect of nonlinearity is considered due to possible soil-pile slippage resulting from stong motion. In addition, the loading rate dependency of the soil resistance is considered in this study. Furthermore, parametric studies are carried out to investigate the effects of various soil and pile parameters on the pile response. It is conclded that the strong vertical excitation has an importance effect on vertical seismic pile response.

Keywords: kinematic response, pile, slippage, finite element method, time domain.

1. INTRODUCTION

Pile foundations are one of the oldest ways for constructing structures on the soft soils. Generally in the seismic analysis of structures, interaction between soil, foundation and structures is neglected and assumed that base of structures is rigid. In addition, interaction between soil and pile is also is neglected and assumed that excitation imposed to the base of structures is same as free field excitation. However the effect of interaction between soil and pile foundation may change the response of the structures. Mylonakis and Gazetas [1] showed that the seismic excitation transmitted to the base of structures is less than free field excitation. Kavvadas and Gazetas [2], Nikolaou et al. [3], Makris and Gazetas [4], and Ghazavi and Madhoushi [5] investigated the effect of interaction between pile and surrounding soil. All mentioned studies are performed under this assumption that the soil behavior is linear and the nonlinearity arising from slip between pile and surrounding soil has been considered. In this study, finite element solution has been used to perform nonlinear analysis in time domain on soil-pile system subjected to P-waves due to vertical earthquake component.

2. PROBLEM DEFINITION AND MODEL DEVELOPEMENT

The soil-pile system considered in this study is shown in Figure 1. The soil is idealized as distributed springs and dashpots that act along the pile shaft and a lumped spring that act on the pile base. The soil is assumed to have thickness H, Young's modulus E_s, Poisson's ratio ν_s, mass density ρ_s, untrained shear strength c_u, and material damping β. The pile is assumed to be elastic with Young's modulus E_p, length L, diameter d and mass density ρ_p. Soil spring behavior is assumed to be elastic upon a critical state expressed as R_d. After this state is reached the spring forces are maintained constant and damping forces are reduced to zero. The excitation consists of vertically propagating harmonic compressional waves imposed at the base of the soil layer. The governing differential equation of the pile motion is developed and then analysis is performed using finite element method in time domain for accounting slippage between the pile and surrounding soil.