ABSTRACT

Nonlinear Seismic Analysis of Pile Groups in Layered Soils due to Kinematic Interaction Effects

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During earthquakes, piles undergo stresses due both motion of the superstructure (i.e. inertial interaction) and that of the surrounding soil (i.e. kinematic interaction). In practice, structural engineers commonly take into account stresses induced by the inertial interaction, which is responsible for pile head failure, but they neglect the effects of the kinematic interaction that is responsible for failures along pile's length in the case of layered soils with highly contrasting mechanical characteristics even in the absence of the superstructure. Thus, the evaluation of kinematic forces developing in piles during earthquakes has been receiving increased interest from the researchers.

Numerical methods for the analysis of kinematic soil-pile interaction can be classified into two groups; continuum-based approaches and Winkler methods [1-3]. It has been customary in professional engineering and research practices to assume a linear behaviour for the soil and the pile foundation. However, under strong excitation, the nonlinear behaviour of soil media at the soil-pile interface has a strong influence on the response of the pile foundation. The aim of this study is to investigate the influence of soil nonlinearities on the kinematic interaction forces of pile groups embedded in layered soil deposits during seismic actions. Figure (1) shows the assumed soil-pile group case with 5 by 5 piles embedded in two layer subsoil profile. The pile has been considered as an elastic beam, while the soils have been modelled using the elastic-plastic solid element. The corresponding 3D finite element mesh has been shown in Figure (2). Based on the symmetry, only half of the model is meshed.

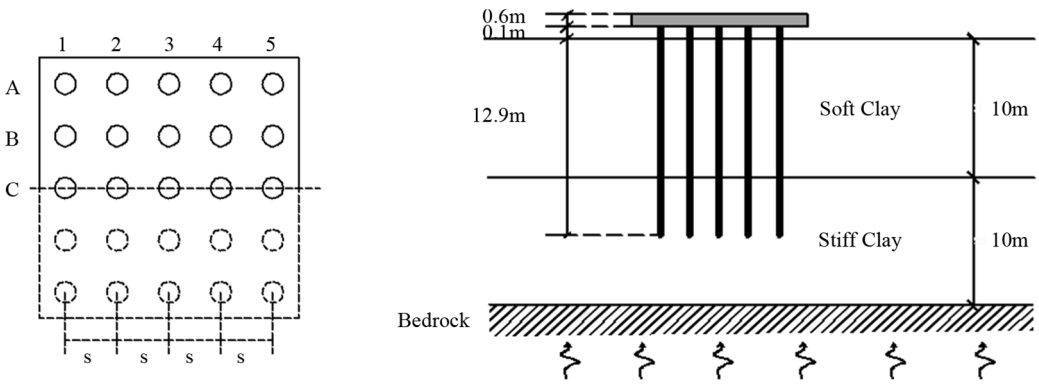

Figure 1. Soil-pile group model.

Dynamic numerical analysis has been performed using the FE program ABAQUS [4]. Necessary parameters to simulate the examined cases are listed in Table (1). It is worth noticing that the comparison with available experimental and theoretical results in the literature has been made to validate the numerical model. The maximum displacements and the envelopes of kinematic bending moments and axial forces along the piles depth have been reported in Figure (3) due to the 1978 Tabas, Iran earthquake ground motion at the Dayhook station. As shown, it can be observed that the kinematic force distributions present relative maximum values very close to the layer

interface. On the other hand, the diagram of the maximum displacements is characterized by a shape very similar to the first vibration mode of the soil deposit with maximum value at the piles head and almost zero value near the bedrock. In addition, the effects of kinematic group interaction lead to a decrease of bending moments at the pile head and also the layer interface as compared to the results from the single pile. Finally, the influence of main parameters governing the seismic response of piles like the space-diameter ratio, number of piles in the group, pile dimater, pile-to-cap fixity condition and the variation of soil layers properties are discussed.

Keywords: Pile Group; Kinematic Interaction; Nonlinear Seismic Response; Finite Element

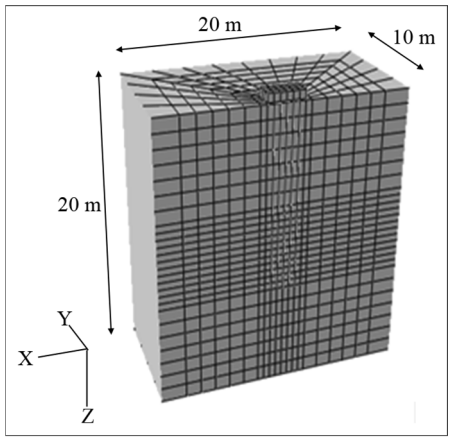

Figure 2. FE model for soil-pile group with 5 by 5 piles.

Table 1. Geotechnical parameters of the soils and piles

Model Elements	Material	Density, (Kg/m^3)ρ	Poisson's Ratio, ν	Friction Angle, Φ (deg)	Dilatancy Angle, ψ (deg)	Young Modulus, E (MPa)	Damping Ratio, ξ	s-Wave Velocity, v_s (m/s)
Upper Soil Layer	Soft Clay	2100	0.49	0	0	100	0.05	126
Lower Soil Layer	Stiff Clay	2500	0.4	0	0	4.48×10^3	0.02	800
Piles and Cap	Steel	7850	0.3	-	-	2.1×10^5	-	-

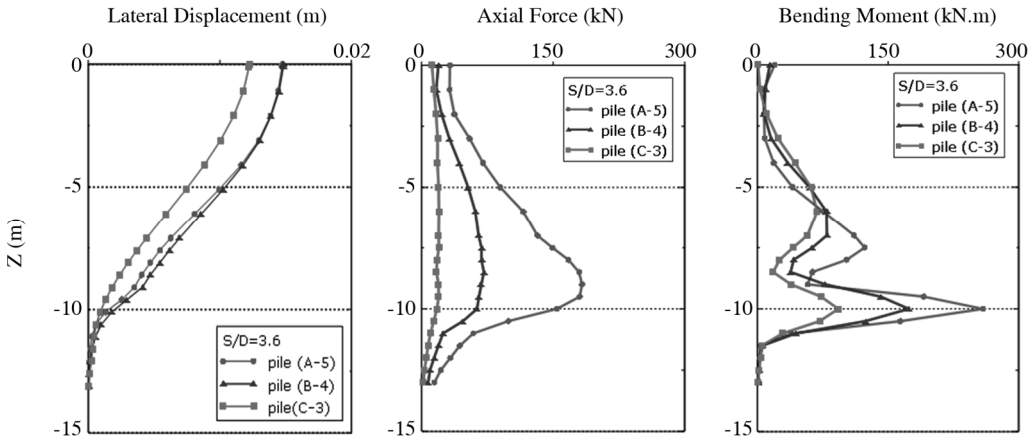

Figure 3. Maximum lateral displacement, axial force and bending moment within the piles

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