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THE EFFECT OF A TRANSIENT DYNAMIC LOADED PILE ON A NEIHBOURING PILE FOR NONHOMOGENEOUS SOILS

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ABSTRACT This study presents an investigation of the interaction effect of one loaded pile on a neighboring pile under transient dynamic loadings. Analyses are carried for non homogeneous soils. The hybrid boundary element formulation is used to represent boundary integral representation of soil domain and pile equations represented by linear structural components. The formulation is presented for a transient point force acting in the interior of a non-homogeneous, isotropic half space. A time stepping boundary element algorithm for soil domain is used together with an implicit time integration scheme for finite pile domain.

INTRODUCTION

Pile foundations are used to support structures on weak soils. Due to the need for a reliable design method for massive and sensitive structures such as nuclear plants, bridges, offshore platforms under impact loads, the transient elastodynamic analysis of piles has attracted substantial research interest in the last few decades.

For the elastostatic case of Gibson soil, Poulus (1979) proposed an approximate solution whereby Mindlin's equations (1936) are used in conjunction with the appropriate soil modulus at various points along the pile. Banerjee and Davies (1978) utilized a two layer half space solution to approximately model the soil inhomogeneity. Using a boundary element algorithm they were able to analyze the static behavior of both axially and laterally loaded single piles as well as pile groups.

Banerjee and Mamoon (1990) attempted to synthesize a complete transient equivalent of Mindlin's solutions, but the integrals are in implicit form that preclude analytical integration. For Gibson soil, a similar method of Mamoon and Banerjee (1992) is implemented in the current work to analyze pile and pile groups in time domain.

THEORY

The hybrid boundary element formulation is used to represent boundary integral representation of soil domain and pile equations represented by linear structural components.

Continuum Equations

The elastodynamic, small displacement field in an isotropic homogeneous elastic body is governed by Navier's equation:

$$(\lambda+\mu)\frac{\partial^2 u_p}{\partial x_p \partial x_q}+\mu\frac{\partial^2 u_q}{\partial x_p \partial x_p}-\rho\ddot{u}_q=0 \tag{1}$$

where λ and μ are the Lame's constants

ρ is the mass density of the deformed body

$\ddot{u}_q = \dfrac{\partial^2 u_q}{\partial t^2}$ are the accelerations and the subscripts *p* and *q* ranges from 1 to 3.

Since the solid has semi-infinite extent, the equation is cast in terms of the Green function for the half space, that reduces the domain of integration to the pile-soil interface only. Then, the integral equation can be written as:

$$u_p(\xi,t) = \int_S \int_0^t G_{pq}(x,t;\xi,\tau) t_q(x,\tau) d\tau ds \tag{2}$$

where u_p is the displacements of the soil; G_{pq} is the Green's function for the half space, t_q is the tractions at the pile soil interface, ξ and x are the spatial positions of the receiver and the source point, respectively.

Pile Equations

Since the pile cross section is much more thinner than the length of it, the piles are modeled as a one dimensional bar.
In the lateral direction, the pile is assumed to act as a thin strip whose behavior is governed by the beam equation. By adding the inertia terms, the governing equations for time harmonic beam subjected to axial and lateral excitations are given by:

$$m\ddot{u}_z^j - E_p A_p \frac{d^2 u_z^j}{dz^2} = -\pi D t_z^j \tag{3a}$$

$$m\ddot{u}_x^j + E_p I_p \frac{d^4 u_x^j}{dz^4} = -D t_x^j \tag{3b}$$

where, E_p is theYoung's modulus of the pile material; I_p is the second moment of inertia of pile; A_p is the cross-sectional area of the pile; *D* is the diameter of the pile u_x^j and u_z^j are the lateral and axial displacements at time t^j, respectively; t_x^j and t_z^j are the lateral and axial tractions along the pile at time t^j, respectively.

Assembly of Pile and Soil Equations

It is necessary to introduce a global equation constraint to be able to solve the coupled system of equations. By imposing a constraint on the traction vector $\{t_p\}$. This constraint arises from a consideration of the global equilibrium of the entire system. In an incremental form, this can be represented as:

$$[B_1]\{\Delta t_p^j\} - [B_2]\{\ddot{u}_p^j - \ddot{u}_p^{j-1}\} - [B_3]\{\ddot{u}_c^j\} = \{\Delta F^j\} \tag{4}$$

Using compatibility relations, final form is presented as:

$$\begin{bmatrix} G+D & b_p \\ B & -E \end{bmatrix} \begin{Bmatrix} \Delta t_p{}^j \\ \Delta u_c{}^j \end{Bmatrix} = \begin{Bmatrix} R_s^j - B_p^j \\ \Delta F_c^j - H^j \end{Bmatrix} \tag{5}$$

Examples

A study is done to investigate the interaction effect of one loaded pile on a neighboring pile under axial and lateral triangular loading. Analysis is carried for homogeneous and Gibson soils. By changing pile spacing between two independent piles, interaction diagrams for the peak values of the analyses are drawn in figures 1 and 2 for homogenous and Gibson soils respectively. Following parameters were used in the analysis:

Pile Length L = 15. meter,
Pile Diameter D = 1. meter,
Number of elements N = 30,
Pile to pile spacing for groups $S = 2.5D$
Pile Modulus E_p = 25 GPa,
Density of pile ρ_p = 2300 kg/m^3,
Density of soil ρ_s = 1800 kg/m^3, Poisson's ratio of soil υ_s = 0.4,
For Gibson soil ($E_s = E_o + mz$) E_o = 12. 5 Mpa and m = 2. MPa/meter and z is the depth.

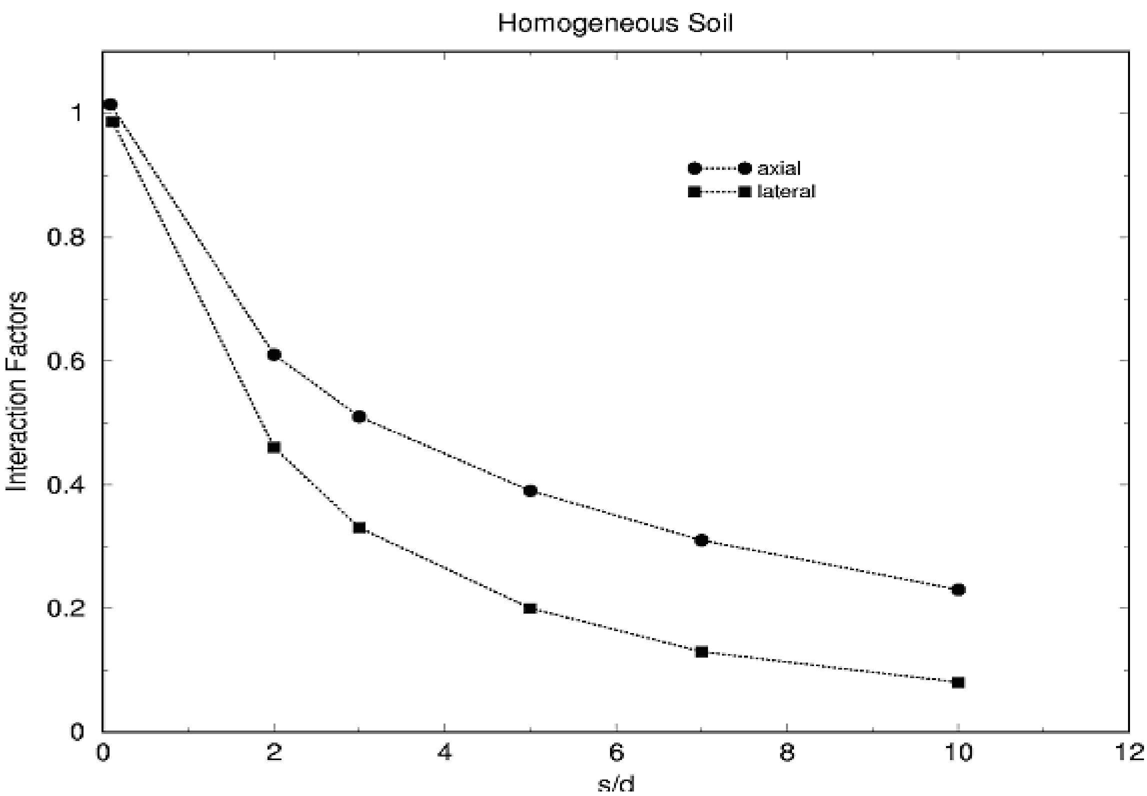

Figure-1. Interaction diagram for homogenous soil.

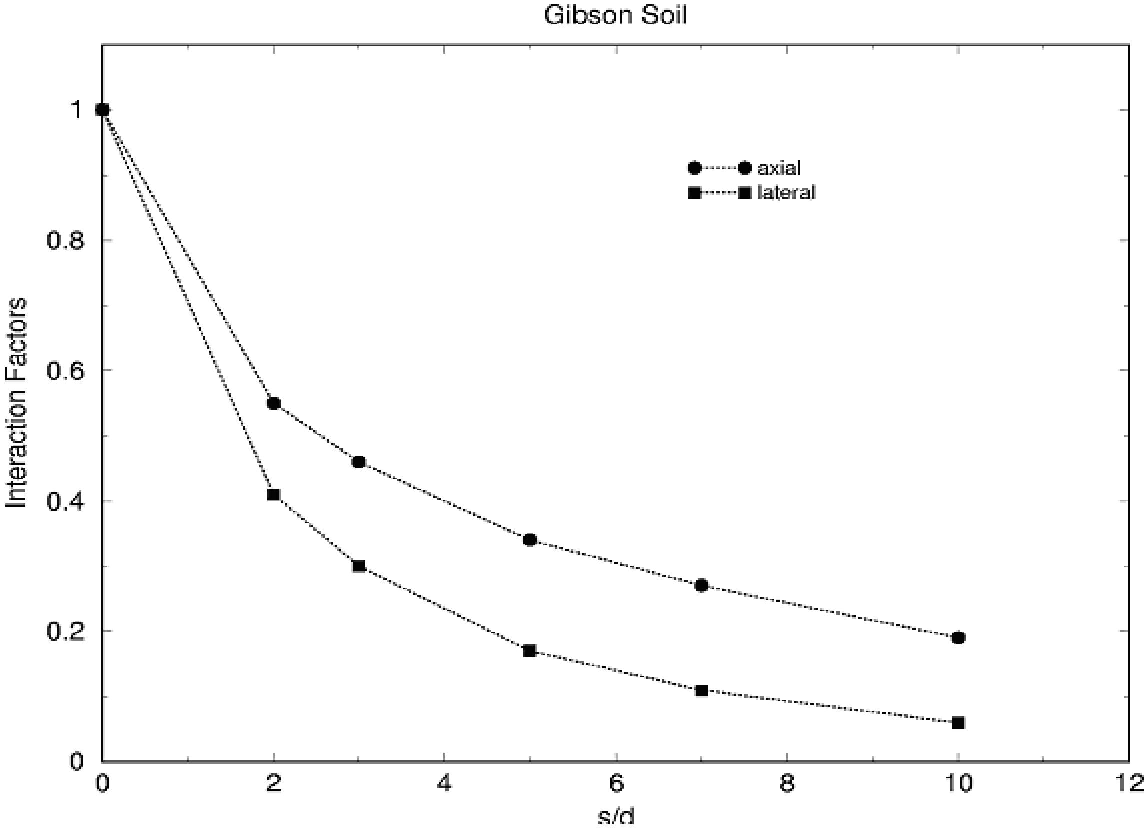

Figure-2. Interaction diagram for Gibson soil.

CONCLUSIONS

The time domain analysis of a pile and a pile group was studied for Gibson soil. The hybrid boundary element formulation was used to represent boundary integral representation of soil domain and pile equations represented by linear structural components. A time stepping BEM algorithm together with an implicit time integration FEM scheme was used for modeling the piles. It can be observed that with increasing S/D ration interaction effect tends to vanish. For homogeneous soils the interaction is higher than those in Gibson soil for both axial and lateral loading cases considered.

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