Form 2

Dissertation Abstract

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Dissertation title	DYNAMIC BEHAVIOR OF PILE FOUNDATIONS WITH FREQUENCY-DEPENDENCY AND INTENSITY-DEPENDENCY (振動数依存性と強度依存性を考慮した杭基礎の動的挙動に関する研究)		

Pile foundations have been used since prehistoric times to transfer structure loads to appropriate depth. To develop reasonable methods of design and analysis of pile foundations, experimental and analytical studies on piles and pile groups have been a subject of much research interest over the years. Accordingly, various solutions for predicting the response of piles are available that range from simple approximate solutions to very complex formulations having varying levels of accuracy. However, in most of the solutions, whether it is simple approximate formulations or complex formulations, the pile and soil both are assumed to behave elastically. The complexity of the soil-pile foundation system formulation becomes more complex with the soil-structure interaction (SSI) phenomenon particularly for dynamic loads such as earthquakes. While a pile considered as an elastic material can be taken as a reasonable approximation, consideration of soil as an elastic or viscoelastic material is not a valid assumption for all levels of strain in soil, as soil exhibits strain-dependent nonlinear behavior.

A direct approach using continuum modeling such as the finite element method can provide realistic dynamic behavior of the soil-pile system, but it requires high computation demand. Alternatively, sub-structuring techniques are used as an efficient and reliable method for dynamic soil-pile system analysis. The dynamic stiffness and damping behavior of the soil-pile system can be replaced by horizontal impedance functions (IFs) in the subs-structuring technique. Experimental investigations in the past have extensively exhibited both frequency-dependent and intensity-dependent characteristics of IFs. Despite such finding, behavior the frequency dependence of IFs at very high-intensity loads approaching yielding is still unknown.

For such, this study focuses on the frequency-dependent and intensity-dependent soil-pile system including soil nonlinearity. Experimental investigations are carried out through an instrumented model pile-soil system placed on a shaking table. Quasi-static loadings and dynamic loadings are applied to get static and dynamic force-displacement relationships. The response of singles piles and pile groups (2×2) with two different initial conditions are studied. In quasi-static loadings, the effect of loading rate in pile resistance is studied. A wide range of lateral loading amplitude at the pile-head is considered in both quasi-static and dynamic loading to induce varying levels of soil strain i.e., soil nonlinearity. In dynamic loading, a wide range of frequency is considered to encompass the typical structural and soil natural periods.

The loading rate effect in the lateral bearing capacity of the is studied over a wide range of loading velocity for a significant lateral deflection of pile head. Displacement controlled loading are applied at the pile head and the force-displacement curves, pile deflection profile, bending moment profile and soil reaction profile are compared for the different loading rate. In addition, soil surface displacement pattern is analyzed using stereo-particle image velocimetry technique. Results indicate the effect of loading rate lateral bearing capacity. However, the pile deflection profile, bending moment profile and soil reaction profile, and soil displacement profile are not affected by the loading rate. These results suggest a similar failure pattern in the soil irrespective of the loading velocities.

Horizontal impedance functions are calculated for a wide range of frequency and amplitude including very high loading amplitude to analyze its behavior near the yielding point of the soil-pile system. Results show the dependency of impedance functions on both the frequency and intensity of the input load. Moreover, the impedance functions become less dependent on the frequency as the amplitude of loading increases and the real part of the impedance function, i.e., dynamic stiffness approaches towards the static stiffness of the soil pile system.

Experimentally measured values of force-displacement relationship and horizontal pile head impedance functions for both single piles and pile groups are further validated by a three-dimensional finite element model. A nonlinear soil model to consider the stress-dependent stiffness together with small strain stiffness is employed in the numerical model. Similarly, soil pile interface and other boundary conditions to simulate the experimental setup are considered. The results from the numerical model for both single piles and pile groups are in good agreement with the experimental data.