Dynamic Field Tests of Single Piles

2010 NZSEE Conference

N. M.Sa'don, M.J. Pender, R.P. Orense, A.R. Abdul Karim & L. Wotherspoon.

Department of Civil & Environmental Engineering, The University of Auckland, Auckland, New Zealand.

ABSTRACT: This paper presents the results of a full-scale field study of single free-head piles embedded in Auckland residual clay. Four hollow steel pipe piles, each with an outside diameter of 273 mm and wall thickness of 9.3 mm were installed at a site in Pinehill, Auckland. A series of dynamic tests ranging from low excitation (using an instrumented impact hammer and a low-mass loading of an eccentric mass shaker) to high dynamically-induced force from the eccentric mass shaker was performed during the spring and early summer after the winter wet weather, so that the soil can be assumed to be saturated to the ground surface. Results from low amplitude dynamic tests indicated a reduction in the natural frequency of the system from 9.6 Hz to 8.2 Hz after experiencing a higher level of forcing amplitude. This reduction in natural frequency demonstrated the non-linear response of the pile-soil system that was caused by the strain softening of the soil and the formation of a gap between the pile shaft and the surrounding soil.

1 INTRODUCTION

Piles are used to support structures in a variety of situations by transmitting actions applied at the pile head to the material beneath the ground surface capable of providing the required resistance. The behaviour of single piles under lateral loading is important for foundations that provide resistance against earthquake, wind and wave loading. In all three cases, dynamic effects are significant, particularly with regard to the development of the damping component of the pile resistance. Earthquake loading differs from the other loads in that the primary excitation comes from the ground below the pile. It is possible to consider the response of a pile to earthquake excitation into two parts, kinematic interaction and the inertial interaction. Kinematic interaction deals with the flexing of the pile shaft in the ground as the earthquake wave travels upwards. Inertial interaction models the response of the pile head to actions generated by the inertial response of the structural mass attached to the pile head. The analysis of this inertial pile response to earthquake excitation is essentially the same as that required for the pile response to wind loading and wave loading. The primary purpose of the pile testing discussed herein is to measure the inertial response of piles in Auckland soils and to investigate how the lateral stiffness decreases with increasing pile head excitation.

In this paper, the main tool used for analysis of the response of the pile is the elastic continuum model (ECM), which assumes a long elastic pile embedded in an elastic continuum (Gazetas 1991). (This approach is complementary to the other common pile-soil interaction model – a bed of independent elastic springs. The main difference is that the bed-of-springs model ignores any continuity in the soil. This assumption is known to be adequate when the pile is "flexible"). The ECM model has the advantage that it has been extended to enable nonlinear behaviour of the soil around the pile to be modelled (Davies and Budhu, 1986).

Site investigation in this research measured the small strain stiffness of the soil using wave activated stiffness (WAK) tests (Briaud and Lepert, 1990), seismic cone penetration tests (SCPT), and low level response of the pile generated by hammer blows and also by excitation from an eccentric mass shaker (Anco Engineers MK-140-10-50) with small masses attached. All these methods indicated a consistent value of the small strain stiffness of the soil. The approach taken to interpret the field response is to estimate the factor by which the small strain stiffness factor of the soil needs to be reduced to give the