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Static and Dynamic Response of a Pile

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ABSTRACT

Static and dynamic load tests were conducted on a 450-mm-diameter reinforced concrete pile driven 17 m into a deposit of uniform silty sand. The static tests consisted of measuring the lateral load versus horizontal deflection of the pile at the mud line. The dynamic load tests were conducted to determine the amplitude-frequency response of the pile for vertical and horizontal vibrations. The natural frequency of free vibration in the horizontal direction was also measured. The soil properties were determined by conducting in-situ and laboratory tests. A comparison of the predicted and the observed pile response for static and dynamic loading conditions has been presented.

INTRODUCTION

Piles have been used extensively to transmit loads to strata having adequate bearing capacity, both under static and dynamic loading conditions. They are generally the preferred type of foundation for supporting offshore platforms. Piles are generally used in groups. However, most design calculations are usually made for a single pile and the results are then extrapolated to account for group action. An understanding of the behavior of a single pile thus plays a very crucial role.

Analysis for the design of piles to resist static lateral loads is generally conducted either by using the approach of Reese and Matlock (1956), or by using the approach of *p-y* curves (Poulos and Davis, 1980). In the approach suggested by Reese and Matlock (1956), the constant of the modulus of horizontal subgrade reaction, n_h, is the basic soil parameter for the analysis of lateral load-deflection behavior of the soil-pile system. This is essentially a linear analysis. The soil nonlinearity can however be accounted for by using strain or deflection dependent values of n_h. In the *p-y* curve approach, the soil strength parameters are used to determine the lateral load-deflection behavior.

The response of a pile under dynamic load is generally obtained with one of the simplified approaches, such as: (a) using the concept of elastic subgrade reaction (Barkan, 1962; Maxwell et al., 1969) for obtaining the equivalent soil springs; (b) treating the pile as a cantilever fixed at the lower end; (c) treating the pile problem as a case of one-dimensional wave propagation in a rod (Richart, Hall and Woods, 1970); and (d) extending the solution of Baranov (1967) for embedded foundations and determining the stiffness of the soil-pile system from elastic half space approach (Novak, 1974, 1977; Novak and El-Sharnouby, 1983; and Novak and Howell, 1977). The method suggested by Novak (1974, 1977), and Novak and El-Sharnouby (1983) is commonly used. The nonlinearity of soil can be accounted for by using strain dependent values for dynamic shear modulus in the expressions for calculating the equivalent soil spring and damping constants for any given mode of vibration.

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This paper presents a comparison of the observed and predicted response of a single pile for static and dynamic loading conditions. Static lateral load tests were conducted on 450-mm-diameter reinforced concrete pile driven 17 m into a deposit of uniform silty sand. Dynamic tests were conducted on a similar pile by subjecting the pile to horizontal and vertical vibration. Soil properties such as the shear modulus and the constant of modulus of horizontal subgrade reaction were determined by conducting in-situ tests. Soil strength parameters were determined by conducting direct shear tests in the laboratory. Lateral load response of the pile for static loading condition was calculated by using strain (deflection) dependent values of n_h. The dynamic response of the pile was calculated using the approach of Novak (1974, 1977), Novak and El-Sharnouby (1983), and Prakash and Puri (1988). The cases of constant shear modulus with depth (homogeneous soil profile) and parabolic shear modulus variation with depth (parabolic soil profile) were considered. The amplitude (shear strain) dependent values of shear modulus were used to account for the nonlinear behavior of soil. The details of the tests conducted and the comparison of the observed and the computed response are given below.

STATIC TESTS

Pile Tests

Static lateral load tests were conducted on a pile 450 mm in diameter having an embedded length of 17 m. Predetermined lateral load was applied to the pile 150 mm above the mud line using a remote controlled hydraulic jack. An adjacent pile was used as the reaction pile. The horizontal deflection of the pile at the mud line was measured with the help of mechanical dial gauges. Lateral load increments were maintained constant and the steady state values of the horizontal deflection were noted. The lateral load was increased in steps. The results from the tests were plotted as horizontal deflection versus lateral load as shown in Fig. 1.

Soil Properties

The soil at the site was generally dense silty sand extending to a depth of about 22.5 m. It was generally nonplastic. The average value of the angle of friction for the soil as determined by conducting a number of triaxial tests in the laboratory ranged from 36.2° to 38°. A horizontal plate load test was conducted at