Short Communications

Initially Bent piles

by

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Introduction

It is known that the piles when driven may not be perfectly straight. A number of cases are reported recently in which long slender piles have become bent during driving (Bjerrum 1957, Fellenius 1972, Hanna 1968, Kim, 1973, Johnson 1962, Parsons 1954). Distortion of the pile from vertical axis is caused due to various reasons (Hanna 1968). Theoretical analysis for bent piles are presented by various investigators (Broms 1963, Burgess 1975, Johnson and Kavanagh 1968). A rational method for the response of initially bent piles to axial load is presented (Madhav *et al* 1975) wherein the results are obtained as a percentage of the load carrying capacity of a straight pile.

Analysis

The governing differential equation representing the force system on the pile with a constant moment of inertia I and p in non-dimensional form is presented by Madhav *et al* (1975) as

$$\frac{d^4 w_2}{dZ^4} + \alpha \frac{d^2 w_2}{d Z^2} + \alpha_2 w_2 = -\alpha_1 \frac{d^2 w_1}{d Z^2} \qquad \dots (1)$$

where $\alpha_1 = \frac{PL^2}{EI}$; $\alpha_2 = \frac{KD}{EI} L^4$; w_2 = non-dimensionalized additional deflection of pile under load P; W_1= non dimensionlized initial shape of pile; E = Young's modulus of the pile material; K = soil modulus and D = diameter of the pile.

Bleich (1952) has pointed out in connection with energy method that a function representing the initial shape need satisfy only the geometric boundary conditions of the problem. Such a function however should be in the form of a series. Hoff (1956) has pointed out that it is generally preferable to select functions that satisfy both the geometric and boundary conditions, because a smaller number of terms then suffices for an acceptable engineering approximation. The geometric boundary condition refer to deflection and slope and natural boundary conditions refer to bending moment and shear at the boundaries. Toakley (1965) has analysed for

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buckling loads for elastically supported struts by assuming Fourier series for the buckled shape. Toakley (1965) has assumed the buckled shape of the pile in a series form and therefore his solutions are valid, as stated by Bleich (1952), though the implicit natural boundary conditions for shear are only partially satisfied in certain cases of the analysis he made. Madhav *et al* (1975) have assumed a very simple function for the initial shape of a fixed-pinned bent pile as shown below :

$$W_1 = \frac{C}{L}\left(1 - \cos\frac{\pi Z}{2}\right) \qquad \text{... (2)}$$

where $\frac{C}{L}$ is the non-dimensionalized offset of the pile tip from the vertical axis. Complete solution for Equations 1 and 2 is presented by Madhav *et al* (1977). The implicit natural boundary conditions for shear of Equation 2 are only partially satisfied. A general shape of a bent pile for fixed pinned boundary conditions is shown in Figure 1.

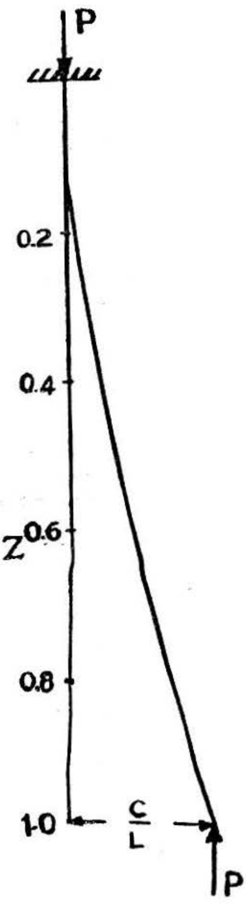

FIGURE 1 Initial shape of fixed pinned bent pile

A function which satisfies fully both geometric and natural boundary conditions for a fixed-pinned bent pile is assumed in this investigation as follows.

$$W_1 = \frac{C}{L(\tau^2 + 4)} (2 + \pi^2 Z^2 - 2 \cos \pi Z) \quad .. (3)$$

The particular solution of Equation 1 for the initial shape representing Equation 3 can be obtained similar to the one presented by Madhav *et al* (1975) and is presented as given below :

$$\frac{W_1}{2} = \frac{2\pi^2 a_1}{(\pi^2 + 4)} \frac{C}{L} \left(\frac{1}{a_2} + \frac{\cos \pi Z}{\pi^4 - \pi^2 a_1 + a_2}\right) \quad ... (4)$$

The solution for the homogenous part and the load carrying capacity of the pile can be obtained similarly. *The results are compared with those* obtained earlier and presented in Figure 2. It is observed that both the

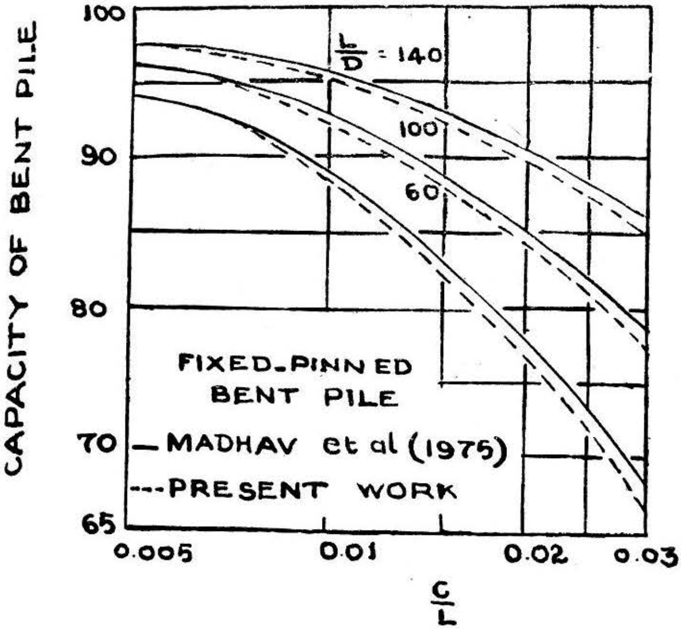

FIGURE 2 Bent pile capacity with respect to pile offset and slenderness ratio

results are very close, the difference being less than 2 per cent. The results are compared for $\frac{L}{D}$ ratios of 60,100 and 140 for different pile offsets, upto, a maximum of 3 per cent. For lesser pile offsets the difference between both the solutions is almost negligible. A maximum difference of 2 per cent is observed at 3 per cent offset. The finding shows that the solution obtained by assuming a smaller number of terms instead of Fourier Series may provide an acceptable engineering approximation, though the implicit natural boundary conditions are only partially satisfied.

Conclusions

The initial shape of a pile can be assumed with smaller number of terms instead of Fourier series, in the pile-soil system for obtaining an acceptable engineering solution.

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