ANALYSIS OF PILES IN SOIL UNDERGOING LATERAL MOVEMENT[a]

Discussion by Joram M. Amir,[2] M. ASCE and Avigdor Rutenberg,[3] M. ASCE

The author has added a significant contribution towards understanding of the interaction between piles and the surrounding soil. It seems, however, that a few points have to be clarified before the suggested method becomes a routine design tool.

The author calculates the pile deflections assuming it is a thin strip. Later in the paper a reference is repeatedly made to pile diameter, thus implying that the results are independent of the shape of the pile. An elastic finite element analysis performed by the first writer assuming plane strain (approximating the condition at large depth) shows, as expected, that under equal lateral soil movements, a round pile develops higher reactions than a flat strip, while still higher reactions are shown by a square pile, all piles being of equal width. For a Poisson's ratio of 0.49, the following shape factors were found: flat strip: 1.000; round pile: 1.085; and square pile: 1.298.

The different behavior of various pile shapes stems, evidently, from the difference in stress distribution on their perimeter. This distribution is highly complex and includes compression, tension, and shear. The symbol, p, as used by the author, is the resultant of all these stresses in the direction of soil movement, so that defining it as the pressure between pile and soil may be misleading. By the same logic, p_y is not yield pressure, although it is measured in units of stress.

Another point which merits consideration is the apparent discrepancy between values of Young's modulus E_s assumed by the author in comparing the suggested method with field measurements, and those which may be deducted from the published data. In the cases reported by Heyman and Boersma (8) and by Heyman (9), the soil profile consisted partly of sand and partly of peat and clay, with cone resistance q_c averaging less than 5 kg/cm². Using correlations suggested by Schmertmann (19) for sands:

$$E_s = 2\,q_c \qquad (7)$$

while Sanglerat (18) suggests for peat and organic clay:

$$E_s = 1.5q_c\text{-}4q_c \qquad (8)$$

It thus appears that a value of E_s somewhere between 7.5 kg/cm² and 20 kg/cm² is more appropriate than the value of 50 kg/cm² used by the author. Using the reduced numbers should, no doubt, effect the comparisons shown in Figs. 10 to 12. It seems, therefore, that more supporting evidence is needed

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before Mindlin's equations, developed for an elastic, homogeneous, and isotropic half space with a horizontal upper surface can be used with confidence in real soils and for piles situated at the toe of embankments, like those in the three cases mentioned.

To conclude, as the application of the suggested method assumes free access to computer facilities, could not a better simulation of the problem, with its involved geometry and material properties, be achieved by the finite element technique?

Appendix.—References

18. Sanglerat, G. *The Penetrometer and Soil Exploration,* Elsevier Publishing Co., Amsterdam, Netherlands, 1972, p. 357.
19. Schmertmann, J. H., "Static Cone to Compute Static Settlement Over Sand," *Journal of the Soil Mechanics and Foundation Division*, ASCE, Vol. 96, No. SM3, Proc. Paper 7302, May, 1970, pp. 1011-1043.

Discussion by René Marche[4] and Édouard Recordon[5]

The author presents a rational method to compute the bending moments and deflections in piles situated in a layer that is subjected to horizontal movements. The writers (20) have also developed a method to compute the bending moments and deflections in piles. They use the modulus of subgrade reaction of the soil instead of the Young's modulus to characterize the soil behavior. The use of one value or the other is not of prime importance as long as specific rules are available to evaluate each of them. Furthermore, the experience gained in the evaluation of one value can be used to evaluate the other as mentioned by the author.

In order to make comparison between observed and predicted behavior of piles, the author analyzes three series of measurement. However, only the conclusions of the author relative to the first series of measurements reported by Heymann and Boersma (8) will be reviewed.

Based on results shown in Fig. 10, the author concludes that the theory tends to overestimate the maximum bending moments, M_{max}, but underestimate the pile head reaction, H. The writers believe that the discrepancies between the theoretical and measured values are primarily due to the assumptions made by the author, assumptions which were incompatible with the physical situation.

The test set up is shown in Fig. 14 and the displacements in the subsoil and near the piles obtained by means of inclinometer after each consecutive extension of the embankment are given in Fig. 15. When the toe of the embankment slope is 15 m from the test piles, the measured displacements of the soil at small depth near the pile is on the order of 20 cm. Consequently, when the toe of the embankment slope is 5 m from the test piles, the trestle, which was constructed to prevent the displacement of the head of the piles, is 15 m from the toe of the embankment slope and consequently it must also have had a displacement of the order of 20 cm. Since the trestle is inefficient in preventing the displacement of the head of the pile, the first assumption of

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