Appendix. Reference

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Bearing Capacity of Auger-Cast Piles in Sand[a]

Discussion by Joram M. Amir,[2] Fellow, ASCE

The technique of auger-cast piling is applicable to many foundation situations, and the author made an important contribution to the understanding of the problems involved in the construction stage of these piles.

The following comments may shed some more light on both the analytical methods presented by the author and on his conclusions.

Presumably, all tests reported made use of hydraulic jacks to measure the loads. This procedure is inherently inaccurate, often giving an error of 20% (*Canadian* 1985). A typical error of, say, 10% is therefore reasonable to expect.

In the determination of the pile capacity, the author uses the 10% rule and, where inapplicable, Chin's (1970) method. Both methods are arbitrary, lack a theoretical basis, and may give results widely apart [e.g., 319 tons for Chin's method versus 211 tons according to the 10% rule (Fig. 3)]. For a mean value of 265 tons this gives a standard deviation of 54 tons, or a coefficient of variation of 20%. Thus, the combined error in the ultimate loads reported may be on the order of 30%.

The use of a bilinear variant of Chin's method to separate the shaft friction from the total load is rather problematic: In the writer's experience, the points on the initial part of the load-settlement curve show too much scatter w in Chin's coordinates to enable the drawing of any straight line. Assuming that such a line can be drawn, it is uncertain whether it will yield the correct shaft friction; theoretically it can even produce friction values that are higher than the total load at 10% settlement.

Disregarding this possibility, and assuming that this method does provide the value of the shaft friction, the coefficient of variation must be on the same order of that for the total load (30%).

The large errors involved in the shaft friction values are reflected in the β-values suggested by the author (Fig. 4). According to these values, for a vertical effective stress increasing linearly with depth the total friction on a 40 ft pile ($\beta = 0.5$) is somewhat lower than that of a 28.4 ft pile ($\beta = 1$). If, as assumed in (7), the vertical effective stress has a limiting value at 6–10 pile diameters, the result for all pile lengths is even more paradoxical: The longer the pile, the less total skin friction!

The author calculates the ultimate point resistance by subtracting the skin friction from the total ultimate load. This is mathematically correct, but one must not forget that in this case the variance of the result is a sum of the variances of the total and skin friction capacities. For the example given in

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[a]February, 1991, Vol. 117, No. 2, by William J. Neely (Paper 25516).

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Fig. 3 (Q_{um} = 211.2 tons; and Q_s = 171.2 tons), the point resistance is 211.2 − 171.2 = 40 tons, with a variance of

$$V_p = V_{um} + V_s = (0.3 \times 211.2)^2 + (0.3 \times 171.2)^2 = 6{,}652 \text{ tons}^2 \quad (8)$$

with a standard deviation of

$$\sigma_p = \sqrt{V_p} = 81.6 \text{ tons} \quad (9)$$

and a coefficient of variation (COV)

$$(\text{cov})_p = \frac{81.6}{40} \approx 200\% \quad (10)$$

This clearly demonstrates the inability of analysis alone to separate skin friction from end bearing. Pile testing strictly following ASTM standards may be a useful aid to design and construction, but a better understanding of the load-transfer mechanism can be achieved only through proper instrumentation of the piles selected for testing.

Appendix. References

Canadian foundation engineerng manual. (1985). 2nd Ed., G. G. Meyerhof, ed., Bitech Publishers, Vancouver, Canada, 337.

Chin, F. K. (1970). "Estimation of the ultimate load of piles from tests not carried to failure." *Proc., 2nd Southeast Conf. on Soil Engrg.*

Closure by William J. Neely,[3] Member, ASCE

The writer thanks Amir for his interest in the paper. Many of the comments made by Amir seem to have arisen as a result of lack of understanding of the method used in the paper to determine the ultimate load of an auger-cast pile.

Amir states that "the author used the 10% rule and, where applicable, Chin's (1970) method." In fact, ultimate loads were deduced from stability plots of the load-movement data. The total ultimate loads Q_{um} was derived from the expression for the straight line [(1)] using a pile-head movement equivalent to 10% of the nominal diameter of the pile. Chin's original method (Chin and Vail 1973) did not include (1) and, as noted indirectly by Amir, if Q_{um} is taken as the inverse of the slope m then the derived ultimate load may be greater than the true ultimate load. Substituting the values of c and m from Fig. 3 in (1) with Δ = 10% of the pile diameter gives an ultimate load of 211 tons (1,875 kN). The actual load-movement curve in Fig. 2 shows that the stability plot method [in conjunction with (1)] produces ultimate loads that are on the safe side.

Amir also notes that the use of Chin's method to separate shaft friction resistance from the total load is problematic. Provided that the pile toe does not bear on an incompressible stratum, the effect of point bearing on pile behavior is negligible at small movements, and the stability plot for the initial stages of a loading test is a measure of shaft resistance only. This is especially true for auger-case piles in sand, in which case, due to the method of construction, the tip response is much softer than for driven, cast-in-place

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