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Where to Plot Average Loads from Telltale Measurements in Piles

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Introduction

A static pile loading test is sometimes instrumented with one or several telltales to measure the shortening of the pile during the test. The measurements are used to determine the average axial load in the pile. Two telltales placed with tips at different depths in the pile provide three values of average load: each gives an average load over its length and the third value is the shortening over the distance between the telltale tips (as the difference between the two full-length values). Similarly, three telltales provide six values. The most important telltale is the one that has its tip placed at the pile toe, because it provides the pile toe movement (by subtracting the shortening of the pile from the pile head movement). If the telltale dial gage is arranged to measure shortening directly and the length considered is at least 5 m, the usual 0.001 inch dial-gage reading gradation usually results in an acceptably accurate value of strain over the telltale length.

When using a telltale value for determining average load, the shortening must be measured directly and not be determined as the difference between movement of telltale tip and pile head movement. This is because extraneous small movements of the reference beam always occur and they result in large errors of the shortening values If you don’t measure shortening directly, forget about using the data to estimate average load.

Load Distribution

The main use of the average load in a pile calculated from a telltale, or of the average loads if several telltales are placed in the pile, is to produce a load distribution diagram for the pile. The distribution is determined by drawing a line from the load applied to the pile head through each value of average load calculated for that applied load. Case history papers reporting load distribution resulting from the analysis of telltale-instrumented pile loading tests invariably plot the average loads at the mid-point of each telltale length considered. But, is that really correct?

Although several telltales are usually placed in the pile, even with only one telltale in the pile (provided it goes to the pile toe) we can determine a load distribution line or curve for each load applied to the pile head. As the toe telltale supplies the pile toe movement for each such distribution, the data establish the load-movement curve of the pile toe, which is much more useful than the load-movement curve for the pile head.

If the average load is determined in a pile that has no shaft resistance—it acts as a free-standing column—the load distribution is a vertical line down from the applied load; the applied load goes undiminished down to the pile toe. In a pile, however, the load reduces with depth due to shaft resistance. Assuming that the unit shaft resistance is constant along the pile, then, the load distribution is a straight line from the applied load to the pile toe, as shown in Fig. 1 (in order to make the figure more clear, it is assumed that the pile has no toe resistance).

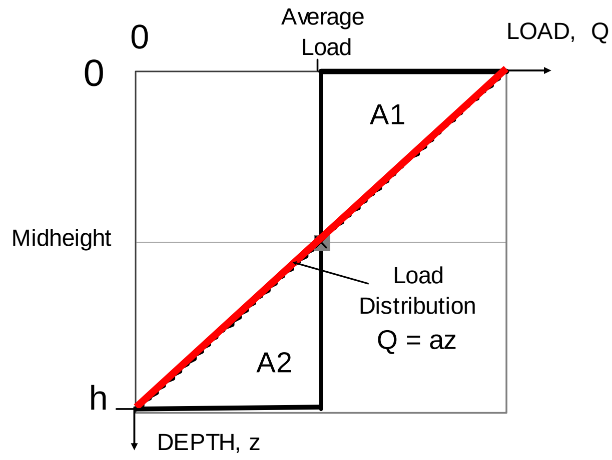

Fig. 1 Load distribution for constant unit shaft resistance

The straight-line load distribution line crosses a vertical line drawn through the average load at midheight of the pile, the midheight of the telltale length, rather. Clearly, a straight-line distribution must have equal areas, A1 and A2, between load-distribution line and the vertical through the average load over the telltale length. This "equal-area-condition" means that, for the case of constant unit shaft resistance, the average load should be plotted at midheight of the telltale length. Actually, a load-distribution of any shape must satisfy an "equal-area-condition". However, this does not mean that the average load must always be plotted at midheight.

Let us assume a more realistic distribution of the unit shaft resistance, for example, linearly increasing with depth, such as a unit shaft resistance proportional to the effective overburden stress. Fig. 2 shows two diagrams, one with unit shaft resistance (az) versus depth and one with load distribution versus depth (z). The shaft resistance is a line proportional to the effective overburden stress and the load distribution curve is the result of the integration of the unit shaft resistance. Fig. 2 also shows a vertical line through the average load and two areas, A1 and A2. For A1 and A2 to be equal, obviously, the average load must be plotted below the midheight of the telltale length. The exact location can easily be found, as follows.

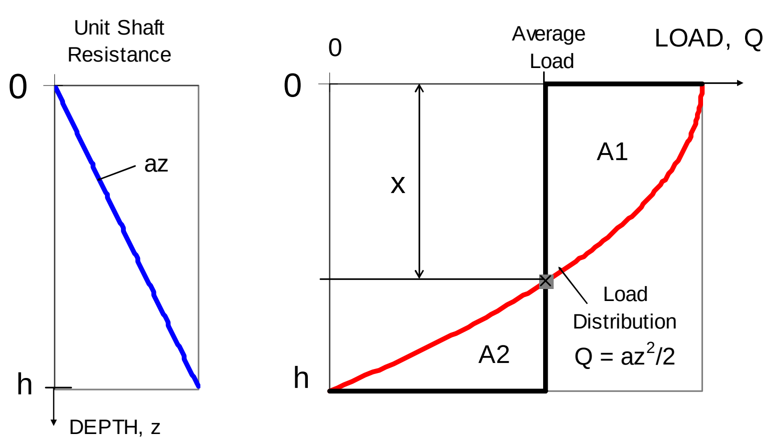

Fig. 2 Linearly increasing unit shaft resistance and its load distribution

Assume that

h	=	height (length) of pile considered (distance from pile head to telltale tip, or distance between two telltale tips
x	=	height of area A1
z	=	depth
az	=	unit shaft resistance (proportional to effective overburden stress)

we can determine

$$A1 = \frac{ax^3}{3}$$

Similarly, we can determine that Area A2 is

$$A2 = \frac{a(h^3 - 3x^2h + 2x^3)}{6}$$

The "equal-area-condition" of A1 equal to A2 gives

$$X = \frac{h}{\sqrt{3}} = 0.58h$$

When the shaft resistance is not constant but proportional to the effective stress, as shown above, plotting the value of average load at midheight of the telltale length, h, is then not correct. The value should be plotted at a distance down from h = 0 of 0.58h. This is not trite matter. The incorrect representation of the average load implies more shaft resistance in the upper portion of a pile and less in the lower portion. The error has contributed to the "critical depth" fallacy.

Conclusions

The possibility, and often also the probability, of the data having been incorrectly plotted and analyzed is a good thing to keep in mind when consulting old case histories. When producing results to go into new case histories, use vibrating wire strain gages rather than telltales for determining load—and limit the telltale instrumentation to one telltale at the toe for determining the pile toe movement.