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INSTRUMENTATION AND DOWNDRAG

BY

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Instrumentation and Downdrag

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ABSTRACT: The distribution of downdrag on end bearing and friction piles is explained and illustrated. From the meager published information and experience some of the important factors affecting field measurements and their interpretation are given.

KEY WORDS: piles, static loads, downdrag, bearing piles, friction piles, field tests, instrumentation, skin friction, evaluation, tests

In normal use, a pile transfers load through soft or compressible layers of soil to deeper, more competent strata. Downward movement of the pile is resisted by the bearing capacity of the pile point and by shearing resistance or skin friction between the vertical surface of the pile and the surrounding ground. Under certain conditions, however, the ground surrounding a pile may move downward with respect to the pile, and the transfer of stress between pile and soil is reversed. This is called negative skin friction or downdrag. Downdrag may be caused by settlement of the ground due to surface loading or ground water lowering.

Although the nature of negative skin friction has been known foı many years, there are few measurements available on full-scale piles. Such measurements are complicated by the long-term changes in effective stresses which always accompany the consolidation of large masses of soil. In addition, the relative movement between the pile and the soil will reverse, usually at an unknown location, and this location will probably change with time or when surface loads are added to the pile. These are complications in addition to the ordinary uncertainties of maximum adhesion forces and degree of mobilization of these forces.

Figure 1 is a schematic representation of the stresses induced in piles due to a combination of applied loads, end bearing, and skin friction. For a pile ending in bedrock or other hard strata, the negative skin

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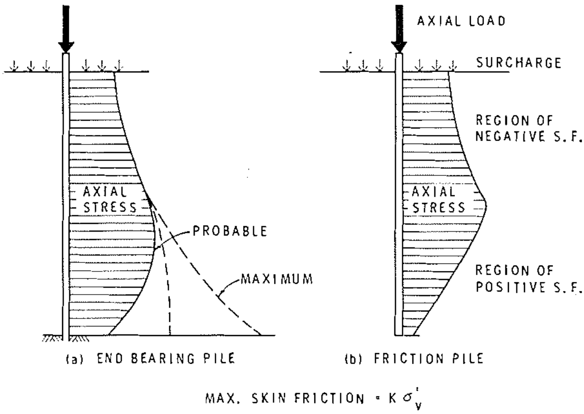

FIG. 1—*Stress distribution in piles due to axial load and skin friction.*

friction or downdrag could be enormous if the entire overburden compressed and moved down relative to the pile. This is illustrated by the "maximum" curve in Fig. 1*a*. For very long piles soil compression throughout the entire depth of soil is improbable, and in the lower regions, therefore, the pile will move down relative to the soil due to its own compression and tip penetration. This results in some positive friction at the lower end and a reduction in the axial stress in the pile. In the case of a friction pile (Fig. 1*b*) the pile will move downward under the combined influence of applied axial load and downdrag until sufficient end bearing and positive skin friction are developed to resist the movement. If the applied axial load is repetitive the relative movement between soil and pile may reverse over certain regions, with each load change, resulting in reversals of friction loads.

Only one paper to this symposium, that by Bozozuk and Labrecque,[2] deals with measurements of negative skin friction. Although the interpretation of loads from strain measurements is complicated because of the changing modulus in the composite steel and concrete section of the piles, it is reasonably certain from these measurements that negative skin friction can develop quickly after small relative movements and that it will continue to develop with time. This agrees with experience at the Norwegian Geotechnical Institute where experimental piles driven in 1962 are still accumulating downdrag forces in 1968 (Bjerrum and Johannessen, 1968).[3]

Figure 2 shows load accumulation in an experimental steel friction pile in which the downdrag is caused by a 30-ft-high fill through which the pile was driven. This preliminary sketch, showing load distribution

[2] See p. 15.
[3] Bjerrum, L. and Johannessen, I., private communication, 1968.

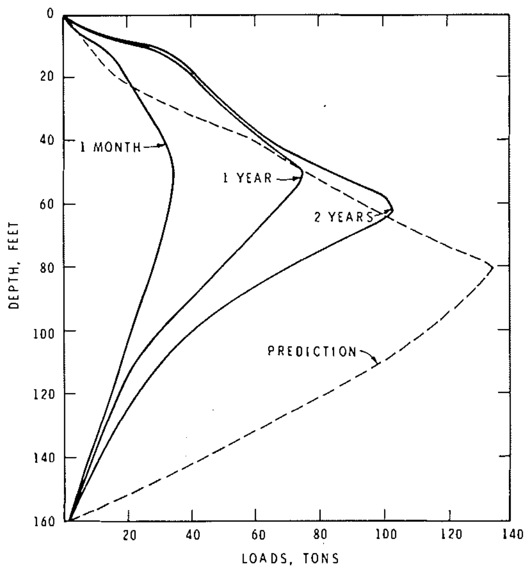

FIG. 2—*Load distribution in 12-in.-diameter floating steel pile.*

in the pile after one month, one year, and two years, is a valuable illustration of the great influence of time on the development of negative and positive skin friction. Details of this field experiment will be published when the observations are completed.

There is a great need for field measurements of downdrag loads on piles. Although little direct experience is available for guidance, a few factors can be enumerated for attention in planning field research.

1. A simple steel pile section will permit the most reliable interpretation of load distribution in the pile.

2. If a cast-in-place composite pile must be used, it should be noted that the concrete may expand in the early stages of hardening, and this complicates the interpretation of results. This was the experience of Bozozuk and Labrecque and has been reported informally by several other investigators. In addition, the modulus of a composite section changes as the concrete ages.

3. Skin friction may develop quickly and continue to develop for a considerable time. Long-term observations therefore are required on pile compression and vertical soil movement.

4. Significant residual stresses may remain after driving, loading, or unloading. This has been demonstrated in a paper to the symposium by Hunter and Davisson[4] and by Hanna[5] (1966). Simple mechanical

[4] See p. 106.

[5] Hanna, T. H., "Distribution of Load in Long Piles," *Ontario Hydro Research Quarterly*, Vol. 4, No. 4, Fourth Quarter, 1966, pp. 1–7.

deformation gages should therefore be augmented by electrical gages to measure strains developed at every stage.

5. Downdrag may be greatly reduced by the application of a thin layer of asphalt to the pile surface. This technique has been described by Golder and Willeumier (1964)[6] and has recently been used successfully in experiments at the Norwegian Geotechnical Institute (Bjerrum and Johannessen, 1968).

[6] Golder, H. Q. and Willeumier, G. C., "Design of the Main Foundations of the Port Mann Bridge," *Journal*, Engineering Institute of Canada, Vol. 47, Aug. 1964, pp. 22–29.