INDOT Research

TECHNICAL *Summary*

Technology Transfer and Project Implementation Information

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Load Tests on Pipe Piles for Development of CPT-Based Design Method

Introduction

Both open-ended and closed-ended pipe piles are often used in practice, but high-quality information available on the bearing capacity of these piles is very limited. The core of the present study was the pile load tests done on two pipe piles: one open-ended and the other closed-ended. The information generated by the load tests is particularly useful for engineers interested in the design of open-ended pipe piles in sand, as detailed data was collected on soil plug formation during driving and on static plug resistance. Better understanding of the load-carrying capacity of these piles can lead to significant cost savings. This appears to be especially true for open-ended piles. Both the driving response and static bearing capacity of open-ended piles are affected by the soil plug that forms inside the pile during pile driving. The formation of the soil plug and its effect on pile load response are still not completely understood.

In order to investigate the effect of the soil plug on the static and dynamic response of an open-ended pile and the load capacity of pipe piles in general, field pile load tests were performed on instrumented open- and closed-ended piles driven into sand. The experimental data accumulated during pile driving and during the static load tests were then used to enhance understanding of the drivability and load capacity of both closed-ended and open-ended pipe piles.

Findings

Driving of open-ended piles can take place with varying degrees of soil plug formation. The open-ended pipe pile in this study was driven in a partially plugged mode. Measurement of the soil plug length during driving permitted calculation of the IFR as a function of penetration depth. It was found, by comparison with the CPT cone resistance profile, that the IFR increased when the relative density of the sand also increased. It was also observed that the cumulative blow count was lower to drive the open-ended pile than the closed-ended pile to the same depth, but that the difference was mostly due to the early stages of driving, when the soil plug was not well developed.

Whether open-ended piles are driven in the fully coring (fully unplugged) mode or in the partially plugged mode, the plug does contribute to static pile base capacity; however, this contribution is not presently well understood. Annular resistance also adds to pile base capacity. The open-ended test pile was instrumented in a way that allows separation of plug from annulus resistance, helping shed some light on this important issue. In addition to separation of factors contributing to the base capacity of open-ended piles, the base capacity of closed-ended piles and the shaft resistance of both closed- and open-ended piles were also studied through the load tests. The base resistance and shaft capacity of the open-ended pile, normalized by average cone resistances, resulted 36% and 52% lower than the corresponding values for the closed-ended pile. For the open-ended pile, the plug resistance was only about 30% of the annulus resistance, and the average shear stress between the soil plug and inner surface of the pile was 45% higher than the outside shaft resistance. Results are presented both raw and normalized with respect to cone resistance q_c.

Based on the field and calibration chamber pile load tests, new relationships for determination of the load capacity of open-ended piles were proposed. The relationships are based on soil-state variables (relative density and stress state) and CPT results. The proposed methods were established based on results from the full-scale field pile load tests and model pile load tests in the calibration chamber. The predicted pile load capacities from the proposed methods were compared with measured capacities from case histories and results calculated from existing pile design methods. The proposed CPT-based method was added to the CONPILE (SPR-2142), the pile load capacity calculation program.

Implementation

The research results are immediately relevant to pile design practice. INDOT and other DOT's should refer to these results when designing piles under similar conditions. Given that research findings suggest significant cost savings can result from extending this study, it would be advisable for INDOT and FHWA to consider additional funding for similar efforts so that results such as those presented here can find their way into pile design practice across the country.

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