Research Brief

Wisconsin Highway Research Program
Project 0092-12-08
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Static Pile Load Tests on Driven Piles in Intermediate-Geo Materials

Research Objectives

- Investigate the use of modified standard penetration tests (MSPT)
- Compare field results with predictions made by the WisDOT driving formula, PDA and CAPWAP
- Improve prediction of pile lengths and pile capacities for H-piles driven into IGM

Research Benefits

- Improved end bearing pressure, side resistance and pile capacity prediction methods that will lower project costs by limiting superfluous materials and reducing damage during driving

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Background

The Wisconsin Department of Transportation (WisDOT) has concerns with predicting lengths and capacities for H-piles driven into Intermediate-Geo Materials (IGM), which are the transition materials from soil to hard bedrock. These materials vary greatly in density, hardness and strength and include sand, gravel, tills, sandstone and granite. This variability makes it challenging to identify, sample and quantify engineering parameters representative of the IGM material.

WisDOT typically designs H-piles using the Federal Highway Administration (FHWA) computer program DRIVEN to determine pile capacities for a given soil profile. When IGM is encountered, the department assumes a large cohesive value will resist the load and the H-pile will achieve the Required Driving Resistance at the top of the IGM layer. However, with the higher Required Driving Resistance established using the Load and Resistance Design methodologies, the H-piles have been found to either run longer than the design length or be damaged, incurring additional cost to the project. In an effort to eliminate this issue, WisDOT reduced the Required Driving Resistance for H-piles and increased the resistance factor, thus reducing the driving concerns. However, there are still unknowns with both the design and construction of H-piles driven into IGM.

The goal of the research was to compare field results with capacities determined with the WisDOT driving formula, and with the Pile Driving Analyzer (PDA) and CAse Pile Wave Analysis Program (CAPWAP).

Methodology

Three sets of data were produced and analyzed: static load tests on three piles and dynamic load tests on 33 piles at a site in Green Bay, four static load tests and 44 dynamic load tests at a second site in Green Bay, and 208 dynamic tests on production piles in the Green Bay area. Results were interpreted to assess the ability of predictive methods to estimate pile capacity. Modified Standard Penetration Tests (MSPT) were performed in some of the IGM's at several sites in the Green Bay area to better quantify their strength.

Static Load Test set up for H-piles driven into IGM.

Pile capacities determined from the seven static load tests were compared with predictions made by CAPWAP at end of driving (EOD) and at beginning

"This research will provide the design guidelines for analysis of H-piles driven into IGM and a more accurate estimate of H-pile lengths and capacities"

–Jeff Horsfall, WisDOT

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of restrike (BOR). Other predictive methods investigated include PDA-EOD (RX9) method, and two dynamic formulas, the FHWA modified Gates and the Washington State DOT methods. Statistics for each predictive method allowed quantitative assessment of the agreement between predicted and measured.

Results

All predictive methods underestimated pile capacity for the seven static load tests. Methods for predicting capacities based on dynamic measurements taken at BOR predicted static load test capacities of approximately 85 percent of the static load test value. The FHWA modified Gates and the Washington State DOT methods predicted approximately 85 and 95 percent of the static capacity as determined by static load tests, respectively.

A second set of test data was created from CAPWAP data recorded at BOR. This data set included the 33 piles at the first Green Bay site, 44 piles at the second Green Bay Site, and 208 production piles in the Green Bay area. These tests used the capacity predicted from CAPWAP BOR as the static pile capacity, which predicts capacity slightly lower than a static load test. The dynamic methods that exhibited the least scatter, for this dataset, were the CAPWAP EOD and PDA EOD, because the methods are based on measurements of energy delivered by the hammer and the measured response of the pile. The two methods predicted, on the average, about 93 percent of the capacity of the pile as determined by CAPWAP BOR.

The scatter was greater for FHWA modified Gates and Washington State DOT tests; however, they yielded reasonable estimates when their ratios were corrected. If CAPWAP BOR predicts 85 percent of the static capacity (as determined from the static load tests), then the corrected ratios of Qp/Qm are 0.98 and 1.11, respectively.

Recommendations for Implementation

Design recommendations were developed to predict the capacity for piles driven into IGMs. The unit end bearing for piles driven into fine grained IGMs should be specified as:

qeb(ksf) = 0.935*MSPT (not to exceed 200ksf).

For piles driven into coarse grained IGMs it should be:

qeb(ksf) = 65*MSPT$^{0.3}$ (not to exceed 300ksf).

Recommendations for end bearing pressure and side resistance were also made for each IGM based on the penetration resistance exhibited by the layer using a MSPT. The recommended unit side resistance for piles driven into fine grained IGMs is specified as a function of the MSPT value as:

fs(ksf) = 0.021*MSPT (not to exceed 2ksf).

The unit side resistance for piles driven into coarse grained IGMs should be:

fs(ksf) = 0.9*MSPT$^{0.25}$ (not to exceed 3ksf).

This brief summarizes Project 0092-12-08,
"Static Pile Load Tests on Driven Piles into Intermediate-Geo Materials"
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