Ohio Department of Transportation Research Project Fact Sheet

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The Problem

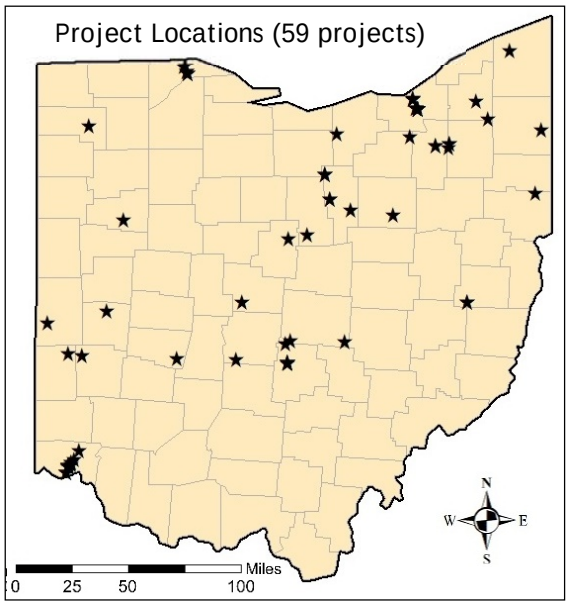
Ohio transportation projects are largely founded on three types of foundations: spread footings, drilled shafts, and driven piles. Spread footings are often used in areas where rock is near the surface or where there is competent soil and the structural loads are relatively light. Drilled shafts are almost always socketed into rock, and consequently are often used in areas of relatively shallow rock, which mostly correlate to the unglaciated portions of the state. Driven piles are frequently used in ODOT projects to support bridge structures. Closed-end cast in place reinforced concrete pipe (CIPP) piles are one of the driven piles commonly used in the glaciated portions of Ohio where more fine-grained soils are found.


Pile driving at HAM-75 Site

When piles are driven in saturated cohesive soils, excess pore water pressures develop due to the disturbance, compression, and displacement of soils by the pile penetration. The effective stresses along the pile length which provide resistance for the friction piles decrease due to the increased excess pore pressures during pile driving. Therefore, resistance losses are observed during pile installation compared to the expected ultimate bearing value.

After pile driving is completed, the excess pore pressures begin to dissipate and effective stresses on the pile increase, resulting in an increase of pile resistance. The increase in resistance continues until the excess pore pressures are completely dissipated. An increase in pile resistance over time after installation, due to an increase in soil resistance, is referred to as pile setup. Other terms such as pile freeze or side shear setup are also used for pile setup. Pile setup has been observed in a variety of driven pile types and broad range of soil profiles. Both soil- and pile-related properties contribute to pile setup.

Until recently, pile setup was not commonly considered in ODOT's standard driven pile design procedures. If substantial pile driving losses are encountered during installation, ODOT often stops pile driving for some time to determine if pile setup will occur. This time delay negatively affects the construction schedule and unforeseen costs are incurred when additional pile lengths need to be installed.



Research Approach

The goal of the project was to develop a prediction methodology for the magnitude of setup, or driving losses, that can be anticipated during driving of CIPP piles driven in predominantly fine-grained soils to account for setup in design. The research goal was achieved through the following well-planned activities:

- Review hundreds of previous ODOT projects where pile setup was observed, and collect relevant data,

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- Observe pile load tests and collect data from selected active ODOT construction projects,
- Investigate the potential effect of site construction activities on pile load test results,
- Analyze test data, identify critical soil parameters contributing to pile setup, and correlate pile setup behavior to the critical soil properties,
- Propose formulas to predict pile resistance gains over time, and
- Recommend setup factors to be used in design to estimate driving losses.

Static load test at LUC-75 Site

Findings

The research led to significant findings that will benefit ODOT and the public by reducing project costs through avoided pile quantity overruns, change orders, and project delays. The main findings of the project are:

- Construction activities at a project site, such as installation of other piles, can significantly affect the load test results,
- Some of the most commonly cited and used existing models are not suitable to predict setup for CIPP piles driven in fine-grained soils of Ohio. Most of them significantly underestimate pile setup and all have large variability,
- With the new models developed, pile resistance gain with time can be predicted reasonably well. The proposed models depend on pile and soil parameters, and pile resistance during installation,
- For setup of pile total resistance, the current setup factors recommended for fine-grained soils by FHWA GEC-12 and the ODOT Bridge Design Manual, which were based on a wide range of pile types, pile sizes, pile materials, and most importantly a broad range of geologic deposits, are in very good agreement with the data obtained from projects in Ohio,
- For setup of pile side resistance, the current setup factors recommended for fine-grained soils are significantly lower than what the piles driven in Ohio soils experience. The current setup factors were developed based on total pile resistance and should not be used for side resistance, and
- For CIPP piles in fine-grained Ohio soils, pile driving setup factors of 2.00 for the total resistance and 3.00 for the side friction are recommended with more than 95% confidence levels.

Recommendations

Key recommendations for the implementation of the research findings are:

- The existing empirical pile setup equations should not be used for CIPP piles driven in fine-grained soils of Ohio,
- Dynamic testing should be performed on the first pile driven at a site. If there were recent construction activities at the site prior to driving the first pile, such as fill placement or preloading, possible effect of those activities on subsurface conditions and on the dynamic test results should be evaluated,
- If a pile tested during driving is not the first pile driven at the site and the dynamic test results show lower resistance than anticipated, the pile should not be driven longer than the estimated design length just because the load test shows low resistance,
- Dynamic load testing on the second pile driven at the site should be performed at least seven days later, preferably 14 days, or on the pile furthest, preferably at least 100 ft, away from the first pile. If these time or distance recommendations cannot be followed at the site, any unexpected dynamic load test results from second or consecutive piles driven at the site should not be used to make decisions on extending pile lengths,
- Pile restrikes should be performed at least 7 days, preferably 14 days later, on piles driven in predominantly fine-grained soils, and
- The current setup factors for side friction recommended by the ODOT Bridge Design Manual should be updated. For the CIPP piles in fine-grained Ohio soils, setup factors of 2.00 for the total resistance and 3.00 for the side friction are recommended with more than 95% confidence levels.

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