USE OF PILE DRIVING ANALYZER (PDA) FOR DETERMINATION OF DRIVEN PILE CAPACITY

Acknowledgements

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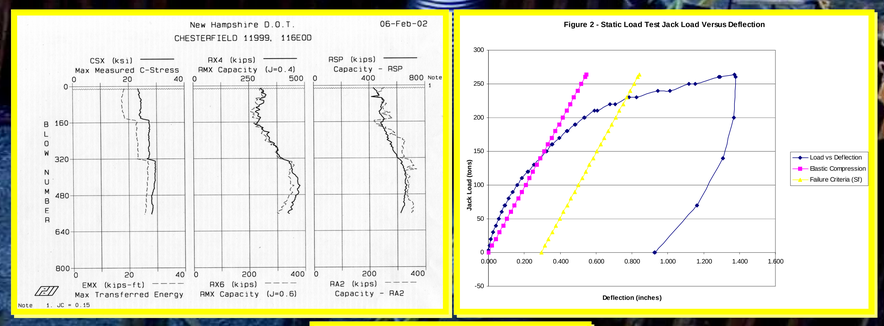
Pile driving has historically been a task of faith. Once below the ground surface, there was no certainty about what was happening. Wouldn't a crystal ball, or x-ray glasses be handy to visualize pile damage or other hazardous condition?! The Pile Driving Analyzer (PDA) turned out to be better than either.



Typical Data Plots

Problem Statement

Pile foundations are used to transfer bridge foundation loads through weak soil materials to more competent underlying soil materials or bedrock. The load carrying capacity of the pile is provided through side friction and end bearing.

The primary challenge is to drive the piles to a depth that will provide the required ultimate capacity without having the pile extend to a greater depth, since any additional length would add unnecessary cost to the project.

The pile driving analyzer (PDA) was studied under this research project to evaluate its effectiveness in predicting pile capacity by comparing the PDA capacity predictions with static load test results.

Background

A static load test is the benchmark method for determining the ultimate capacity of a pile. This test measures the pile's vertical displacement under incremental loads until the pile's ultimate capacity has been achieved. Static load tests are expensive, time consuming and may not be representative of the pile support conditions throughout a site, due to variability in subsurface conditions.

Acceptance of a driven pile is based on achieving a particular hammer blow count per increment of pile penetration (i.e., blows per inch). Dynamic equations have been used to estimate the acceptance blow count, but have limited accuracy due to numerous pile driving variables.

The PDA technology was initially developed and supported by FHWA, Ohio DOT and Case Institute of Technology through the early 1970's. After 1972, the technology has been developed commercially by Pile Dynamics, Inc. (PDI) in the USA, and by at least one European company. The PDI system was evaluated and purchased under this research project.

PDA Testing Equipment

The PDA system consists of two strain transducers and two accelerometers bolted to opposite sides of the pile to measure the strain and acceleration in the pile. The signals from the transducers are relayed through a cable to the PDA data acquisition system.

The PDA conditions and converts the strain and acceleration signals to force and velocity records versus time for each blow of the pile hammer. These dynamic measurements are then input by the PDA into various equations to predict the pile capacity.

The Case method equation is based on wave mechanics theory with a damping constant that is related to the soil type, and provides an instantaneous prediction in the field during driving. The CAPWAP method provides a more rigorous, post-installation analysis of the dynamic measurements to determine the pile capacity.

Case Study

- Chesterfield-Brattleboro Bridge Project – Route 9 over the Connecticut River.
- NH Abutment: Deep sand deposit > 200 feet. Designed with 132 steel pipe piles, 18-inch diameter, with 200-kip design load and 400-kip required ultimate capacity. Ordered pile length of 89 feet.
- Total Pile Foundation Cost: $908,000, based on $47.50 per foot of pile, $150,000 equipment mobilization, $145,000 pile splices, and $55,000 static load test.
- PDA prediction using the Case method had good correlation with the static load test results (450 kips from static load test, 470 kips from PDA prediction).
- The PDA testing permitted a lower pile design safety factor. This resulted in a pile savings of at least 12 feet per pile for a total savings of $75,000. The savings on this project alone paid for the costs of this research

Key Findings

- PDA testing provides a more reliable and rational basis for evaluating pile capacity. This permits a lower safety factor to be used for the pile design and construction, which saves on pile materials and driving costs, and reduces the need for expensive static load tests.
- The PDA measures pile stress during driving. This permits modification of the pile driving methods, if the pile stress is excessive.
- The PDA provides a measurement of the hammer energy delivered to the pile. This provides the ability to assess and modify the contractor's pile driving system, if the hammer energy is inadequate.
- The PDA is able to determine whether pile damage has occurred. This permits remediation of the damaged pile and reduces the potential for future foundation problems.

Implementation

The PDA is now used routinely on all NHDOT pile projects. Several PDA tests can be conducted, if varying conditions are encountered. The PDA implementation has resulted in significant cost savings by having a more efficient pile design without compromising safety or the foundation service life, and has resulted in a higher level of quality assurance.

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