CONSIDERATIONS FOR TESTING

Every project can benefit from a well-designed, properly executed and carefully interpreted test pile program

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Across the industry, load tests are often thought of as merely a box that must be checked in order projector fulfill specifications. The real value of a load test program is using them to optimize the project and provide value to all parties, contractors and owners. This article is a summary of a webinar recorded for PDCA members in April 2025, and is available for review and additional context at www.piledrivers.org. To understand how a load test can be used to add value, we must first understand what constitutes a good load test and the limitations of the selected test. To that end, we're going to lift the hood and look into several cases where we used dynamic load testing, static load testing and general guidelines for good correlation. With that base, we'll review a case study on a project utilizing both static and dynamic load test results to optimize the foundation and significantly reduce the cost on the overall project.

Background: wizardx/123RF

Brief history of load testing

Static load testing involves the installation of a pile and the application of load to the pile as it is jacked against a fixed point, reaction piles or a weighted reaction frame installed in proximity to the test pile. The process is time- and cost-intensive and increases exponentially as the required load increases.

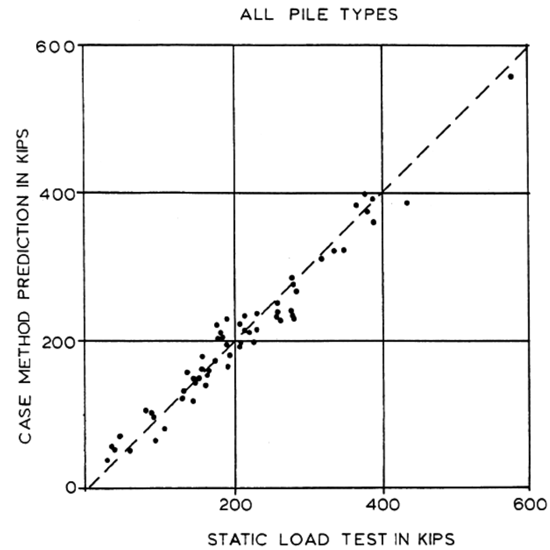
More than a century ago, engineers began searching for a more efficient and cost-effective approach to predicting pile capacity and this search led to the use of driving formulas. Driving resistance was monitored, a static load test was run and the data was used to correlate driving resistance to the results of the static load test. These correlations were used to develop formulas that could predict pile load capacity.

Unfortunately, driving formulas are often an over-simplification of a much more complex problem. Given the over-simplification associated with driving formulas at one end of the spectrum and the expense associated with static load testing at the opposite end of the spectrum, dynamic testing was born out of the idea that new technology could provide a reliable, cost-effective solution between those two ends. Could instrumentation provide measurements and capacity tests that would be more reliable than energy formulas and be less costly and time consuming than a static load test?

With the then-recent advancements in technology allowing the measurement of stress waves and funding from what is now the Federal Highway Administration and the Ohio Department of Transportation, Case Institute of Technology began research to determine the feasibility of instrumenting piles in an effort to measure stress waves accurately and digitize this data in such a way that one could reasonably and reliably interpret the information for the purpose of assessing pile capacity.

Research on dynamic testing began in earnest in the mid-1960s. The initial phase of this research was published in 1968. Two other phases of research concluded in 1975 with a paper, entitled "Bearing Capacity of Piles from Dynamic Measurements." The research and subsequent paper concluded that there was a clear relationship between dynamic and static load tests, as seen in **Figure 1**.

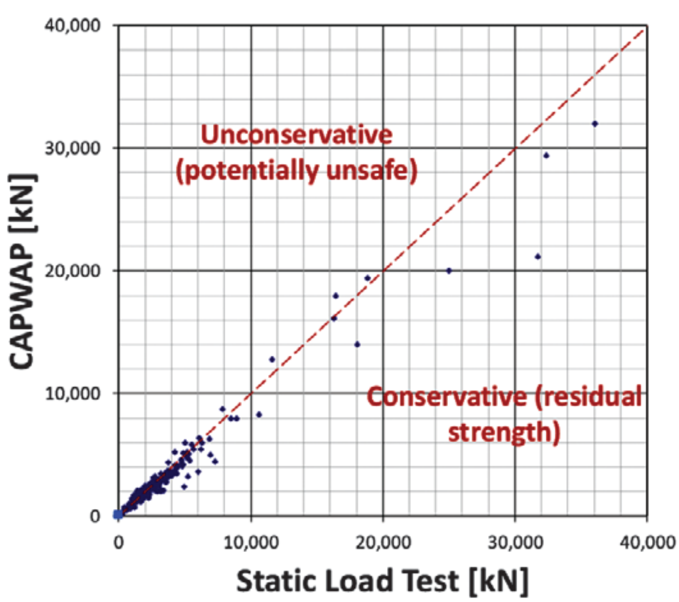
FIGURE 1



Based on the research and its conclusion, Pile Dynamics Inc. (PDI) and the dynamic testing industry was born. The test method gained acceptance and found its way to sites worldwide. PDI regularly updated its correlation database. With more than 300 correlations tests collected through 2004, Garland Likins published a capstone correlation database that included piles – driven and drilled – from around the world that were tested to failure with both dynamic and static load testing, showing the correlation between the two. See **Figure 2**. The 2004 capstone database indicated that if a pile is tested to failure and interpreted properly using a dynamic and static load test, we can expect very good correlation between the two tests.

Understanding that good correlation can be expected between properly run and interpreted static and dynamic loads tests, it's important to understand the limitations in both test methods and what defines a good test when considering what's most

FIGURE 2



2004 CORRELATION STUDY

N=303

Correlation of CAPWAP with Static Load Tests
Likins, G.E., Rausche, F. | August 2004
Proceedings of the Seventh International Conference on the Application of Stresswave Theory to Piles 2004: Petaling Jaya, Selangor, Malaysia; 153- 165.
Keynote Lecture

While a restrike is often used to verify additional capacity beyond the capacity available at the end of drive, it's not always good news. There are soil conditions that lose capacity with time and show lower capacity at restrike.

appropriate for a particular project. What questions should be asked when making preparation for the load test?

CONSIDERATION 1 – Will the load test be run to failure?

It's important to note that, for the purpose of this discussion, "failure" is defined as geotechnical failure at the soil-pile interface, not structural failure of the pile. Often, load tests are performed up to the design load, or a factor thereof, to validate the design. When the design load is met, the test is stopped, and the project moves forward to production. If the project hopes to optimize the material or schedule based on the result of the load test, the test should be performed to failure. If not, the results of the load test would be considered lower bound and conservative, and it's possible that an opportunity to optimize the foundation based on the full capacity of the pile was missed. With respect to a static load test, a test might be considered lower bound if the jack was maxed prior to reaching the accepted failure, or settlement, criteria. In the case of a dynamic test, the test would be considered conservative if the hammer could not produce enough energy to affect a penetration rate greater than one-tenth of an inch per blow when operating at its rated energy. In order to fail the pile and mobilize the full resistance of the soil, a larger hammer must be employed. If the pile is tested to failure, it may be necessary to consider equipment with a capacity range greater than that required to validate the design load only.

If a site is expected to see a capacity gain with time, as is the case on most sites, it would be prudent to retest the pile after a significant wait time to assess the potential long-term resistance.

CONSIDERATION 2 – Does the project expect to gain capacity through soil setup?

The capacity evaluated during a dynamic test is time-dependent. When driving the pile in the ground, the pile is disturbing the soil, driving up pore water pressures, reducing the effective stress and pushing the soil away from the pile-soil interface. The capacity evident during initial installation of the pile may not be indicative of the long-term capacity of the pile. If a site is expected to see a capacity gain with time, as is the case on most sites, it would be prudent to retest the pile after a significant wait time to assess the potential long-term resistance. This is typically called a restrike test, and the resulting capacity gain over time can be used to either provide significant savings over the original design, or worst case, soil setup and the added capacity evident during restrike may be necessary to maintain the current design if the capacity evident at end of drive is not sufficient.

In the case of both a static and dynamic test, it's important to wait a sufficient amount of time to develop additional capacity prior to performing the load test or restrike. If the test is performed too early, it may result in significantly less capacity than required by design and add unnecessary expense to the project.

With a dynamic restrike, it's also important to ensure that the hammer is running optimally at the time of restrike. This is sometimes referred to as "warming up the hammer." To be clear, this is not necessarily a function of reaching an optimal temperature as much as making sure that the hammer is running efficiently and at the desired energy prior to restriking the test pile. Many suboptimal (low energy) strikes on the test pile at the beginning of the test can serve to break down the soil resistance at the pile-soil interface and result in pile capacities less than the full available resistance. In order to avoid this issue and potentially render the test ineffective or be told to restart the setup period, it may be necessary to move to and strike another pile prior to starting the test on the actual test pile. The inconvenience, if necessary, will be worth the effort to ensure optimum results for the test pile program.

While a restrike is often used to verify additional capacity beyond the capacity available at the end of drive, it's not always good news. There are soil conditions that lose capacity with time and show lower capacity at restrike. If the project site is in an area known to have relaxation-prone soil, those soils would be another reason to perform a restrike test. While the end-of-drive capacities appear to indicate adequate resistance, the restrike may show less capacity and require that additional pile length be driven to achieve a competent bearing stratum and the long-term resistance required to support the project. Several examples of areas of the country that experience this condition are provided in the full presentation. At minimum, weathered shales or dense saturated sands would be areas to consider performing a restrike test to assess the potential for capacity loss with time.

CONSIDERATION 3 – Are there times you should not consider dynamic testing?

There are soil types where the capacity prediction from a dynamic load test is not necessarily going to correlate well with a static load test. This is particularly the case if driving into soils that expect

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Both static and dynamic load tests should be considered engineering services and should be provided by firms experienced in the selected test method.

to experience settlement over an extended time that may not be captured in a dynamic test. Examples of these soils might be silts or other highly plastic soils that might expect to experience creep failure. Understanding that the load applied during a dynamic load test cycles in approximately 40 milliseconds, there's no way for this test method to accurately predict the creep failure expected in certain soil types. These effects must be estimated through static analysis or quantified through maintained static load tests. Regardless of the test method, it's important to understand that the results of the test are subject to interpretation and the failure criteria used. Studies have shown that, from the same data set, reported capacity values for a static load can vary significantly. In a report published by Bengt Fellenius in 2017, 94 participants were asked to use the same static load test curve to assign a capacity value. Of the 54 responses received, capacities ranged from 450 kN to 1,200+ kN with a mean of 888 kN and a standard deviation of 215 kN.

Similarly, dynamic load testing may produce varied results if the data is not collected and interpreted by an engineer experienced in the test method. Both static and dynamic load tests should be considered engineering services and should be provided by firms experienced in the selected test method.

What can a project hope to accomplish through a well-designed, executed and interpreted pile test program? Let's consider the I-480 Valley View Bridge project. Again, it's difficult to convey the full detail of this program in the limited space available in this summary article, but we would encourage the reader to use the resource below to watch the full presentation for additional details.

I-480 Valley View Bridge Project

Scan or click here to watch the full presentation for additional details about this project

The I-480 Valley View Bridge structures span the Cuyahoga River Valley, nearly 4,155 feet and supports 180,000 vehicles a day during peak travel times. With bridge decks over 40 years old and at the end of their lifespan, the Ohio Department of Transportation (ODOT) decided to replace the bridge decks of the existing twin bridge structure.

A new bridge would be constructed between the two existing structures to ensure that four lanes of traffic would be maintained in both directions during bridge deck replacements. When the project was completed, the new bridge structure remained in operation to carry two additional lanes of traffic in each direction.

Project pile and load test details:

- 18-inch diameter closed end pipe piles, 0.5-inch wall thickness, 120 to 180 feet long
- 1,100 kip target nominal resistance
- Dynamic load test (DLT) pile program included measurements taken at end of initial drive (EOID), beginning of restrike after one day (BOR1), BOR3, BOR7, and BOR30+
- Static load test (SLT) pile program included three static loads tests run to 2,000 kip maximum load before BOR30+ dynamic load test

See **Figure 4**.

FIGURE 4

Pile Dynamics, Inc.

SLT – PDA COMPARISON

Pile	SLT (Davisson)	CAPWAP
P1-1	1,450 kips	1,495 kips
P4-1	940 kips	945 kips
P9-1	1,870+ kips (no failure)	2,081+ kips (0.05" set)

Photos: Palmetto Pile Driving

A pre-production design phase test program was performed with SLT tests run at 30+ days and interpreted using the Davisson failure criteria, which correlated well with the DLT/CAPWAP results, also measured and interpreted at 30+ days. More importantly, the DLT performed at the EOID and at prescribed intervals ahead of the DLT and SLT performed at 30+ days indicated that the capacity available based on long-term setup was expected to be 60% to 400% greater than the capacity measured at the end of initial drive. See **Figure 5**.

Why is this important?

The combined DLT and SLT program performed at 30+ days and the measured capacity at the EOID allowed the owner and contractor to refine production pile lengths and drive piles to varying depths based on a driving criteria that accounted for added resistance due to setup that may not have been apparent at the EOID. With a variable depth driving criteria in hand and anticipated setup accounted for, ODOT was able to use fewer, shorter piles than had been required for the original structures. Design based on the original structures would have required nearly 1,300 piles and 170,000 LF of pile. The final design required 513 piles and only 64,000 LF of pile – a savings of 106,000 LF, nearly 20 miles of pile!

Beyond the LF reduction above, the project benefited from an accelerated pile installation schedule, equipment optimized for production pile installation and a reduction in the risk and unknowns associated with the pile scope.

While the results above may not be reproducible on every project, they do provide support that every project can benefit from a well-designed, executed and interpreted test pile program, whether the goal of the program is to validate or optimize the current design. A few key reminders:

- Dynamic and static load tests are engineering services, not "black box" applications
- It is important to understand the goal of any load test program and to design the program (method selection to installation) in such a way that the program is set up to succeed
- It is important to know the limitations of any test method
- It is important to evaluate all information critically
- Proper site information (soil borings, installation records and load test records) are important for proper evaluation ▼

FIGURE 5

COMPARISON OF END OF DRIVE AND LONG TERM RESTRIKE RESISTANCES