construction issues

Capacity Testing For Deep Foundations

The New Paradigm

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Capacity testing of deep foundations (piles and drilled shafts) isn't what it used to be; and that's a good thing. Historically, load tests were not typically carried to failure; thus little was learned about the foundation's ultimate capacity. Engineers would be satisfied that the foundation "passed" the test with an adequate "factor of safety". However, because the ultimate capacity was unknown the factor of safety was akin to a factor of ignorance.

When the foundation moved too much under the test load, it was common to hear that "the load test failed." Quite the contrary, the load test was successful; something was actually learned about the foundation's ultimate capacity!

Fortunately, today's trend is to carry more deep foundation load tests to failure and ultimate capacities. In this context we mean the failure load to overcome soil resistance, not structural failure. Although this trend emerged primarily from highway and bridge projects where design phase load testing programs are implemented, it has applicability to building projects as well. Carrying load tests to failure enables designers to develop parameters for ultimate skin friction and end bearing, select economical foundation types, and minimize undue conservatism in design. Additionally, information is available to bidders on pile drivability, drilled shafts excavation rates, obstructions and other factors.

"...today's trend is to carry more deep foundation load tests to failure and ultimate capacities."

Moreover, we now have more tools to measure ultimate capacity and verify integrity of deep foundations. Such tools include dynamic testing with the Pile Driving Analyzer™, Osterberg Cell™ testing, Statnamic™ testing, and the use of fully instrumented piles.

There are also methods to evaluate the integrity of just-installed foundations using non-destructive techniques, including pile integrity testing and cross-sonic logging (drilled shafts).

Finally, we have advanced our comprehension of deep foundation behavior with a better understanding of phenomena such as setup (and relaxation), residual loads and rational methods for incorporating drag loads.

Static Load Tests

Static load testing is the most widely accepted way to test deep foundations. Static load tests can be performed on individual units or groups.

Static load tests may be performed as an axial test (compression or tension) or a lateral test. Loading procedures are detailed in ASTM procedures and building codes. Loads are applied in increments, and the resulting movements are recorded. Control of the applied load and measurements of pile movement is extremely important. Static load is applied by a hydraulic jack acting against either a dead load (*Figure 1*), or reaction elements. Load measurements are preferably made with a calibrated load cell and a calibrated jacking system equipped with a pressure gage.

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Typical load tests have multiple levels of redundancy in measuring movement. Dial gages, a mirror and wire line each attached to a reference beam is the most common method used. Movement of the reference beam should be checked with a surveyor's level referenced to a fixed benchmark.

Load test data may be interpreted in different ways to determine the ultimate load. A movement-based criterion such as found in most codes, or via the Davisson Method, provides a basis to select design loads with acceptable movement performance.

Dynamic Testing

Dynamic monitoring and analysis of pile driving was first suggested in 1951 by E.A.L. Smith (Raymond Company). It was first developed as a research project, but its

Figure 1: Static Load Test with Dead Weight Reaction, New Haven, CT

Figure 2: Typical Static (compression) Load Test, New Haven, CT

usefulness was recognized. Its development progressed on a commercial basis.

Dynamic monitoring has evolved to become a fairly common, quick and economical load testing procedure. It is part of many standard specifications and is controlled by an ASTM Standard.

The principal dynamic method is the Case Method of analysis, using the Pile Driving Analyzer (PDA). The PDA was developed by Pile Dynamics, Inc. to measure strain and acceleration at the top of a foundation subject to an impact load. The PDA performs analyses with the data collected along with input from the operator to predict hammer energy, stresses, integrity, and the ultimate capacity of the foundation element. Typically used for driven piles, the PDA can be used to predict the ultimate capacity of drilled shafts and other foundation elements.

"...measure strain and acceleration at the top of a foundation subject to an impact load."

A CAPWAP analysis is generally performed on selected hammer blows to determine the distribution and magnitude of soil resistance forces along the foundation element into static and dynamic parts.

Figure 3: Attaching PDA Sensors to a Driven Pile for Dynamic Testing

Statnamic Testing

Statnamic testing is a relatively new method developed by Berminghammer Foundation Equipment in 1989 for testing high capacity foundations in both axial and lateral directions. This is a rapid load test that combines the simplicity of static analysis with the efficiency and economy of dynamic testing.

In this test, solid fuel is ignited inside a pressure chamber, generating high pressures and accelerating a set of reaction masses. An upward force is exerted on the reaction masses while an equal and opposite force pushes on the foundation. The device mounts to the top of foundations and includes a load cell and laser displacement sensor to record load and displacement during the entire testing.

This test provides the load-displacement behavior and the side friction and/or end bearing capacities, comparable to an instrumented static load test. The static load-displacement behavior is derived using the Unloading Point Method[2] to account for damping and inertial effects.

"...provides the load-displacement behavior and the side friction and/or end bearing capacities..."

Unlike dynamic testing, during Statnamic testing, a controlled, pre-determined load is applied directly to the foundation without introducing high tensile forces. Thus, the capacity of large diameter foundations can be fully mobilized without risking damage. However, the rapid rate of loading does not model long term load settlement behavior.

Osterberg Load Cell Testing

Static load tests are sometimes performed on high capacity drilled shafts to confirm a design load established by engineering analysis. Rarely are the tests carried to "failure" to determine the ultimate load, because conventional load testing is limited by the maximum amount of reaction that can be practically provided.

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Figure 4: 2000 Ton Statnamic Device with Mechanical Catching System, Stratford, CT

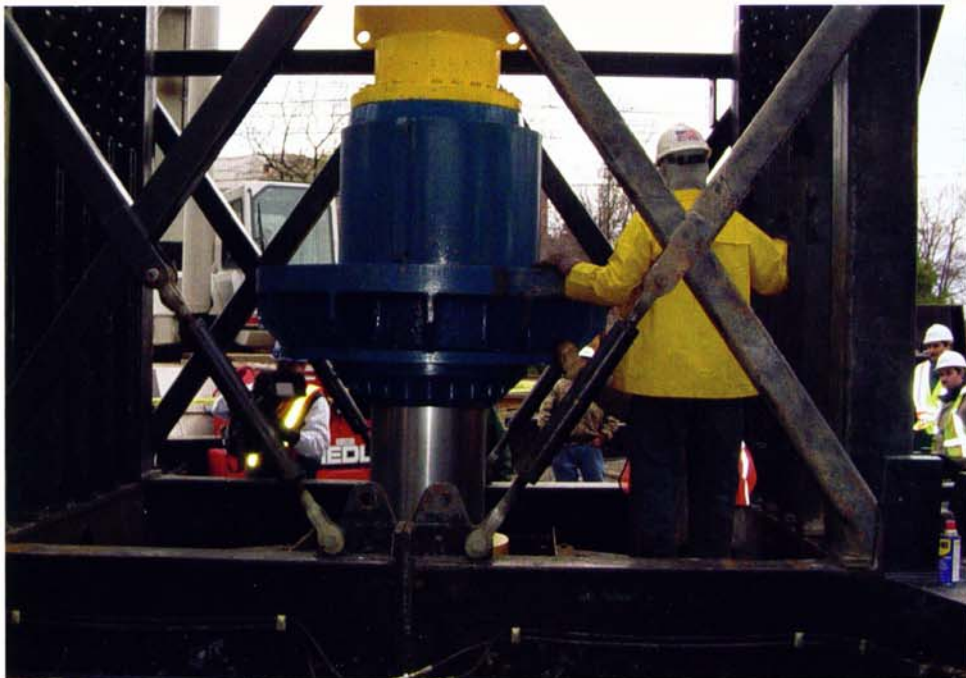

Figure 5: Statnamic Pitson (with load cell and displacement sensor) mounted on top of shaft, Stratford, CT

Figure 6: O-cell attached to drilled shaft enforcing cage, Stratford, CT

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The Osterberg load cell was developed in response to this limitation by using the resistance (skin friction and end bearing) of the foundation element as the "reaction load."

This is accomplished by means of a specially designed cell that is usually placed at the bottom of the foundation element. Once installed, the cell is pressurized to apply a bi-directional load pushing against the foundation element from below and the bearing material from above. The pressure is increased until the element reaches its ultimate capacity in skin friction, end bearing, or both.

"...using the resistance of the foundation element as the reaction load."

Summary and Conclusions

The available methods of deep foundation testing provide opportunities to better understand deep foundation behavior and ultimate capacities. Thoughtful use of such tests enable designers to have more confidence in the selection of appropriate deep foundations and maximization of capacities.

PDA testing has emerged as a most useful tool for pile load testing. O-cell and Statnamic testing are more applicable to drilled shafts and high capacity piles.■

References:

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