GRL + PDI

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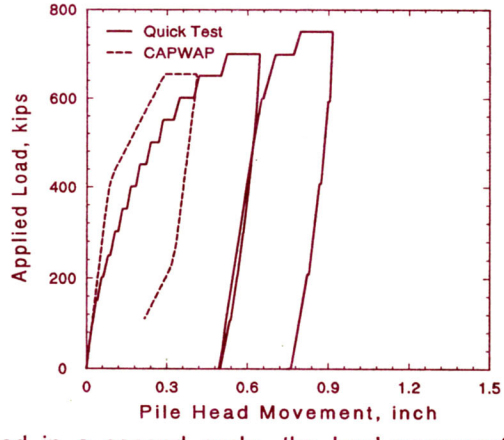
Information gathered by the engineers of
Goble Rausche Likins and Associates, Inc. and *Pile Dynamics, Inc.*

WHAT IS PILE CAPACITY?

by Dr. George Goble

What exactly do we mean by capacity? Deep foundations transfer loads to deeper, stronger soil layers, or limit settlements in soft soils. The foundation is adequate until at some high load the settlements are excessive or the foundation slowly displaces into the ground. However, to make design decisions we need a precise definition of pile capacity.

Determining pile capacity is complex for several reasons. First, pile installation causes both permanent and temporary soil strength changes. Therefore, testing a pile service bearing capacity becomes meaningful only **some waiting time** (days or weeks) after installation. Second, while material testing is usually done on small samples, pile testing is done full scale. It is not trivial to arrange the **reaction load** or reaction piles so that the test pile strength is not altered. Also, pile tests need the same **measurement accuracy** as laboratory tests. A recently calibrated load cell and displacement gages on unyielding supports must be used. Third, applied load induces displacement. If a greater load



is applied in a second cycle, the load-movement curve will approximately follow the previous unloading curve until **higher loads** and displacements are imposed. A static load test curve with two load cycles is shown. Finally, **a pile statically tested to failure can still be used** in service, if soil failure governs as is commonly the case. Indeed, when the pile advances during installation of an impact driven pile, each hammer blow constitutes a "load test to failure." A dynamic pile test of this impact by a Pile Driving Analyzer® and CAPWAP® produces a load movement curve similar to a static test (a dynamic test does not include creep; see Figure).

How are load tests performed? In a **Maintained Load Test,** an axial load increment of about 25% of the design load is imposed and held for an extended time until displacement becomes less than a specified rate. The test duration is measured in days and thus the test cost is high and the possibility of a test error increases. The more modern **Quick Load Test** rapidly applies static load increments of 10 to 15% of the design load and holds them for a brief time interval. This test is often completed in under two hours. In the above figure from a Quick Test, the increases in displacement at constant loads may result from **creep or consolidation**. A **Constant Rate of Penetration Test** imposes a continuous slow rate of displacement. The **displacement rate,** if too fast, can cause increased capacities above the true static load. For **Dynamic Load Tests**, rate effects on capacity must be determined by analyzing measured pile velocities.

In static tests, variable loading rates and times influence creep and thus the definition of pile capacity. Therefore, longer holding times for the loads better measure long term behavior, but at a greatly increased cost. However, even two or three day tests will not measure long term settlement since loading periods in weeks or even years are required to assess consolidation and creep.

Now, for a measured load test curve, how shall we determine the pile capacity? Many load test curves have a sharply defined plunging failure load, but the load test curve shown does not have a well-defined failure load. Nevertheless, a **failure criterion** is required. One popular procedure constructs a line having a slope of the axial pile stiffness with a specified offset. The intersection of this line with the load test curve defines the failure load. Other criteria define failure at a fixed displacement (*e.g.,* 20 mm or 3/4 inch), at a displacement equal to a percentage of the pile diameter, or at a displacement relative to load (slope criterion). Different failure definitions on the same load movement curve can produce widely variable results.

In summary, static load test application and interpretation requires (1) **accurately measured** load and displacement, (2) a proper **loading rate** for the soil conditions to avoid rate effects or to include creep effects, (3) a proper **failure criterion,** (4) **sufficient waiting time** after pile installation to include strength changes caused by driving, and (5) a carefully designed and installed **reaction load** system to avoid influencing the capacity.

Different static load test methods on the same pile or similar piles often produce greatly differing results. Differing failure criteria on the same test yield a range of results. Thus, direct comparisons of static and dynamic tests are often difficult to assess. This problem is compounded by differing wait time effects. Thus, capacity variations are likely. Generally, dynamic tests correlate better with conservative failure definitions and when the waiting time of the dynamic restrike test is comparable to the static test wait period.

What is pile capacity? Each type of test establishes pile bearing capacity under its own circumstances and conditions. To assure an adequate margin of safety, the engineer selects the safety factor to account for the test type, failure definition, waiting time after installation and the percentage of piles tested.

GRLWEAP FOR WINDOWS RELEASED: The wait is over. Pile Dynamics is now shipping the new GRLWEAP for WINDOWS. GRLWEAP is the most widely used Wave Equation Analysis for Pile Driving program. To order GRLWEAP for Windows, contact Judy Fox by phone, fax or email (judy.fox@pile.com).

WAVE EQUATION AND DYNAMIC TESTING SEMINAR : The seminar held in March in Orlando, FL had a great turnout. If you missed it, see your next opportunity in the Calendar of Events.

USERS DAY: The '99 Users Day was held in March in Orlando, FL. Attendees shared field experiences and discussed methods and applications. Thanks to our guest speakers Dave Watkins of Gulf Foundations, Don Budnovich of the Florida DOT and Nigel Dillon of Lloyd Acoustics Ireland for very informative lectures.

READERS AND CLIENTS WRITE:
Bill Armaghani of Ardaman & Associates on the recent Orlando Wave Equation seminar: "... it was one of the best seminars I had in regard to content and presentation."
Walter Grantz Chief Engineer of the Chesapeake Bay Bridge and Tunnel Project: "...before the project started, I was unconvinced that the use of PDA would be a cost-effective benefit to the project. It turned out to be well worth the cost as it frequently provided key evaluations at times when very costly situations required immediate decisions."
Richard Yu of Soil Dynamics Malaysia reports that his company has submitted all necessary evidence for ISO certification and that the auditor of the Department of Standards has recommended award of certification. He ends his message writing "I wish to thank PDI...for your advice and support."
ECS, Ltd reports in their Winter 98 "News and Views" that "The efficient utilization of the PDA has proved to be very valuable at Ford's Landing, which has significantly variable soil conditions." (Ford's Landing is a townhouse development on the Potomac River Front in Old Town Alexandria, VA.)

SPT TESTING: The relatively new ASTM D6066 recommends that all jobs that use SPT to evaluate Liquefaction Potential measure energy transferred to the SPT rod. The **SPT ANALYZER and INSTRUMENTED RODS**, by PDI, help engineers acquire these measurements. The Pile Driving Analyzer® (PDA) may also be used with instrumented SPT rods to measure transferred energy; GRL engineers provide the service.

PDA TESTING ON AUGERCAST PILES: The successful dynamic testing of continuous flight auger piles in Brazil is documented in a paper for "Deep Foundations on Bored and Auger Piles" (de Mello and Paraiso, 1998). Sergio Paraiso of GEOMEC built a hammer with a variable weight that can be incremented up to 200 kN to perform the tests. PDA testing on drilled shafts and Franki piles is also very popular in Brazil.

CALENDAR OF EVENTS
Summer and Fall 99

Jun 7-8: and	New York, NY: ASCE Continuing Education: Deep Foundations: Design, Construction and Quality Control. Call (800) 548-2723.
Sep 30-Oct 1:	Seattle, WA: ASCE Continuing Education: (see above)
Jun 20-23:	Tri-State Engineering Society Meeting in Destin, FL. Sponsored by the Engineering Societies of Alabama, Louisiana and Mississippi. Call (318) 439-4552.
Jun 23-25:	4th Annual Pile Foundation Design Short Course in Logan, Utah. Call (435) 797-2896 and see the enclosed brochure.

In The Planning Stage – See Next Newsletter

September/ October/ November:	PDA Users Day in Europe; GRLWEAP Seminar in United Kingdom; Wave Equation Seminars and Workshops in Baltimore and in San Francisco.

PDA HELPS THE ENVIRONMENT: We are proud of two very **GREEN** projects.

1) Jorge Beim of PDI Engenharia, Rio de Janeiro, did PDA testing on the new foundations for a failing offshore interceptor sewer. The pipe normally discharges into the Atlantic Ocean several miles offshore of the Ipanema Beach. Pile installation and testing had to be fast and affordable, to minimize pollution of this very popular beach .

2) *Steve Abe* of GRL California worked on a fish screen being built on the Sacramento River. A fish screen is a large structure used to insure that salmon fry can survive the trip down the river after the salmon spawn. The screen was designed with sheet piles to be used during construction and permanent H-piles to provide bearing. The contractor proposed to use the sheet piles as permanent bearing piles and eliminate a large portion of the H-piles. However, the owner did not know what kind of capacity to assign the sheet piles and a static load test in the river was not feasible. GRL proposed PDA testing. The owner saved approximately $200,000 on the foundation cost due to the redesign. The big advantage to the contractor was that not having to remove the sheets and reducing the number of H-piles knocked 4 months off his construction schedule. And the salmon were protected too.

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