



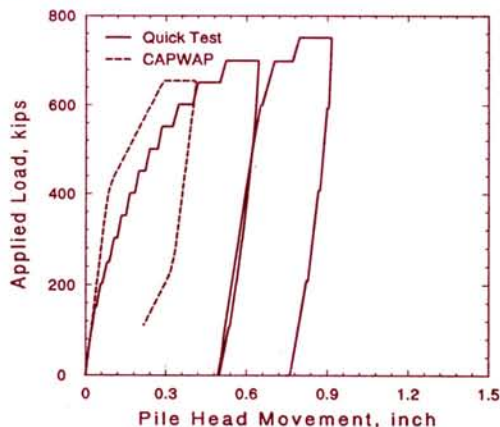
Information gathered by the engineers of  
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## WHAT IS PILE CAPACITY?

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.