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Compressive Static Load Test of Piles Standards and Methods

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THE REASON TO DO PILE LOAD TESTS

TABLE 13.1 FACTORS OF SAFETY FOR DESIGN OF PILES

Construction Control Method[a]	Factor of Safety, F: Downward Loading (Hannigan et al., 2006)	Factor of Safety, F: Upward Loading
Static load test with wave equation analysis	2.00[b]	3.00[b]
Dynamic testing with wave equation analysis	2.25	4.00
Indicator piles with wave equation analysis	2.50	5.00
Wave equation analysis	2.75	5.50
Pile driving formula[c]	3.50	6.00

[a] Most of these terms have not yet been defined, but all of them will be discussed later in this chapter and in the following chapters.

[b] If the static load testing program is very extensive, the factors of safety for downward and uplift loads might be reduced to about 1.7 and 2.5, respectively.

[c] Hannigan et al. refer specifically to the Gates formula.

THE REASON TO DO PILE LOAD TESTS

TABLE 13.3 GEOTECHNICAL RESISTANCE FACTORS FOR DRIVEN PILES USING DYNAMIC ANALYSES, LOAD TESTS, AND PILE DRIVING FORMULAS (AASHTO LRFD Bridge Design Manual, 2012)

Method Used to Determine Pile Capacity	Resistance Factor, ϕ
Driving criteria established by successful static load test of at least one pile per site condition and dynamic testing* of at least two piles per site condition, but no less than 2% of the production piles	0.80
Driving criteria established by successful static load test of at least one pile per site condition without dynamic testing	0.75
Driving criteria established by dynamic testing* conducted on 100% of production piles	0.75
Driving criteria established by dynamic testing,* and quality control by dynamic testing* of at least two piles per site condition, but no less than 2% of the production piles	0.65
Wave equation analysis, without pile dynamic measurements or load test but with field confirmation of hammer performance	0.50
Federal Highway Administration-modified Gates dynamic pile formula (End of Drive condition only)	0.40
Engineering News (as defined in Article 10.7.3.8.5) dynamic pile formula (End of Drive condition only)	0.10

* Dynamic testing requires signal matching, and best estimates of nominal resistance are made from a restrike. Dynamic tests are calibrated to the static load test, when available.

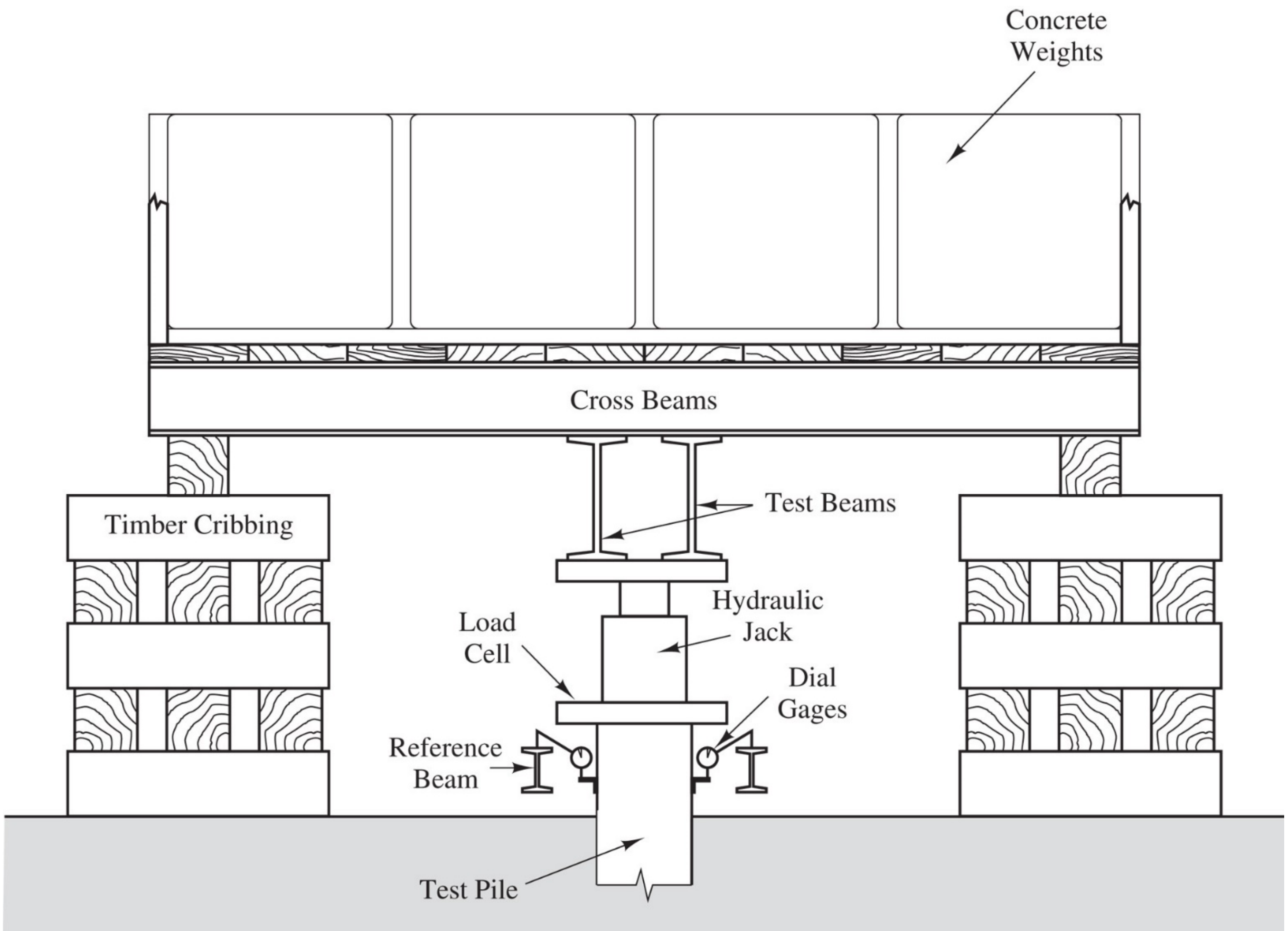
$$\sum \gamma\, Q \leq \varphi R$$

γ = AASHTO load factor;
Q = applied load;
R = pile resistance
φ = resistance factor

Conventional Static Load Tests - Procedure

- There are two categories of static load tests: controlled stress tests (also known as maintained load or ML tests) and controlled strain tests. The former uses predetermined loads (the independent variable) and measured settlements (the dependent variable), while the latter uses the opposite approach.
- ASTM D1143 describes both procedures. The vast majority of tests use the controlled stress method, so it is the only one we will discuss.

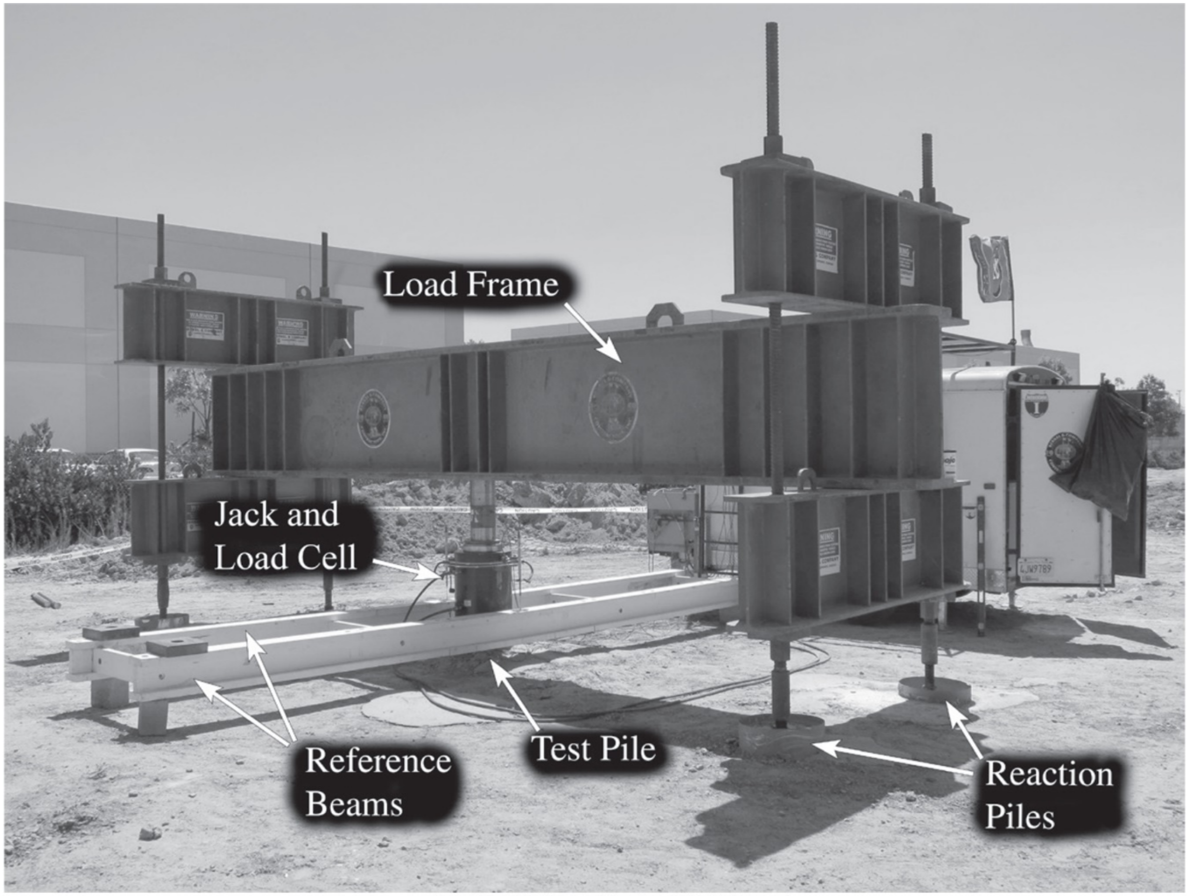
Use of a hydraulic jack reacting against dead weight to develop the test load in a kentledge static load test.



Kentledge (Dead weight) Type Test Frame

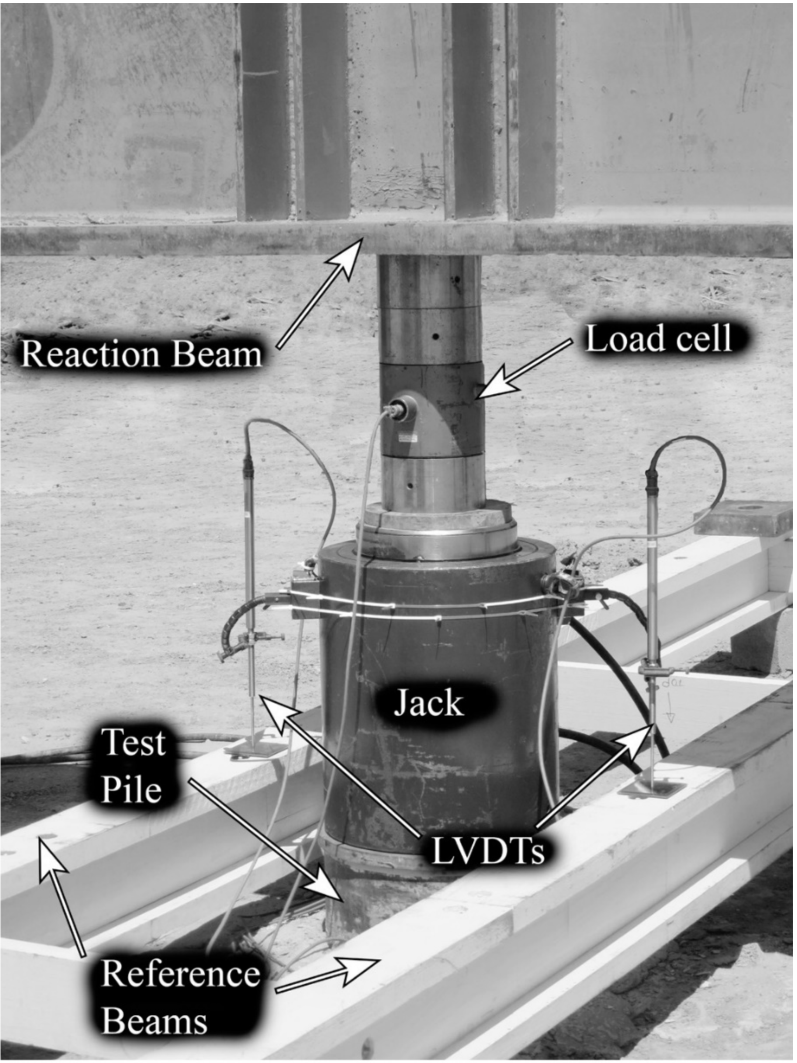
Photo courtesy of Underpinning & Foundation Skanska, Inc.

A static load test using a beam and reaction piles to develop the test load.



Construction parameters are variable as required by the different organizations and standards (DOT's, MTA's, ASTM etc.) and project detailed specifications.

Loading and Measuring Apparatus



This close-up of the test in previous slide shows the 5,300 kN (1,200 k) capacity hydraulic jack being used to generate the test load. The jack reacts against the beam above, which loads the test pile in compression and the reaction piles in tension. The load is being measured using a load cell (note data cable) and the settlement is being measured using linear displacement transducers and reference beams.

Traditionally, engineers measured the applied load by calibrating the hydraulic jack and monitoring the pressure of the hydraulic fluid during the test. However, even when done carefully, this method is subject to errors of 10-20 percent or more (Fellenius, 1980). Therefore, it is best to place a load cell (an instrument that measures force) between the jack and the pile and use it to measure the applied load.

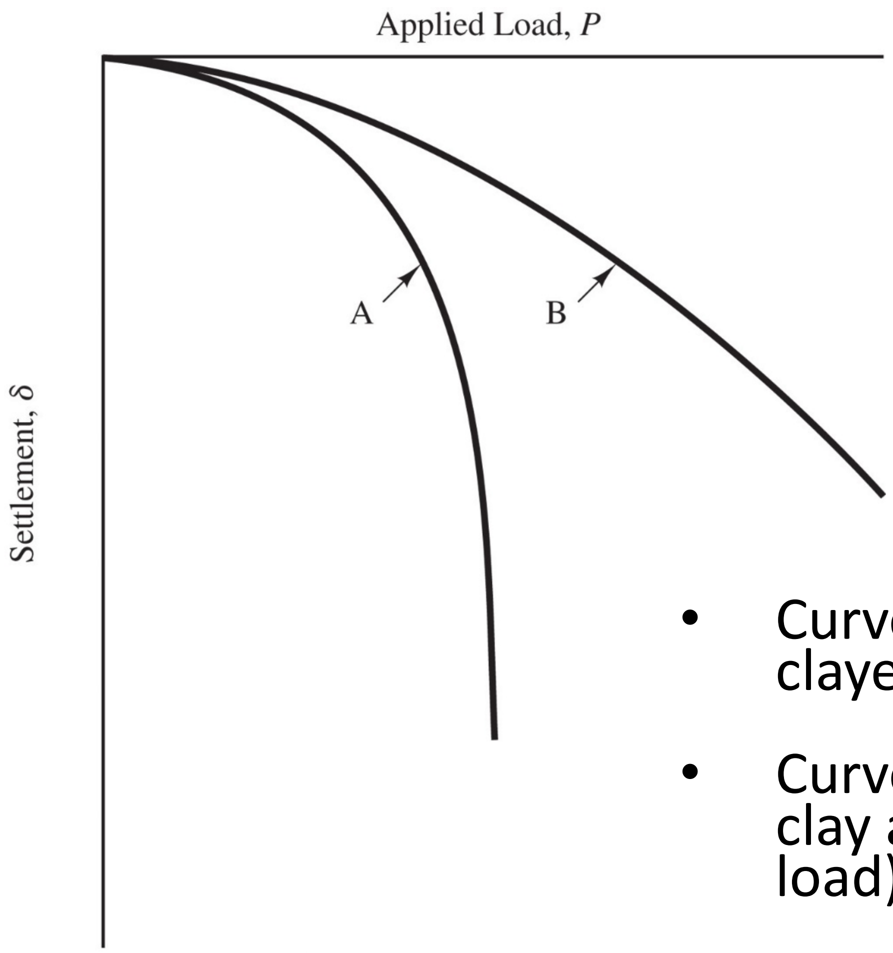
Conventional Static Load Tests - Procedure

- Deep foundation construction, especially pile driving, alters the surrounding soil. This alteration often produces excess pore water pressures, which temporarily change the ultimate load capacity.
- Therefore, it is best to allow time for these excess pore water pressures to dissipate before conducting the test. This typically requires a delay of at least 2 days in sands and at least 30 days in clays.

Conventional Static Load Tests - Procedure

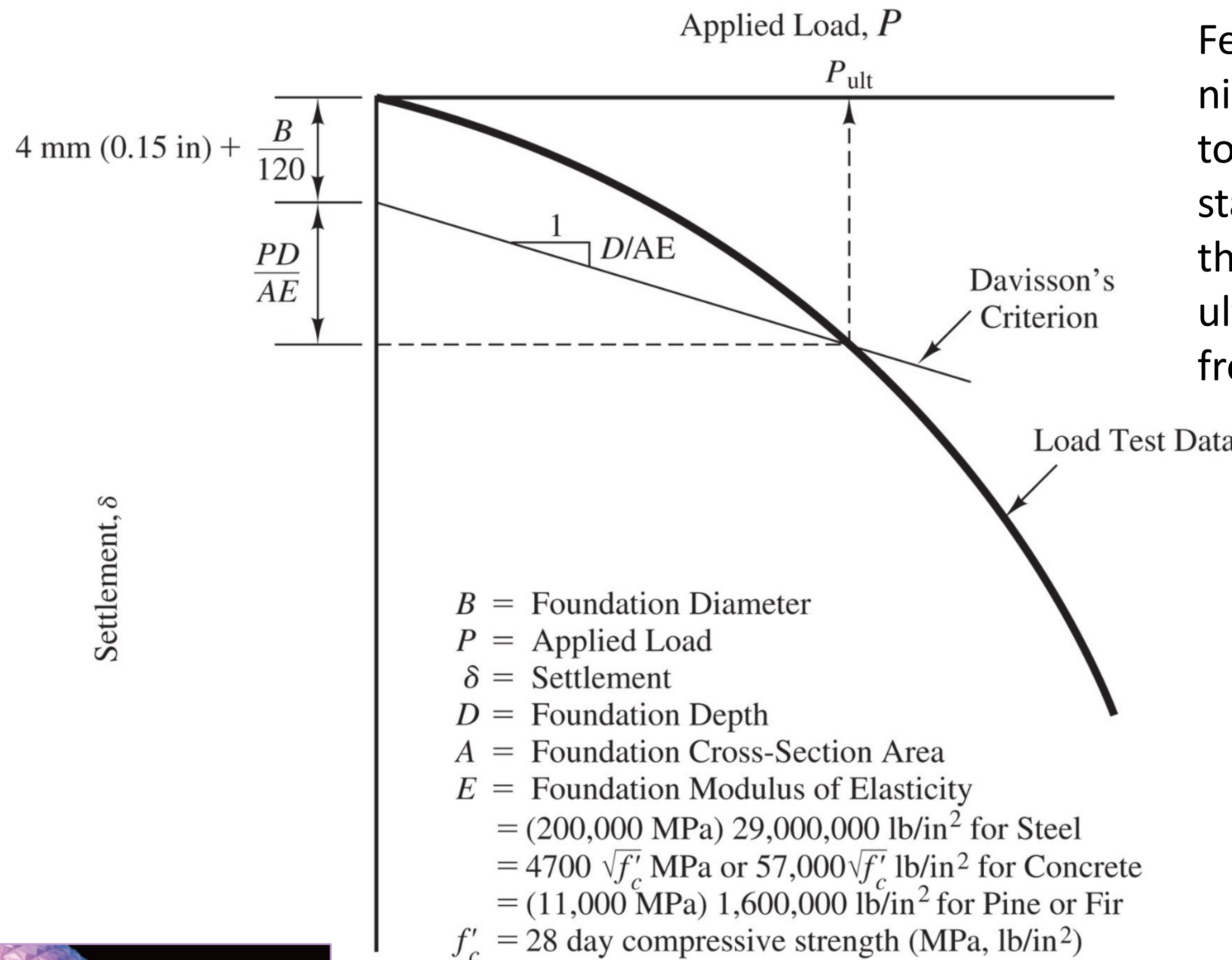
- More recently, the quick ML test is beginning to dominate. This method is similar to the slow test except that each load increment is held for a predetermined time interval regardless of the rate of pile movement at the end of that interval.
- Typically, each load increment is about 10 percent of the anticipated design load and is held for 2.5 to 15 minutes.
- This process continues until reaching about 200 percent of the anticipated design load or “failure” and generally requires 2 to 5 hours to complete.

Typical load-settlement curves



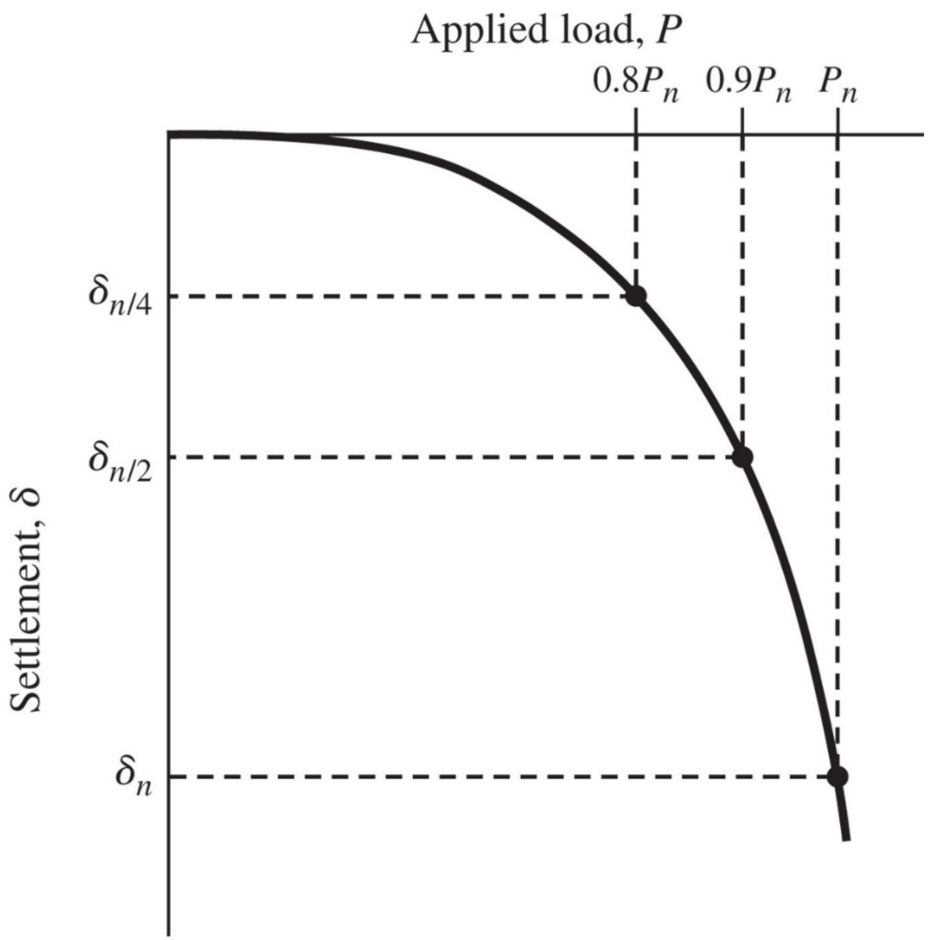
- Curve A is typical in soft and medium clayey soils (note plunge)
- Curve B is typical of intermediate, stiff clay and sandy soils (ever-increasing load).

Davisson method of determining P_n from static load test data.



Fellenius (1980) used nine different methods to analyze the results of a static load test and found that the computed ultimate capacity varied from 362k to 470 k.

Brinch Hansen method of determining P_n from static load test data.



J. Brinch Hansen (1963) proposed a definition for pile capacity as the load that gives four times the movement of the pile head as obtained for 80 % of that load.
The following simple relations can be derived for computing the capacity or ultimate resistance, Qu, according to the Hansen 80%-criterion for the Ultimate Load:

$$Q_u = \frac{1}{2\sqrt{C1C2}} \quad (1)$$

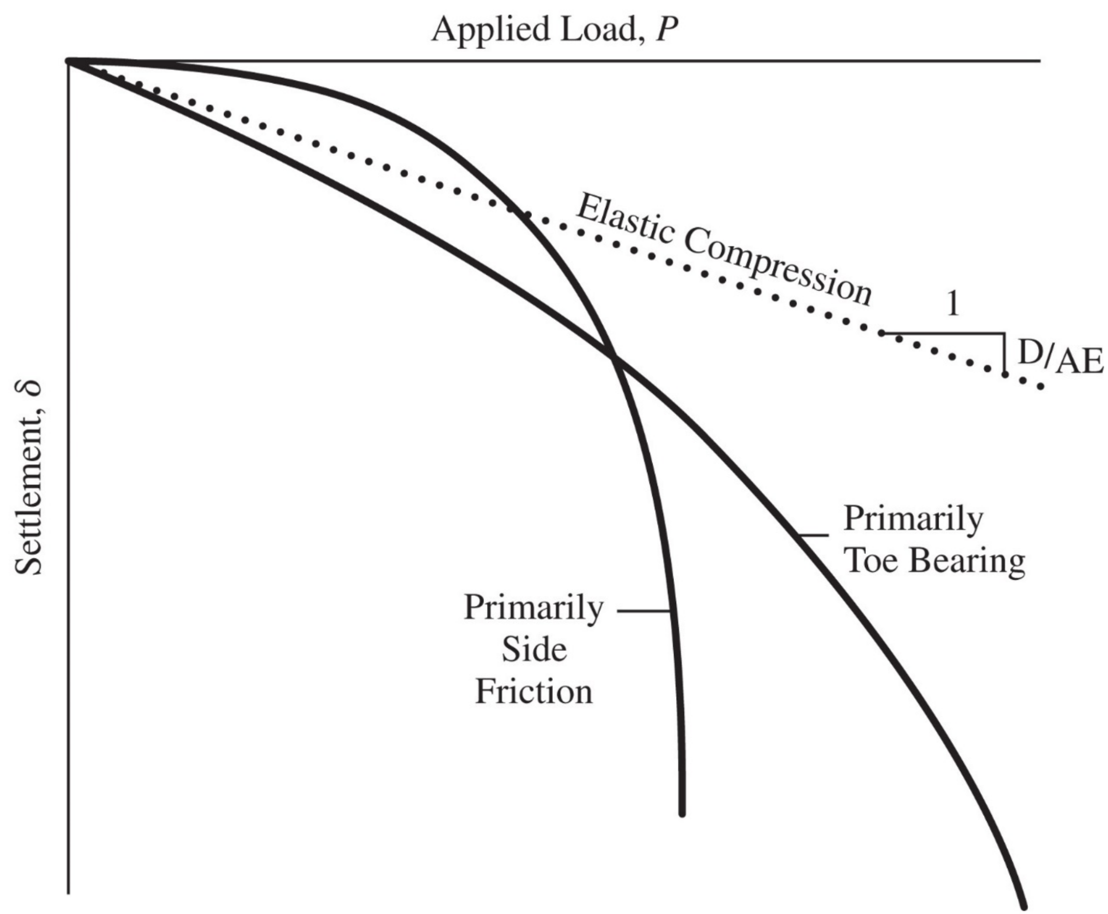
$$\delta_u = \frac{C_2}{C_1} \quad (2)$$

Where
Qu = capacity or ultimate load
δu = movement at the ultimate load C1 = slope of the straight line
C2 = y-intercept of the straight line

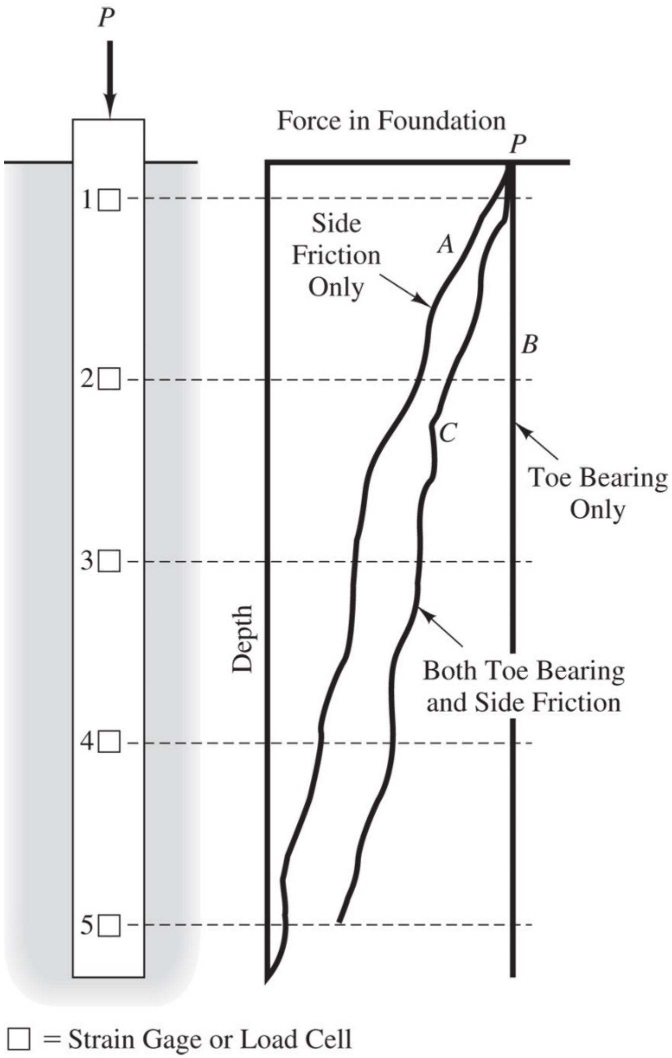
Fellenius, 2001

$\delta u = \delta n$
$Qu = Pn$

Implied load transfer from the shape of load-settlement curve.



Typical instrumented static load test

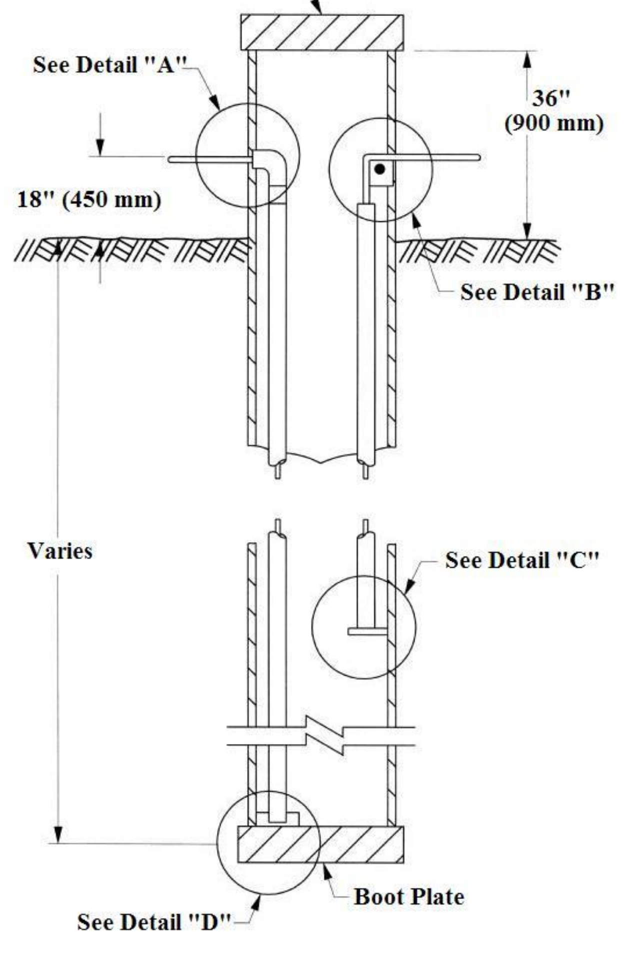


- If the applied load is transferred into the ground entirely through side friction, the plot of force vs. depth will be similar to Curve A (i.e., the force in the foundation gradually dissipates with depth, reaching zero at the toe).
- Conversely, if the resistance is entirely toe bearing, the plot will be similar to Curve B (i.e., constant with depth).
- Most foundations have both side friction and toe bearing, and thus have plots similar to Curve C.

Instrumentation of Static Load Tests

Instrumentation using Telltale Rods

Another method of conducting instrumented static load tests is to install telltale rods inside the foundation. These rods extend from the top of the foundation to some specified depth, and are encased in a protective sleeve. By comparing the settlement of these rods with the settlement at the top of the foundation, we can compute the force in the foundation, which in turn may be used to compute f_s, and q'_t.



Typical Section
Not to Scale

QUESTIONS ?

THANK YOU!

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