Three Case Studies on Static and Dynamic Testing of Piles

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The design and construction of pile foundations requires the engineer to evaluate the capacity of a pile. Traditionally, the engineer performs static tests to prove that the design is safe. However, due to time and cost considerations, static tests are now often replaced by dynamic testing methods as illustrated by the following case histories.

Case 1

As part of a Deep Foundations Institute program in North Carolina, a demonstration of pile driving and pile testing was performed. A 305 mm (12-inch) prestressed pile of 16.5 m (54 ft) length was driven into sandy and clayey silts by a Conmaco 65E5 hammer to a final penetration resistance of 5 blows/inch. Upon restrike three days later, the penetration resistance had increased to 10 blows/25 mm (10 blows/inch) indicating soil setup. On a WEAP bearing graph, the restrike blow count indicated that the capacity had increased to 1,735 KN (390 kips).

The pile was tested dynamically during the restrike using a Pile Driving Analyzer and the results were further analyzed by the CAPWAP method. This analysis indicated a capacity of 1,870 KN (420 kips). After the analyses had been performed, a static test was then performed that same day to ASTM D-1143 specifications: the pile was loaded to a maximum load of 1,840 KN (414 kips) and had a Davisson offset limit load of 1,820 KN (410 kips).

Comparison of the static test curve with the "simulated test" result by CAPWAP is quite good as shown in Figure 1 and indicates the accuracy of the dynamic tests.

Case 2

For a large bridge project, the Pile Driving Analyzer (PDA) was specified initially as a quality control tool to check hammer performance during production driving and to reduce the amount of static testing. HP12x53 piles were used as friction piles in silt for the abutments and were to have design load of 310 KN (70 kips). The PDA indicated about 710 KN (160 kips) at the end of driving at a penetration resistance of 17 blows/0.3 m (17 blows/foot) and 1,250 KN (280 kips) during restrike to a penetration resistance of 11 blows/0.3 m one day later using an ICE 640, confirming that set-up had occurred.

An ASTM D-1143 maintained-load static loading test was run to twice the design load 620 KN (140 kips). The pile easily held this load and had zero net movement. Unfortunately, most static testing performed is of this "proof test" variety where the actual safety factor is not determined but only a minimum value established. An ASTM constant rate of penetration test (CRP) was then performed to soil failure and indicated 1,260 KN (284 kips) as the Davisson offset limit load (Figure 2), confirming again the dynamic method accuracy.

To assist in driving the piles for the piers, the contractor rented a second "identical" hammer. At this location, the piles were long and driven to rock. However, the second hammer drove erratically and only transferred, on average, about 60% of the energy transferred by the first hammer. Because of the resulting high blow counts, the contractor replaced this hammer with a Vulcan 510 for better productivity using it at both full and half stroke. By comparing measured values of transferred energy, the driving criterion for any hammer/stroke was assessed without needing additional static tests.

For one particular pier where rock was at about 46 m (150 ft) depth, some piles were driving considerably deeper; some lengths were reported to be as high as 96 m (315 ft)! By means of the PDA, it was determined then these piles were indeed damaged. An example of one such pile is given in Figure 3. Severe damage is indicated at a dept of 30 m (98 ft) and no toe reflection is seen in the dynamic data at the supposed length of 48 m (158 ft). This pile was replaced. The extent and location of damage on several other piles were assessed, and piles with good "toe bearing support" and sufficiently high capacity for their effective lengths were accepted. A few extra piles were added to replace or supplement damaged piles with low capacity.

Case 3

A Delmag D30 was used on HP12x74 piles for working loads up to 890 KN (200 kips). After an initial test program that included both static and dynamic tests, some piles were restruck (without dynamic testing) and were found to have a reduced penetration resistance. To determine if this was a consequence of soil relaxation or due to better hammer performance, additional dynamic tests were carried out. It was determined that the hammer was performing significantly better than during the previous test program. The dynamic tests indicated 2,225 KN (500 kips) capacity, providing a sufficient margin of safety.

Both ASTM maintained and ASTM

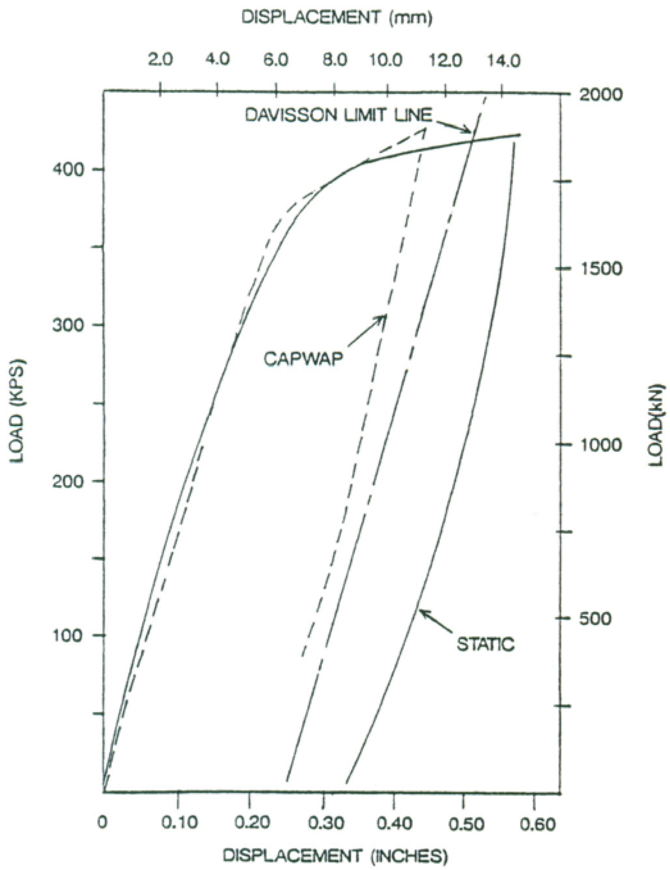

Figure 1: Case 1-Loading Test. Load-Movement Diagram

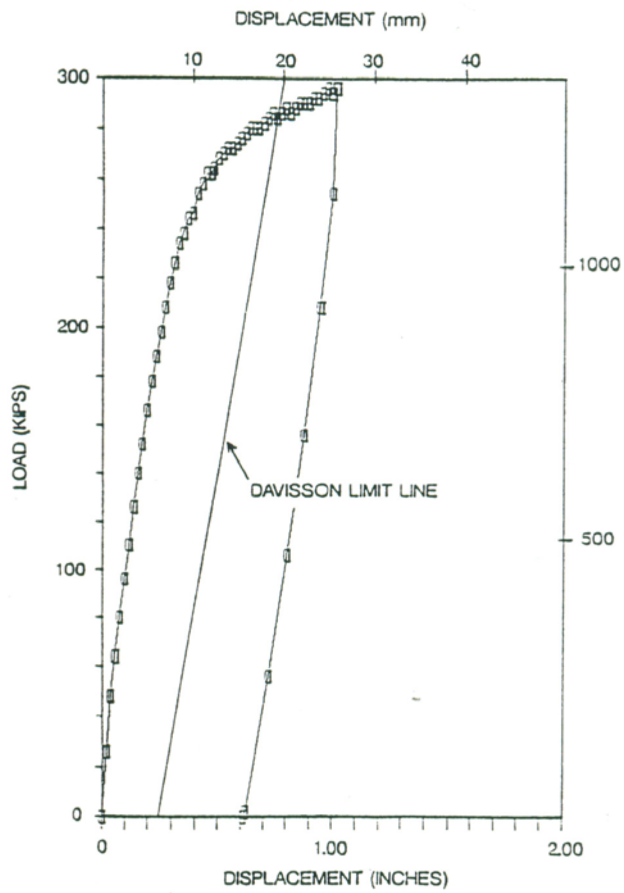

Figure 2: Case 2-CRP Test. Load-Movement Diagram

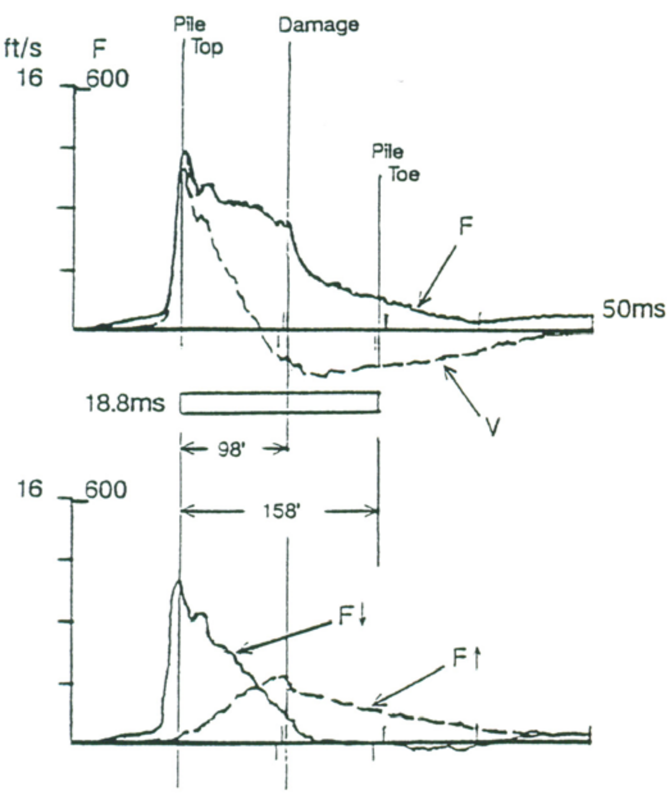

Figure 3: Case II Damaged Pile Wave Traces

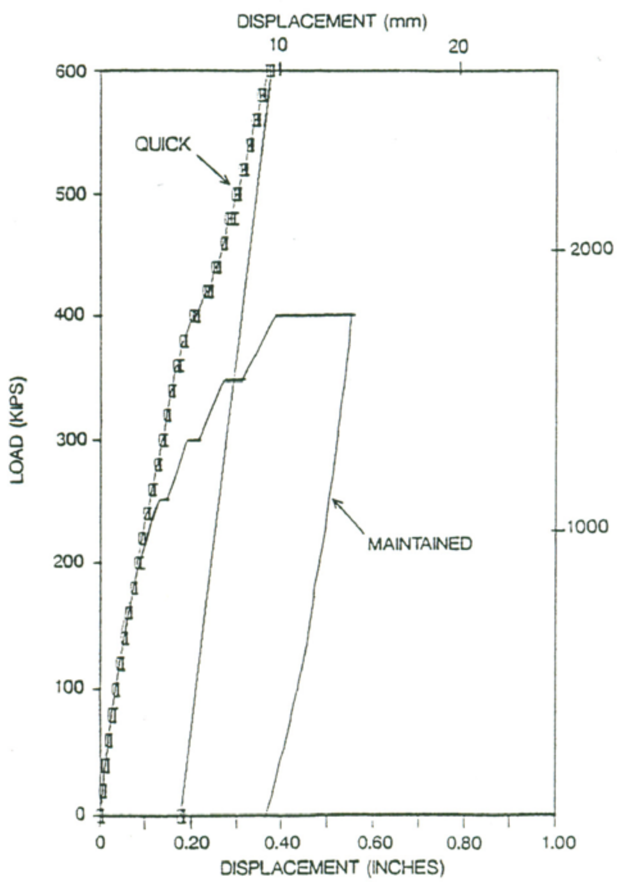

Figure 4: Case III - Static Test Results

quick static tests were also performed as further verification. The results shown in Figure 4 reflect the difficulties experienced in the load measurement and certainly confirms current thought (Fellenius, 1980) regarding such tests not always being absolutely accurate. Due to uncertainties encountered in the static tests, all that could be said with certainty was that the pile should hold a least 400 kips.

Summary

Three cases are presented with both static and dynamic pile testing results. Comparisons of capacities from both methods showed good agreement and the static test results were not always judged to be more accurate!

Considering the extra information of hammer performance evaluation, pile integrity inspection, and driving stress determination, the dynamic testing can solve more problems and answer more questions than conventional static testing. Considering the low cost of dynamic testing and the obvious flexibility of this method, it should be part of most quality control programs for pile foundations.

Reference

Fellenius, B.H. 1980, "The Analysis of Results From Routine Pile Load Tests," Ground Engineering, Vol. 13, No. 6, pp. 19-31.

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