Pile Driving Demonstrations – Then & Now

By Frank Rausche and Pat Hannigan, GRL Engineers, Inc.
Clayton Signor, Signor Enterprises and Joe Caliendo, Utah State University

It was a sticky, hot June day in 1972, when approximately one hundred geotech experts, participants in an ASCE Specialty Conference, were filling the bleachers at a grassy site on the Purdue University Campus in Lafayette, IN. While the sky turned black, the Foundation Equipment Corporation drove an H-pile with a DELMAG D- 12 to a depth of about 35 ft. Prior to the pile driving demonstration, days had been spent preparing the test equipment and moving it into a van to the site and organizing the test pile with strain gages. Purdue Professor Gerry Leonards asked Case Institute of Technology Professor George Goble to attempt measuring the residual stresses in the pile (not an easy task under any circumstances and particularly not when the main emphasis was a demonstration).

In addition to strain gages along the pile length, George Goble, Frank Rausche and Garland Likins (the GRL team) also used a top transducer and accelerometers and connected them to the first routinely working Pile Driving Analyzers (PDA). But before that could happen, the sky unloaded huge buckets of water over the site and onlookers, making the readings jittery. However, the capacity of the pile was accurately read from the PDA's digital display and then confirmed by a static load test, performed immediately following the pile installation. Analyses of the results, later performed at Case Institute of Technology in Cleveland, OH, were presented in a Proceedings paper[1].

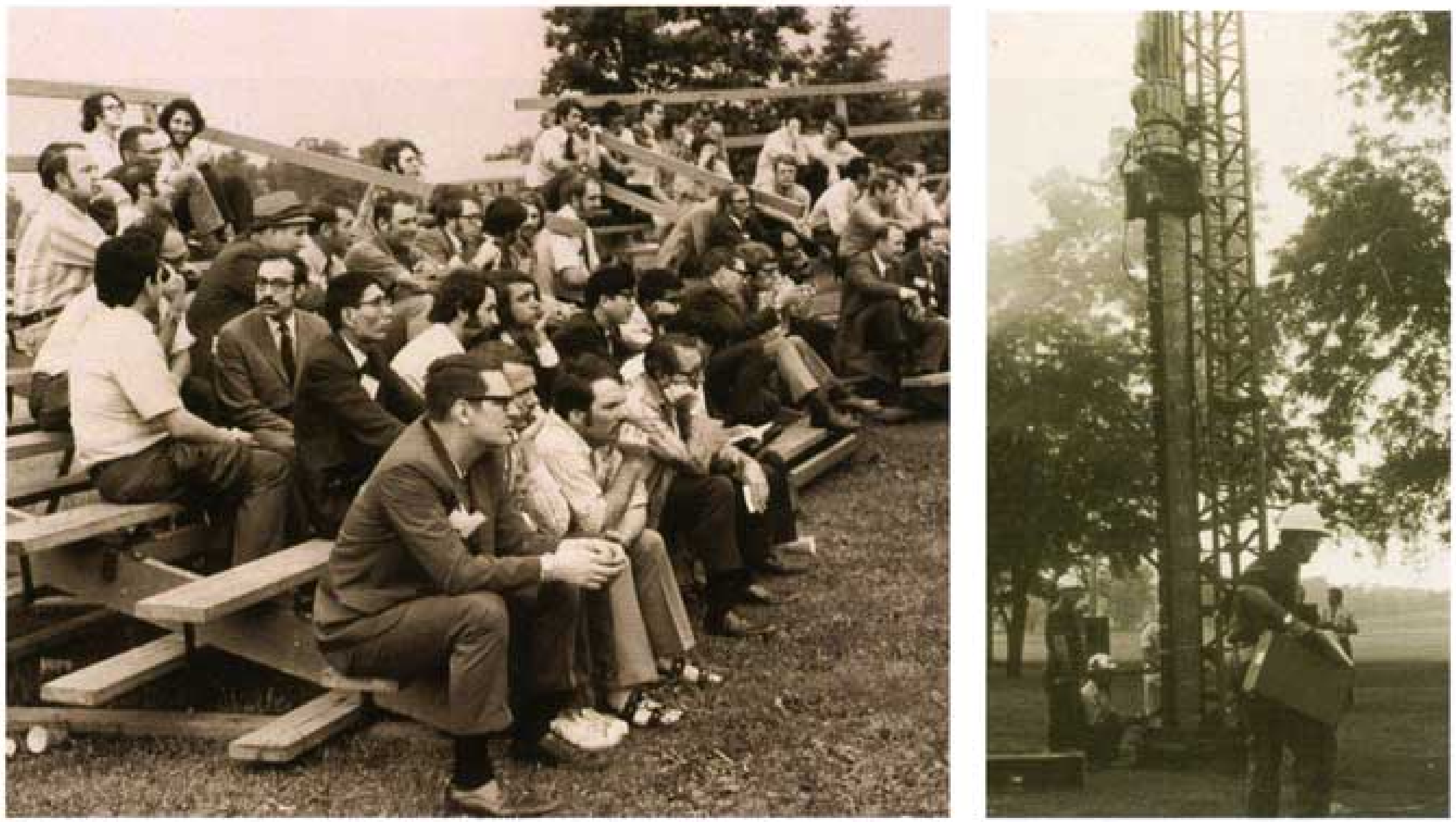
Several pile driving and testing demonstrations were attempted following the Purdue experience. Difficulties with driving equipment; soil resistance that was either too low or too high for a meaningful demonstration, uplifting test dead loads and other problems made the demonstrations difficult and caused the GRL team only hesitatingly to recommend additional demonstrations.

Pile Driving and testing demonstration at PDPI in Logan, UT

Forward 37 years to June 2009: During the 2009 Professors' Driven Pile Institute Proceedings, 26 university professors saw within a short morning period the driving and dynamic monitoring of a steel pipe and two concrete piles. A day earlier, after Utah State University's Prof. Joe Caliendo and his team had statically tested two piles under compressive and lateral loads, GRL Engineer's Pat Hannigan performed a restrike test on a load test pile and the energy calibration of an automatic and a cathead and rope safety hammer. Hannigan had brought along his PDA, Model PAX, and utilized wireless sensors to acquire the data. The results from PDA and the more rigorous CAPWAP analysis were shown a short time later to the participants in a class room of Utah State University2. The longest time was spent on the demonstration of static compressive and a lateral load tests.

As part of the SPT demonstration, the participants were invited to operate the cathead and rope machine and compare their result. PDA calculated transferred energies were displayed and stored by the PDA. These transferred energy values, divided by the SPT rated energy (140 lbs ram weight times 2.5 ft drop height = 350 ft-lbs potential energy) yield the transfer efficiency which has been plotted both for the automatic and the cathead and rope hammer in the figure below. Obviously, the professional

[1] Demonstration onlookers watch George Goble carry instrumentation to a sheltered place



Demonstration onlookers watch George Goble carry instrumentation to a sheltered place

PDPI instructor Pat Hannigan installs wireless gages

SPT operator did a much better job than the three professors while the automatic hammer provided consistently high energies.

SPT Transfer efficiencies for Automatic and Cathead and rope hammers

The demonstration of the static and dynamic load tests in Logan are always rather challenging. The demonstration site consists of a 7 ft crust and then very soft soils to a depth of roughly 45 ft where a bearing layer prevents the artesian water below from flooding the site. A steel pipe pile had been installed in previous years and it is used to demonstrate the static load test. The same pile is then tested by driving the pile for approximately 3 inches with a Kobelco 13 hammer. This year the PDA indicated capacity was 160 kips. The static load test failed at 170 kips. Unfortunately, the transferred energy was only 3,300 ft-lbs and for that reason, the equivalent blow count was 30 blows/ inch. Under those circumstances, it is understandable that the CAPWAP calculated load-set curve does not show a clear failure. A comparison of static and dynamic load-set curves is shown below.

Not quite as ambitious, yet equally impressive as far as smoothness of operation, speed of data acquisition and data processing was a July 2, 2009 demonstration organized by Rusty and

PDPI participant tries for high SPT energy

Pile Driving and testing demonstration in Austin, TX

Clayton Signor. More than 30 geotechnical engineers attended the demonstration in Manor near Austin, TX. Signor Enterprises demonstrated driving and restrike testing of two 6-5/8 inch diameter pipe piles (one had been installed 6 days prior to the demonstration) and one HP 10x42. John McIntyre, P.E., consultant to Signor, operated sensors and PAX in a remote mode, i.e., Garland Likins of GRL Engineers, Inc. from Cleveland, OH, monitored the data through the internet in real time as the piles were driven. He checked, and then relayed the results to the audience as the testing proceeded. Signor used a Pile Master 36-3000 air hammer (ram weight 3,000 lbs; rated energy 9,000 ft-lbs) to drive the piles into the Taylor Formation, a problematic expansive clay soil found in Texas. End-of-Drive (EOD) blow counts of the 25 ft long pipe were less than 2 blows/ inch while the beginning of restrike (BOR) required 10 blows/ inch. Energy calculated by the PAX suggested a nearly 100% efficiency of the uncushioned hammer. Load-set curves calculated by CAPWAP show roughly a 2-fold gain of capacity. The relatively small pipe pile had an ultimate capacity of nearly 230 kips and could safely support a load of more than 55 tons. The H-pile, driven after the restrike pipe test to 10 blows/ inch, reached an EOD capacity slightly higher than the restrike tested pipe. It can be safely anticipated that the H-pile will eventually be able to safely support 100 tons. However, verifying that capacity would require a hammer with a higher energy.

CAPWAP calculated load-set curves for pipe piles during installation and restrike

One interesting aspect developed during testing when the

The Pile Master 36-3000 driving a 6-5/8 inch, 25 ft long pipe pile in Manor, TX

energy measured in the pile by the PDA turned out to be 30 to 60% higher than anticipated. The crew had thought to run the hammer at a stroke of 1.5 ft corresponding to a potential energy of 4,500 ft-lbs. However the measurements indicated 6,000 ft-lbs and greater values in the pile. Careful inspection revealed that the hammer was significantly over stroking and that during hard driving the energy in the pile was not much different from the potential energy of the hammer. These findings point out that the wave equation model of this hammer has to use a much higher efficiency than the 0.67 value that is generally used for traditional air hammers.

For each hammer blow, the plot below shows the maximum compressive stresses, transferred energy and capacity at the time of testing. Obvious trends as the blow number increases and thus the depth of installation are an increasing stress, slightly reducing transferred energy and a clear gain of bearing capacity.

Noise levels during driving, monitored by Rusty Signor, were in the mid 80 db range at a distance of about 50 ft from the pile driver. Ground vibrations were barely noticeable. It was concluded that these relatively small piles can be reliable and quickly installed, reaching high capacities with minimal environmental impacts.

While it is always a challenge for those organizing a demonstration, today's equipment both for pile installation and load testing has come a long way and makes for an interesting, dynamic and instructive event – barring any down pours. ▼