PILE TESTING COMPETITIONS – A CRITICAL REVIEW[1]

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INTRODUCTION

A number of pile testing competitions, using low-strain techniques, took place in different countries between 1987 and 1997. These affairs soon started a heated debate by the professional community. Since the outcome of these competitions was obviously contentious, they should be critically reviewed. Such a review may serve as a basis for more productive competitions in the future. These, in turn, will highlight both capabilities and limitations of existing methods and contribute to the advancement of these techniques.

In this paper, the authors describe for each competition the testing scope and program, piles tested, the nature of the defects installed, the participating parties, and the results obtained. They go on to analyze each competition, specifically stressing those items that if done differently could have brought a significant improvement to the outcome. Based on the lessons learned from these events, the authors present some ground rules for future pile-testing competitions. In conclusion, the authors recommend that the preparation of the testing program for future competitions make use of the expertise available within APTLY, the International Alliance of Pile Testing Laboratories.

PILE TESTING BY THE SONIC METHOD

The sonic method was first applied a quarter of a century ago (Steinbach & Vey 1975). Since then, it has established itself as the leading method for testing the integrity of all kinds of piles. With the advent of handheld computing, sonic testing has become more reliable and at the same time more affordable.

The sonic method is based on pressing a sensor against the top of the pile while hitting it with a hammer. The hammer blow created a low-strain wave that travels down the pile and is reflected

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from the toe, as well as from any abrupt change in the pile impedance. The hammer may be either plain or instrumented, and the results may be analyzed and presented in either time or frequency domain. An extensive treatment of the sonic method is presented by Turner (1997). The popularity of the method brought a proliferation of both instrumentation and testing laboratories. As a consequence, it naturally became a subject for competition.

PILE TESTING COMPETITIONS

Objectives

In principle, pile-testing competitions should be held with the following objectives:

1. Kindling the competitive spirit amongst developers, manufacturers, and users of equipment
2. Indicating where advances in the state of the art are required.
3. Establishing the actual (as opposed to claimed) capabilities and limitations of the method
4. Serving as milestones to monitor progress in both instrumentation and analysis tools
5. Providing an opportunity for potential clients to obtain reliable comparative data regarding the performance of available instruments

Principles

To reach the above goals, competitions must, as far as possible, simulate realistic testing situations. Therefore:

1. The tests should be carried out on real piles, conventionally constructed in real soil
2. The piles should have different lengths and length-to-diameter ratios
3. Intentional anomalies should be carefully designed and constructed to resemble anomalies actually encountered in practice
4. The anomalies should be of growing importance, from hardly discernible to almost complete discontinuity
5. Pile heads should be well-prepared, consisting of relatively smooth, good-quality concrete
6. Tests should be carried out by experienced personnel, familiar with the testing systems

7. Participants should be provided with a soil profile (borehole log) and pile data as usually provided on real projects

Real projects normally involve testing several piles on a given site, which aspect is important to retain for a competition. Therefore, a competition should preferably take place on piles at an actual construction project and include a large number of "ordinary" piles at that site.

COMPETITION OVERVIEW

Following is a brief summary of three such competitions, held in Belgium, The Netherlands and the USA, respectively.

Ghent 1987

In 1987, an integrity testing competition was held in Ghent, Belgium (De Jaeger et al. 1987). Altogether, twenty piles were tested, constructed by four different methods, five piles each:

1. Atlas helicoidal (sawtooth profile) piles, diameter 430/530 mm
2. De Waal precast concrete driven piles, 320x320 mm
3. Socofonda CFA piles, diameter 460 mm
4. Fundex piles, bored with rotated casing and cast in situ , diameter 390 mm

The five testing firms that participated were given the pile diameters, and told that the pile lengths lie between 11 and 16 metres. The task in hand was to determine the correct length.

The best overall results were obtained in the Socofonda and in the Fundex piles. The lengths obtained for the Socofonda piles were 93% and 100% of the correct lengths, While in the Fundex piles the spread was between 94% and 102%. Such results are perfectly acceptable. On the other hand, poor results were reported for the precast piles (82% to 120%) and the Atlas piles (from 101% to 125% for three of the piles, with no results at all for the other two). The conclusions from this exercise are as follows:

1. The precast driven piles were difficult to test both due to higher skin friction and to having the highest L/D ratio (41 to 53).
2. The Atlas piles also produced poor results, although they had the lowest L/D ratio (26 to 30). Since all testers reported lengths that were too high, they probably forgot that a

helicoidal pile has a much lower apparent wave velocity than a straight-shafted pile (Vyncke & van Nieuwenburg 1987).

3. The CFA piles and the smooth-skinned Fundex piles were the easiest to test. This is due to smoother skins and lower L/D ratios (32 to 37) than the precast piles.
4. The organizers declared that the piles were between 11 and 16 metres long. Thus, a tester who would have reported a uniform length of 13.5 m (The mean of the above limits) for all the piles would be accurate to within ±10% in 90% of the piles!
5. While highlighting the influence of construction method on testability, the exercise totally neglected the most important purpose of sonic testing - finding defects!

Delft 1992

The Delft competition took place in conjunction with the Fourth International Conference on the Application of Stress-Wave Theory to Piles (Smits 1996). Twelve laboratories participated in the event, employing six different types of instruments. The ten test piles were made of precast concrete and installed in the following way: First, closed-ended pipes were driven to the requested length. The precast piles were then lowered into the empty pipes and put on a thin sand-bed. The space around the piles was then filled with a bentonite-cement mixture pretending to represent the local soil stiffness.

Two of the piles were straight shafted, with respective lengths of 17 and 18 m. Their cross-section was 250 mm square. Of the rest, six piles were produced with the cross-section along a given length either enlarged to 300 mm. square or reduced to 200 mm square, or both. The two remaining piles had a sawed notch, 10 mm. thick and occupying one half of the cross section. Similar notches were also produced in two of the piles with enlarged section.

The testing circumstances were unique in two respects: First, the participants were not allowed to approach the piles, and the testing was done by the notary public's clerk. Second, the participants were given the pile shapes, and their task was to decided which is which.

The participants managed to guess correctly only between three and seven piles, with a mean success rate of 44%. The scores for the individual piles varied between zero (straight shaft, L = 18m) to 100% (straight shaft, l = 17m).

As expected, the event triggered a lengthy debate in the Ground Engineering magazine (Stain 1993, 1993a, Ellway 1993). The main criticism was aimed at the following points:

1. Most sonic testing is done on cast in situ piles, with an inherent variability of both concrete quality and soil friction and a rough top surface. Precast piles in an artificial "soil" with smooth tops thus cannot represent real-life conditions.
2. The extremely high L/D ratio (72) is far beyond normal testing limits.
3. Most of the anomalies, and especially the saw cuts, were beyond the theoretical limitations of the sonic method.
4. Inexperienced people, not familiar with fine points of the test carried out the actual testing.

In certain aspects, the Delft competition was a large backward step from the Ghent affair, only reinforcing the (erroneous) conclusion that sonic testing is little more than guesswork.

Houston 1996

This competition (Samman & O'Neill 1997) took place on the campus of the University of Houston, Texas. Altogether, twenty-two piles were tested. Eleven of the piles had a diameter of 460 mm and were bored to a depth of 4.6 m. The other eleven piles were 760 mm in diameter and 7 m long in the ground. Some of the piles were constructed with polymer slurry while the rest were cast in the dry. Six of the piles were regular ones, while sixteen piles had planned built-in defects. These defects were produced from 25 mm thick horizontal mats, made of soft rubber. The mats were placed at different depths, but not more than one per pile. Each occupied between 10 and 50 percent of the total cross section of the pile.

Eight laboratories took part: Two government, five commercial ones and one academic. The contestants were asked to report for each pile whether it is OK or defective, and in the latter case specify the depth and severity of the defects. The participants were to submit two reports: A preliminary report on the same day, and a final report within five days.

The results, as can be expected, were far from satistfactory: In the OK piles, only 7% of the tests confirmed their integrity. In the anomalous piles, defects were found in 82% of the cases. These rates improved somewhat in the final reports, to 25% and 83%, respectively. The success rate for the defective piles may seem impressive, but a deeper look into the matter is far less encouraging: Of all the reported defects, only 36% managed to fit the depth of the defects within ±20 percent. Of these, only 37% provided the size of the defects within ±20 percentage points. On the other hand, the participants reported on the average 1.3 "phantom", i.e. nonexistent, defects per pile. None of the contestants, or the testing instruments used, demonstrated a markedly outstanding performance.

In view of such poor results, the organizers declared that sonic testing "may not be reliable enough to be regarded as a stand-alone measure of the assurance of drilled shafts". Could it be that not the sonic method was to blame, but the organization of the competition? In principle, the Houston competition had the correct ingredients to simulate a realistic testing assignment. The main factor that turned the Houston test into a failure was the nature of the "defects": To be applicable, the sonic method utilizes a wavelength that is large in relation to the pile diameter. A defect with a vertical dimension of 25 mm is therefore well outside the performance envelope of the sonic method unless it occupies all or most of the cross section of the pile. Since the defects in Houston occupied at most one half of the total pile area, it took a lot of good luck to discover any of them. The fact that some defects were placed as close as 300 mm to the top only made things worse.

Since most competitors were keen to find defects, and the nature of the defects made them practically undetectable, the competitors found defects even in perfectly good piles. This is the only explanation for the low discovery rate in the good piles (plain coin tossing would do markedly better!)

No.	Criterion	Ghent 1987	Delft 1992	Houston 1997
1	Theoretical basis	3	2	1
	The use of real piles in real soil.	1	3	2
	Different lengths and L/D ratios.	2	3	1
	Piles include anomalies	3	1	2
	Anomalies of growing importance	3	1	2
	Anomalies at different depths	3	1	2
	Data provided to Competitors	3		
	Pile head preparation			
	Full publication of results	1	2	3

Since ultrasonic cross-hole testing is gaining popularity, suitable competitions in this category would be extremely beneficial.

Summary

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