Discussion of "Evaluation of Static Capacity of Deep Foundations from Statnamic Testing" by Dan Brown, ASTM Geotechnical Testing Journal GTJODJ Vol 17 No. 4 Dec. 1994

Discussion by George G. Goble[1], Frank Rausche[2] and Garland Likins[3]

KEYWORDS: piles, drilled shafts, load tests, instrumentation, statnamic method

The author's careful review of the Statnamic method and the presentation of test data are of great value to the geotechnical profession. Since Statnamic is a patented method it is difficult to obtain the independent evaluation that normally occurs when a new concept is presented. The discussers would like to commen[illegible] contained in the paper.

The developers of the Statnam[illegible]nceded (Middendorp et al.1992) that Statnamic is really a dynamic event. T[illegible]posed method of evaluation assumes that the test pile is rigid and examin[illegible] on the pile at the instant that motion stops. This approach was suggeste[illegible] laboratory research supervised by H. P. Nara at the Case Institute of Technology and was further developed in an extended project at Case sponsored by the Ohio Department of Transportation and the FHWA. The simplest version of the methods developed was published by Goble et al. (1967, 1970) and is identical with the method currently proposed for Statnamic. Later developments at Case abandoned the rigid body assumption for a more realistic and accurate elastic model.

The Statnamic test is fundamentally different from static tests in that *Statnamic uses a specified applied load* rather than the *imposed displacement that is applied by the static test*. In a static test, a volume of hydraulic fluid is pumped into the loading system, inducing an associated displacement. The load induced will depend on the stiffness of the pile and the test frame. When the load equals the strength of the pile soil system, pile displacements will continue to increase without any increase in load. In the Statnamic case, the total of the pile's static and dynamic soil resistance is much larger than the Statnamic mass, causing a much

---

[1]Professor Emeritus, University of Colorado at Boulder;
Principal, Goble Rausche Likins and Associates, Inc., Boulder, CO.

[2]President, Goble Rausche Likins and Associates, Inc., Cleveland, OH.

[3]President, Pile Dynamics, Inc., Cleveland, OH.

higher upward acceleration and displacement of the Statnamic mass while the pile has comparatively little downward movement. Thus, the explosive gas pressure and the applied Statnamic force will only be slightly affected by the resistance characteristics.

The applied Statnamic force must be in equilibrium with the sum of the pile's static resistance plus the pile's velocity related resistance plus the pile's acceleration related inertia. Normally, both the static and dynamic resistances of the pile are not known in advance. Selecting a Statnamic force to achieve a significant permanent set after the test requires application of a Statnamic load larger than the sum of all resistance components. ***Due to the relatively slow Statnamic load build up, all static plus dynamic resistance forces occur more or less simultaneously, and the applied Statnamic force must be much larger than the pile's ultimate static load to achieve soil failure and could cause pile structural failure.*** In normal impact dynamic testing, the load quickly reaches its full value; stress waves distribute the impact loading in time so that the applied force need only be similar to the pile's static capacity to achieve soil failure.

The damping coefficients, $C_4$, tabulated by the author, show a surprisingly large variability. In cases where Statnamic forces considerably larger than the static capacity are applied, high pile velocities are generated. In the data presented, the peak velocity ranged from 0.2 to 3.5 m/s, a range of more than an order of magnitude. If Shaft 2 at College Station is dropped, the largest maximum velocity is still 1.2 m/s. This large range of peak velocities may partially explain the large range of damping coefficients $C_4$. For sands, the range of damping coefficients is from -0.4 to -5.4. Clay sites have similar values and ranges. No clear relationship is observed. Coyle and Gibson (1970) in laboratory tests demonstrated that the peak dynamic resistance was a strongly nonlinear function of the velocity, a result confirmed by others (Heerema 1979, Litkouhi and Poskitt, 1980). In fact, Janes (1995) presents results of Statnamic tests that show that the Statnamic damping "constant" $C_4$ varied on the same pile by a factor of 3 when the applied Statnamic force was doubled.

During the loading phase, the loading rate can be controlled by the amount of explosive and reaction mass. However, the unloading rate is not controlled, and large decelerations are generated, occurring near the time of load evaluation by the Statnamic equilibrium point method. Thus, the inertia term correction in the Statnamic capacity analysis can be quite sensitive to high accelerations for large shafts with a large mass; the pile mass may be further increased by some undeterminable soil mass moving with the pile. In fact, the unloading phase is so short that the rigid body assumption is violated and stress waves are generated in the pile, causing large tension stresses. Several records presented by the author clearly show this tension at the top of the shaft (due to upward inertia of the Statnamic device during rebound); tension in the shaft would be higher still due to the extra shaft mass. In general, damage cannot be detected in the Statnamic measurements due to the slow load application.

The results presented include several with obvious measurement problems. The data were obtained by measuring the displacement with a non-contact displacement measurement device that can be sensitive to vibrations from both ground and wind. Those measurements were then differentiated to obtain the velocity and a second time to get acceleration. The greatest accelerations occurred during the unloading phase, where the capacity is evaluated. Double differentiation to obtain acceleration magnitudes is an unreliable process, particularly when the displacement measurements are subjected to filtering in the signal conditioning and computation process, which introduces another variable, as the author points out. Most of the measurements indicate derived accelerations that are obviously incorrect in the early part of the record where some even have incorrect signs. Under these circumstances, the Statnamic inertia correction and capacity results become highly questionable.

The author notes that Cupertino Shaft 4 was not loaded to failure in either the static or the Statnamic case. For Texas A & M Shaft 2, the displacement measurement went out of range, so the point of zero velocity could not be determined as recommended. The selected $C_4$ damping coefficient does not match either the other Texas A & M tests or other sites with similar soils. The test in Barrie, Ontario, also probably did not fail and the Statnamic test was not run on the static test pile, making the correlation results for this shaft questionable. These cases should be excluded from the correlation of Fig. 32.

It is unfortunate that the author did not have more data available since many more tests have been reported. The results presented by Janes et al. (1994) from tests conducted at the University of British Columbia Pile Research Site in the Fraser River Delta near Vancouver, Canada are of interest. One of the results taken from that paper, Fig. 9, is shown here and Fig. # 1. The pile was a steel pipe about 30 m long, driven closed ended through 15 m of soft organic silty clay and 15 m of dense, fine to medium sand into a normally consolidated clayey silt with sand layers. The load deflection curve followed the static test curve quite well up to the static failure load at about 1100 kN. The Statnamic "static" load then increases to over 2000 kN, about double the ultimate capacity measured by a static load test, and then unloads with near full rebound. *If the Statnamic test does not cause true soil failure and a reasonable permanent set then the Statnamic test becomes unreliable and may grossly overpredict capacity.*

In Janes et al. (1994), it is concluded that the test must be carried to a soil failure condition typified by the author's Fig. 3. Results from Cupertino and Shreveport should not have been included since soil failure clearly was not achieved. In these cases, the Statnamic "capacity" was determined solely by the Statnamic force applied. To achieve soil failure, it may be necessary in some cases to load the pile substantially above the pile static capacity due to the dynamics. In three of the four remaining valid correlation cases presented (Rio Puerco, Albuquerque, and Texas A &M Shaft 7), Statnamic significantly overpredicted the capacity ultimate loads from the static tests.

The Statnamic name may be misleading to the engineer not familiar with the dynamics involved in this test method. ***The test is clearly dynamic and must cause significant permanent pile set after the test to be useful in determining ultimate "static" loads.*** Due to the test's potential for large overpredictions, it should always be correlated with static test results. To be of value, tests of this relatively high cost should produce results that are as reliable as the static test. This does not appear to be the case from the Statnamic results presented. There is very little "Class A" data available. Additional data, independent evaluation, and perhaps method modification will be required before Statnamic can be used without a calibrating static test.

## References


Coyle, H. M. and Gibson, G. C., 1970. "Empirical Damping Constants for Sands and Clays, Journal of Soil Mechanics and Foundations Division, ASCE.

Eiber, R. J., 1958, "A Preliminary Laboratory Investigation of the Prediction of Static Pile Resistances in Sand", *Master's Thesis*, Department of Civil Engineering, Case Institute of Technology, Cleveland, Ohio.

Goble, G. G., Scanlan, R. H. and Tomko, J. J., 1967, "Dynamic Studies on the Bearing Capacity of Piles," *Highway Research Record*, No. 167, Bridges and Structures, April, National Research Council, Washington, D.C.

Goble, G. G. and Rausche, F., 1970, "Pile Load Test by Impact Driving," *Highway Research Record*, No. 333, National Research Council, Washington, D.C.

Heerema, E. P., January 1979, "Relationship between Wall Friction, Displacement, Velocity, and Horizontal Stress in Clay and in Sand for Pile Driveability Analysis, *Ground Engineering*, January.

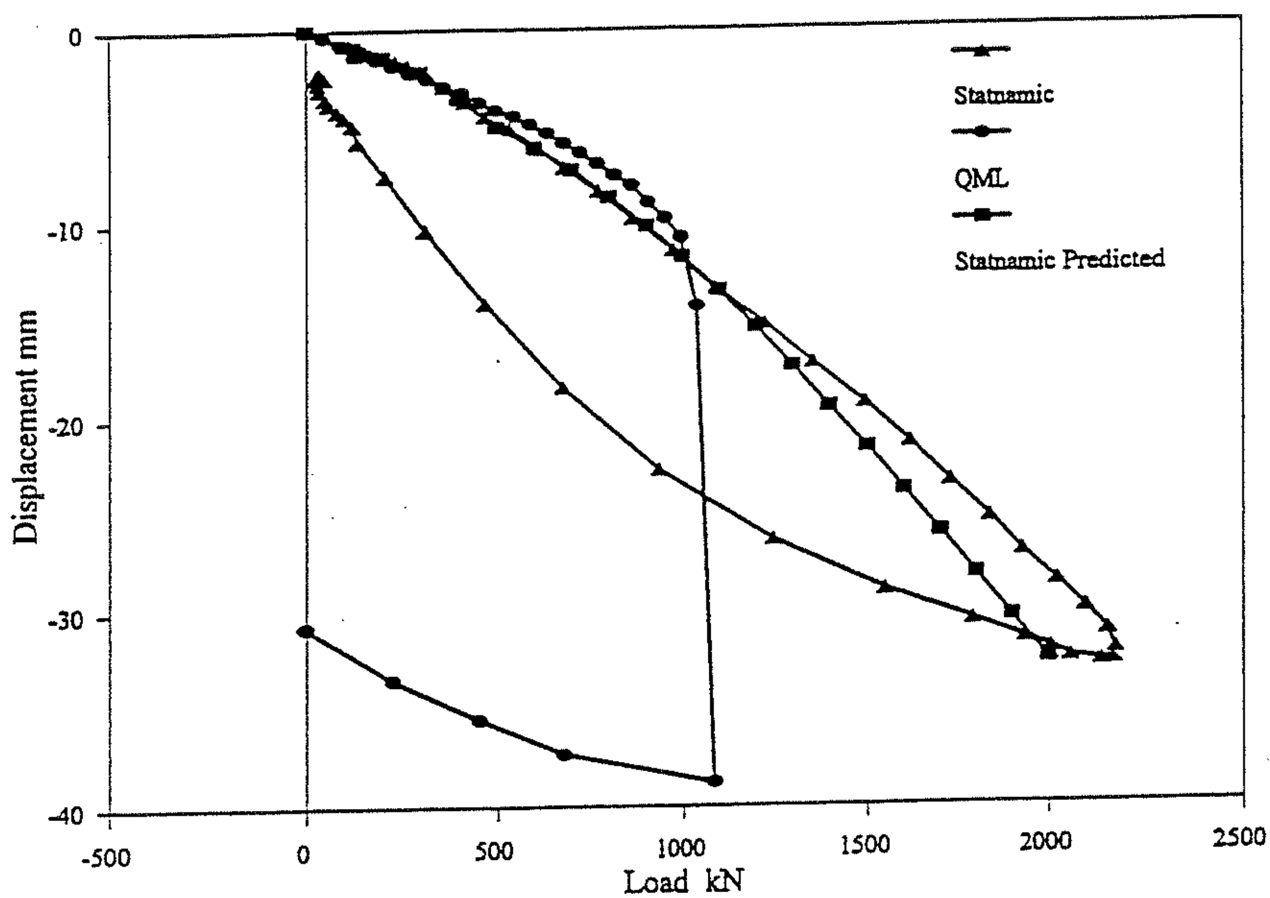
Janes, M., Sy, A. and Campanella, R., 1994, "A Comparison of Statnamic and Static Load Tests on Steel Pipe Piles in the Fraser Delta," *Proceedings*, Eighth Annual Symposium on Deep Foundations, Vancouver Geotechnical Society, Vancouver, British Columbia.

Janes, M., 1995, "Statnamic Load Testing of Bridge Pier Foundations in North America," *Proceedings*, Thirty-First Symposium on Engineering Geology and Geotechnical Engineering, Utah State University, Logan, Utah.

Litkouhi, S. and Poskitt, T.J., 1980, "Damping Constants for Pile Driveability Calculations," Geotechnique 30(1).

Middendorp, P., Bermingham, P. and Kuiper, B., 1992, "Statnamic Load Testing of Foundation Piles," *Proceedings*, Fourth International Conference on the Application of Stress-Wave Theory to Piles, Balkema, The Hague, The Netherlands.

REFERENCE: Goble, G. G., Rausche, F., and Likins, G., "Discussion on 'Evaluation of Static Capacity of Deep Foundations from Statnamic Testing' by Dan Brown," Geotechnical Testing Journal, GTJODJ, Vol. 18, No. 4, December 1995.




**STATNAMIC AND STATIC TEST RESULTS FOR FRASER RIVER PILE 5 (JANES 1994)**

# 1995
# PDA USERS DAY

# CLEVELAND, OH
**(Sept. 15, 1995)**