Study on new test technology of pile foundation bearing capacity

Zhang Xue-feng

1Research Institute Of Highway Ministry Of Transport, 100088, Beijing, China
28144484@qq.com

Abstract. A revolutionizing pile foundation testing technology, STATNAMIC has been analysis in the paper. This method is the testing method of bearing capacity for the pile foundation that has the advantages such as economical, speedy, accurate and reliable etc. By burning solid fuel in a combustion chamber, a controlled and pre-determined load is applied directly to the pile foundation without introducing high tension forces. The duration of loading is substantially longer than both the impulse produced by dynamic testing and the natural frequency of pile foundation. Moreover, owing to test without anchor pile, thus it would be able to save cost of manufacturing the anchor pile and the constructing period. And, finally it is not limited to the type of pile, the pile gradient and the surroundings of pile.

1. Introduction

STATNAMIC test pile method is an international advanced pile load test method, 1989 was successfully developed by Berming Hammer and the Institute of Construction and Research (TNO) of the Royal Academy of Sciences in the Netherlands [1], [2]. Through a special device to change the impact of the dynamic test for the gentle continuous thrust, then it can be achieved through a smaller weight to a higher load level and obtain a decomposable load test curve, and finally through the analytical treatment to obtain static load curve. STATNAMIC test pile method not only applied enough pressure, but also for a certain period of time to achieve the effect of static [3], [4]. STATNAMIC test pile method is simple, relative cost lower than the static load, more importantly, the method itself is reliable and accurate, and it has been in the Netherlands, Canada, the United States, Germany, Japan, Korea and Singapore and other countries recognized and applied.

2. Methods

The pile foundation static load test method and the STATNAMIC method have their own characteristics, and their own test methods and data analysis systems have been formed. However, there are still some controversies about the scope of application of the test. Therefore, the application scope of the STATNAMIC method should be studied to clarify the applicable conditions of the STATNAMIC method.

The research on the scope of application of the STATNAMIC method is based on the collection of the existing STATNAMIC method test and theoretical analysis data, from the test principles, test data collection methods, test results reliability, and test methods. The application scope of the STATNAMIC method is studied in the aspects of economy, the destructiveness of the test process to the pile, and the dependence of the test method on external conditions.

3. STATNAMIC test mechanism

The STATNAMIC method absorbs the advantages of the dynamic test method, and simulates the static force, can measure the bearing capacity separately [5], [6]. The STATNAMIC method uses the most accurate instrumental observation system: the load is measured by a calibrated pressure ring, and the displacement is observed with a laser sensor (see Figure 1). The acceleration is measured directly.
with a built-in speed meter. The force signal and displacement signal are collected by the TNO Profound Foundation Pile Diagnostic System (FPDS) pile diagnosis system (see Figure 2), and the dynamic damping caused by the movement of the pile is deduced by the finite element method [7]. Curve, and thus get the same results with the static pressure.

STATNAMIC method The test technique connects the piston with the pressure chamber to the pile head. A back pressure block connected to the cylinder is placed on the piston [8]. The solid fuel propellant ignites in the piston, producing a high pressure gas and accelerating the back pressure block. An equal reaction force gently pushes the pile into the soil. The force applied to the top of the pile and the displacement of the pile top can be accurately measured using a load cell and a laser sensor [9, [10]. The data is collected by the FPDS device and the result is an image-force-displacement curve. The mobilized capacity and static load displacement status can be displayed immediately in the field.

The continuous phase of the Statnamic loading test is shown in Figure 3, in the figure:

a) The pre-launch phase;
b) The fuel is ignited and the combustion of the fuel produces a high pressure and accelerates the back pressure block. At this stage, the actual pile loading occurs, the reaction force pushes the pile into the earth;
c) When the fuel explodes the high pressure to hold the counteracture moment instantly, due to gravity, the surrounding loose grit quickly falls into the bottom of the press tray, forming a thick cushion layer on the pile top;
d) When the back pressure block down, the gravel to block it, the impact of gravel cushion cushioning energy consumption after the transfer to the pile around the test pile in the soil, the role of the pile at the force of only 1%. The size and loading time of the loading during the test can be controlled by the capacity of the combustion chamber and the piston, cylinder shape, the amount of fuel, and the weight of the back pressure block.
In the static and dynamic state, the force distribution and displacement distribution of each particle in the pile are all the same as static, and the individual points of the pile are sinking at a certain speed, that is, the pile is sagged as a whole. At this time the force of the pile is consistent with the following equation:

\[ F_{stn} = F_u + F_a \]  \hspace{1cm} (1)

Where:
- \( F_{stn} \) — static and dynamic;
- \( F_u \) — Static soil resistance, U is a function of displacement;
- \( F_a \) — an inertial force, a function of the acceleration.

In the static and dynamic measurement, the static and dynamic load with the sensor placed in the pile head records, displacement U laser sensor with a record, acceleration a with the accelerometer records, all by the computer automatic control, ignition combustion is completed, a complete PS curve will draw. The measured results are shown in Figure 4. The entire installation of the test process 2 to 3 hours to complete, the efficiency of the static load test more than 10 times.

4. Analysis of the applicable scope of STATNAMIC method
Through the analysis of the principle and device of static and dynamic load test (STATNAMIC), this paper summarizes the application of this method as follows:

1. The dynamic and static load test (STATNAMIC) method can test the pile foundation in land and water environment, as shown in Figure 5 and Figure 6.

![Figure 5. Terrestrial Environment Loading Test Photo](image1)

![Figure 6. Deepwater Environment Loading Test Photo](image2)

2. STATNAMIC method test technology can be used in any loading direction. Statnamic has been successfully used for ramps and horizontal loading tests, as shown in Figures 7 and 8.

![Figure 7. Horizontal Loading Test Photo](image3)

![Figure 8. Slope Pile Loading Test Photo](image4)

3. At present, the tonnage of the static test method has reached 70MN. Both the steel pile, the concrete pile and the stakes, the static resistance and the dynamic resistance and the single pile and the group pile of less than 70MN can be tested with STAT-NAMIC To determine its vertical bearing capacity.

5. Result

STATNAMIC method has the following characteristics:

1. load and displacement by the electronic load meter and laser level direct measurement;
2. rapid test, real-time access to load – sedimentation curve;
(3) do not need to use anchor pile, can save a lot of anchor pile production costs and duration;
(4) is not eccentric and can cause sufficient displacement of the pile;
(5) is not limited by pile type, pile inclination and pile surrounding environment. It is especially
suitable for measuring pile type of inclined pile and water working.
(6) can be carried out at the bottom of the excavation test pile.

6. Conclusion
Through the above research and analysis, we can draw the following conclusions:
(1) The STATNAMIC method is a new method that combines static and dynamic, retaining
advantages and overcoming shortcomings. Compared with the dynamic measurement method, it
prolongs the loading time, reduces the influence of stress wave propagation, and makes the analysis
method intuitive and easy. Understand, the bearing capacity can be measured quickly and accurately;
(2) STATNAMIC method still belongs to the category of dynamic measurement method;
(3) The STATNAMIC method does not require anchor piles, is convenient and fast, greatly saves
engineering costs and shortens the construction period;
(4) The STATNAMIC method solves the shortcomings of eccentricity and damage to the foundation
pile caused by the heavy hammer by the high strain variation test method for large diameter bored
piles, and the test principle is close to the static load test, and the final test result can be converted into
the static load test result;
(5) The P-S curve obtained by the STATNAMIC method is completely measured, and various
calculation basis are also obtained from the actual measurement, which overcomes the artificial
arbitrariness and obtains reliable and objective results;

7. References
[1] KOVALENKO, Y., BOLOBAN, V., GONCHARENKO, I., BORYSOVA, O., MATVIEIEV, S.,
& MARYNYCH, I. K. V. (2020). Biomechanical assessment of statnamic stability of rhythmic
gymnasts of the stage of specialized basic training. Journal of Physical Education & Sport, 20.
[2] Abbas, H. A., & Yasir, S. F. (2018). Comparative study of linear and non-linear analysis of
Statnamic loading test for different pile lengths. doi:10.1063/1.5062639.
[3] Chew, S., Chuah, L., Tan, H., & Eng, Z. (2019, July). A Comparison Study for Static and
Statnamic Load Tests on Two Instrumented Piles in Southeast Asia. In 10th International
Conference on Stress Wave Theory and Testing Methods for Deep Foundations. ASTM
International.
[4] Haque, M. N., Abu-Farsakh, M. Y., & Nickel, C. (2018). Evaluation of Design Parameters (α and
β) for Open-Ended Instrumented Test Pile. IFCEE 2018. doi:10.1061/9780784481578.012
[5] AFT (2017). Final Report of Axial STATNAMIC Load Testing – Production Shaft
P7-2 at South River Valley (SRV), Edmonton Valley Line LRT Stage 1; August 25, 2017.
Advanced Foundation Testing, Green Cove Springs, Florida
[6] Wang, X., Tweedie, R., and Law, D. (2017). Edmonton ICE District Towers Geotechnical
Investigation and Foundation Design, GeoOttawa 2017, Canadian Geotechnical Society,
8p.
[7] Abu-Farsakh, M. Y., Haque, M. N., & Tsai, C. (2017). A full-scale field study for performance
evaluation of axially loaded large-diameter cylinder piles with pipe piles and PSC piles. Acta
Geotechnica, 12(4), 753-772.
[8] Rybak, J. (2017, October). Some remarks on foundation pile testing procedures. In IOP
Conference Series: Materials Science and Engineering (Vol. 245, No. 2, p. 022092). IOP
Publishing.
[9] Shahbazi, M., Cerato, A. B., Allred, S., El Naggar, M. H., & Elgamal, A. (2020). Damping
characteristics of full-scale grouped helical piles in dense sands subjected to small and large
shaking events. Canadian Geotechnical Journal, 57(6), 801-814.
[10] M. F. Alwalan, M. H. El Naggar. (2020). Finite element analysis of helical piles subjected to axial
impact loading. Computers and Geotechnics, Volume 123, July 2020, 103597.

Acknowledgments
This study was funded by Young Elite Scientists Sponsorship Program by China Association for Science and Technology. The authors thank the anonymous reviewers and the Editor for their constructive comments and advice, which greatly improved the quality of this paper.