Title : Statnamic Load Testing Method As A Substitute For the Conventional Static Load Tests

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SYNOPSIS*: Since its first test in Malaysia in 1994, Statnamic has been gaining grounds locally as a substitute or alternative method for the conventional maintain load test. A decade has passed now and over 500 tests have been performed already to date. It is a practice for most engineers to conduct load test as a quality control measure. Often, where time and space constraint are obstacles, alternative testing methods is required. Statnamic and Dynamic tests are alternatives to conventional Static test. Both of these methods have their advantages which can suit certain projects. Thus, engineers always have options when the needs for load testing their piles arise.*

1.0.0 INTRODUCTION

The construction of the new concrete bridge across Sungai Kurau at Kuala Kurau connecting Federal Route 75 (FT075) to Perak State Route 100 (A100) in the District of Kerian, Perak Darul Ridzuan is an example where the engineers have opted to substitute some of the conventional Static tests with Statnamic tests. This project involves the construction of a new dual two-lane 2 where the total length is 1252m long and consists of a main bridge that has a balanced cantilever box girder with spans of 82 + 140 + 82 m; two approach spans of 5 spans of 44.8m. The bridge is founded on prestressed concrete spun piles totaling 870 nos. with sizes from 700mm, 800mm and 1000mm in diameter. The construction of this bridge involves installing piles over water and to carry out conventional static test on the piles installed is obviously a big hassle and time consuming. Thus, substituting the static test with Statnamic test was a bold solution to save cost and time. However, prior to substituting the Static test, correlation tests were carried out on three piles and in this paper, we will be presenting the correlation results.

1.0.1 STATIC LOAD TEST

The static load testing of pile deals with the testing of pile by the controlled application of an axial load. The setting up of pile testing equipment normally carried out under competent supervision and the equipment checked to ensure that the setting-up is satisfactory before the commencement of load application.

The equipment used for applying load consists of a hydraulic ram or jack. The jack arranged in conjunction with the reaction system to deliver an axial load to the test pile. A calibrated pressure gauge indicating the load is included in hydraulic system and reading of the pressure gauge is recorded. In a maintained load test, movement of the pile head is measured by reference beam and gauges. The loading and unloading is carried out in stages.

The usual basic information from such a test is the load settlement relationship, from which the load capacity and pile head stiffness can be interpreted.

1.0.2 STATNAMIC LOAD TEST

Statnamic load testing was perceived in 1987, and developed into an alternative method for pile load test in 1988 by Patrick D. Berminghammer. As in 2004, Statnamic Load Test method has been used in several countries, including Canada, USA, The Netherlands, Malaysia, Japan, United Kingdom, Australia, Argentina, Taiwan and Korea.

The main principle of Statnamic load testing is based on launching reaction masses from a pile top by releasing high pressure gases from a cylinder. The reaction force required to launch the reaction masses upward acts equally downward on the pile, and drives the pile into the ground. The high pressure gasses are produced by the burning solid fuel within the cylinder assembly. Using Newton's second law of acceleration, the reaction masses are accelerated upward at 20g where a force acts downwards onto the pile will be 20 times the reaction masses weight. Thus, only 5% of the required test load is required for the reaction masses assembly. Loading of the pile is monitored using a calibrated load cell and displacement is monitored using a photo voltaic cell laser sensor. All the data recorded are digitised and stored in a portable computer connected to the assembly as shown in Fig. 1.

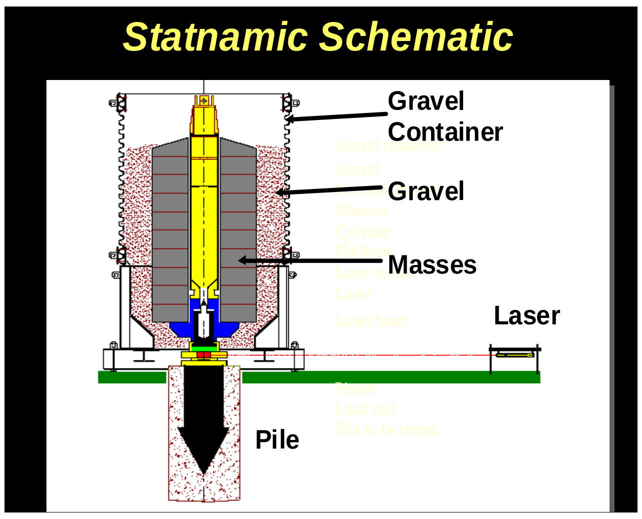

Figure 1 : Statnamic Schematic

The duration of a Statnamic load testing is in the order of 120 to 150 millisecond. This produces a dynamic load on the pile top which is enough to allow the pile react as a rigid body without the influence of stress wave propagation within the pile. The soil is in turn loaded with minimum inertial effects and damping. However, in highly viscoelastic soils, some rate effects are inevitable and influence the interpretation of the test response.

1.1.0 INTERPRETATION OF STATNAMIC RESULTS

In Fig. 2 a pile shown to be modelled as a rigid body where acceleration, velocity and displacement dependent forces are acting. Static soil resistance is represented as displacement dependent forces. Soil damping is represented by velocity dependent forces while inertia forces acting on the pile mass is represented by acceleration dependent forces.

Physical Model

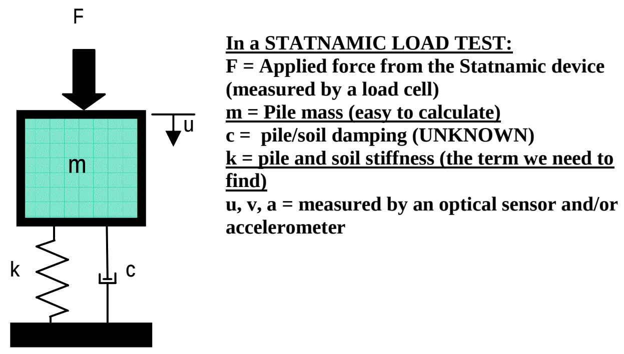

Figure 2 : Physical Model For Statnamic Interpretation

The response of a pile to a Statnamic loading can be mathematically described by the following equation:

$$F^{stn}(t) = F^{u}(t) + F^{v}(t) + F^{a}(t) \qquad (1)$$

where $F^{stn}(t)$ is the Statnamic applied load, $F^{u}(t)$ is the term accounting for the static soil resistance, $F^{v}(t)$ is the term accounting for the effect of damping, and $F^{a}(t)$ accounting for the effect of inertia during the loading/unloading stage.

The three components can be represented by

$$\begin{aligned} F^{u}(t) &= K\,u(t) \\ Fv(t) &= C\,v(t) \\ Fa(t) &= M\,a(t) \end{aligned} \qquad (2)$$

where u(t) is the pile top displacement and v(t) is the velocity at the pile top, a(t) is the acceleration at the pile top, M is the mass of pile, K is the total spring stiffness, and C is the damping component of the pile-soil system.

Substituting Eq.(2) into Eq.(1) yields

$$F^{stn}(t) = K\,u(t) + C\,v(t) + M\,a(t) \qquad (3)$$

Alternatively, Eq.(3) can be written as

$$F^{stn}(t) = F^{soil}(t) + M\,a(t) \qquad (4)$$

where $$F^{soil}(t) = K\,u(t) + C\,v(t) \qquad (5)$$

In a pile load test, u(t), v(t) and a(t) are measured together with $F^{stn}(t)$ at any time t. The mass M of the pile can easily be calculated. The value of K and C are to be determined, and thus the components of $F^{u}(t)$ and $F^{v}(t)$ can then be obtained.

2.0.0 Project Description

Static Load Tests and Stanamic Load Tests were performed for the at the construction of a new concrete bridge across Sg. Kurau at Kuala Kurau connecting Federal Route 75 (FT075) to Perak

State Route 100 (A100), in the District of Kerian, Perak Darul Ridzuan. It involves the construction of a new dual two-lane bridge with two stages of construction. Phase 1 - The Works is for the construction of a two-lane bridge and substructure for dual two-lane bridges. Phase 2 - The Works is for the construction of the second two-lane bridge later.

2.0.1 Description of the piles installed

Pre stressed concrete spun piles were used to construct the foundation of this bridge. The sizes and numbers of piles used are listed in the Table 1.

Table 1 : Summary Of Installed Piles

Pile Type	Diameter	Quantity	Average Length Piled	Location
Pre-cast Concrete Spun Pile	700 mm	429	45-60 m	Approach Bridge
Pre-cast Concrete Spun Pile	800 mm	269	45 m	Elevated Structure
Pre-cast Concrete Spun Pile	1000 mm	172	75 m	Main Bridge

2.0.2 Description of the soil strata

The supporting soil strata are generally very soft dark gray marine silty CLAY with an underlying sand layer. At the river banks this underlying sand layer is profound at a depth from 40m below datum. Within the river channel however, there are deposits of sand intermittent with the clay layer to a depth of 70 m below datum. The sub-surface profile is given in Figure 3.

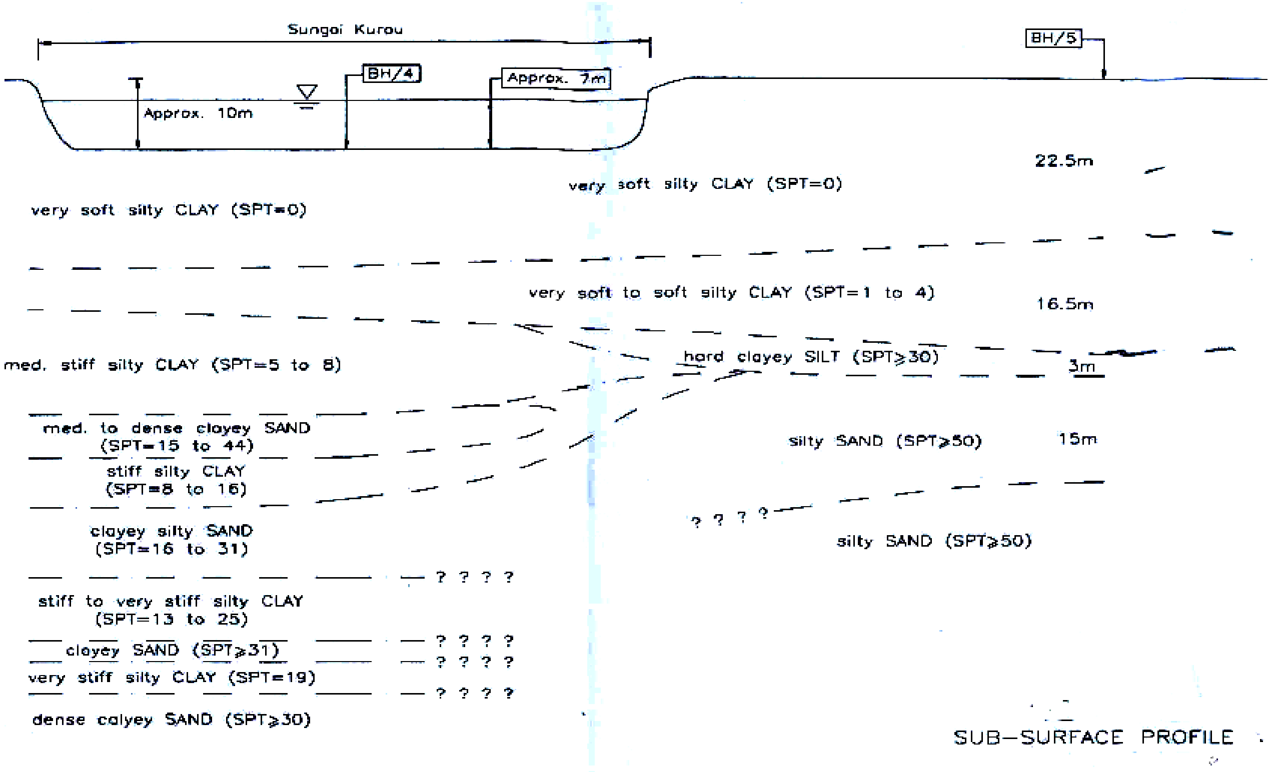

Figure 3: Sub-surface profile at Sungai Kuala Kurau Bridge.

3.0.0 Load Testing Program

Two types of testing methods were used in this project, the conventional maintained load test and Statnamic Load Test.

3.0.1 Static Load Tests Results

The conventional maintained load test was performed on the 3 different pile sizes, 700 mm diameter, 800 mm diameter and 1000 mm diameter. A summary of the piles' details is presented in Table 2 and the load settlement curves are presented in Diagram 1, 2 and 3.

Table 2. Summary of Static Load Test

Location	Pile Diameter (mm)	Design Load (kN)	Date Tested	Test Results
Pier 2-25	700	1300	16/12/2002	Max. Settlement @ 2WL = 10.2 mm Residual Settlement = 0.9 mm
Pier 6-32	1000	3400	25/8/2003	Max. Settlement @ 2WL = 15.3 mm Residual Settlement = 1.2 mm
Pier 12-27	700	1300	15/8/2002	Max. Settlement @ 2WL = 8.7 mm Residual Settlement = 0.9 mm

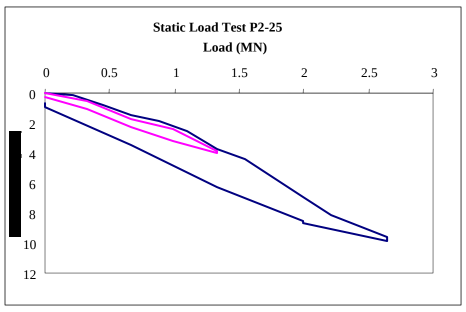

Diagram 1 : Load Settlement Diagram For Pile No. P2-25 For 1st and 2nd Cycle Static Test

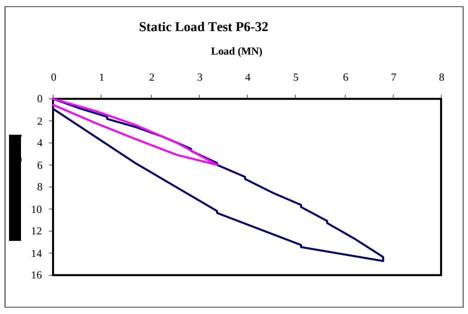

Diagram 2 : Load Settlement Diagram For Pile No. P6-32 For 1st and 2nd Cycle Static Test

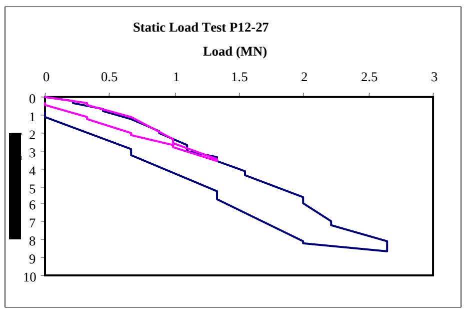

Diagram 3 : Load Settlement Diagram For Pile No. P12-27 For 1st and 2nd Cycle Static Test

3.0.2 Statnamic Load Tests Results

A total of 6 numbers of Statnamic load tests were performed in this project. The results of the tests were analyzed using Unloading Point Method developed by TNO of The Netherlands. Details of the piles and tests results are summarized and presented in the Table 3 and Diagram 4, 5, 6, 7, 8 and 9

Table 3. Summary of Statnamic Load Test

Location	Pile Diameter (mm)	Design Load (kN)	Date Tested	Test Results
Pier 2-25	700	1300	26/12/2002	Max. Static Resist. = 3030 kN Max. Settlement = 13.6 mm Residual Settlement = 0.15 mm
Pier 6-32	1000	3400	4/8/2003	Max. Static Resist. = 7320 kN Max. Settlement = 20.6 mm Residual Settlement = 1.16 mm
Pier 7-22	1000	3400	8/12/2003	Max. Static Resist. = 6830 kN Max. Settlement = 14.6 mm Residual Settlement = 1.59 mm
Pier 8-25	1000	3400	17/11/2003	Max. Static Resist. = 6840 kN Max. Settlement = 19.8 mm Residual Settlement = 3.23 mm
Pier 9-25	700	1300	14/11/2003	Max. Static Resist. = 2920 kN Max. Settlement = 9.0 mm Residual Settlement = 0.11 mm
Pier 12-27	700	1300	22/1/2003	Max. Static Resist. = 2670 kN Max. Settlement = 12.4 mm Residual Settlement = 2.91 mm

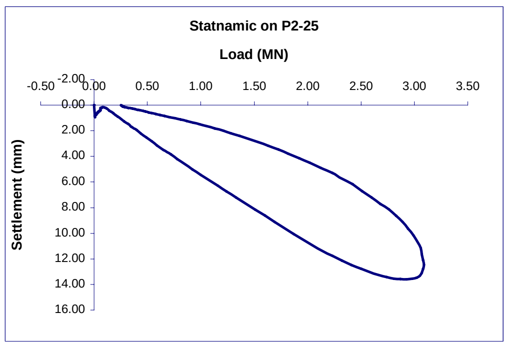

Diagram 4 : Load Settlement Diagram For Pile No. P2-25 For Statnamic Test

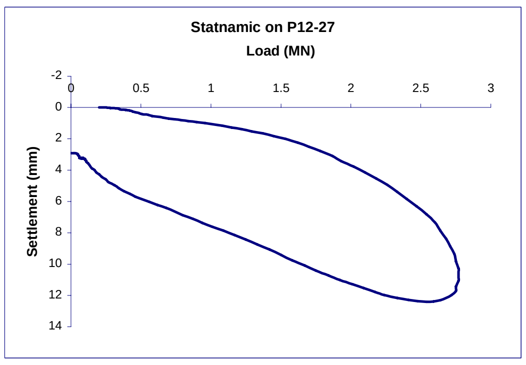

Diagram 5 : Load Settlement Diagram For Pile No. P12-27 For Statnamic Test

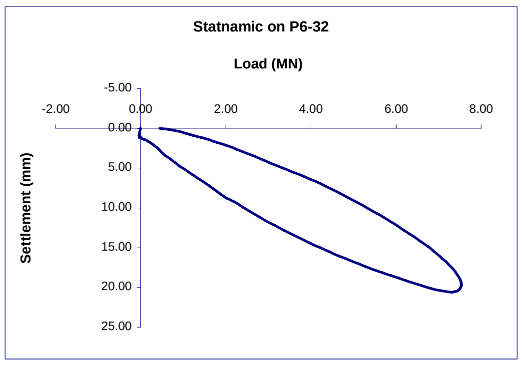

Diagram 6 : Load Settlement Diagram For Pile No. P6-32 For Statnamic Test

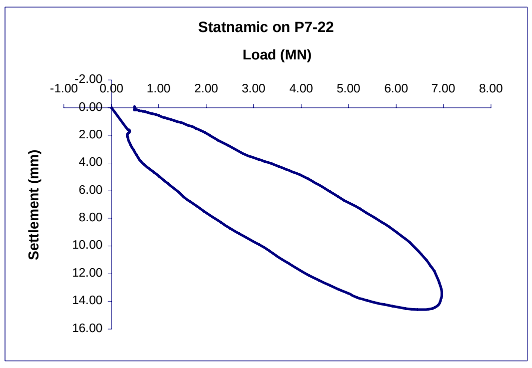

Diagram 7 : Load Settlement Diagram For Pile No. P7-22 For Statnamic Test

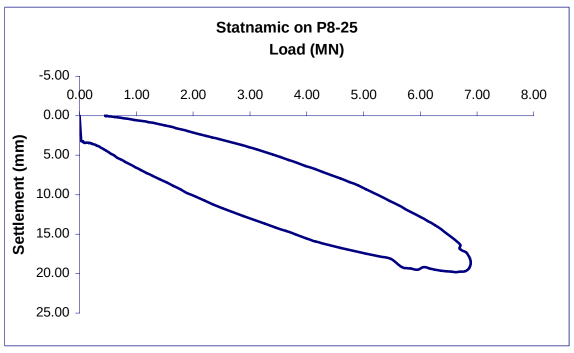

Diagram 8 : Load Settlement Diagram For Pile No. P8-25 For Statnamic Test

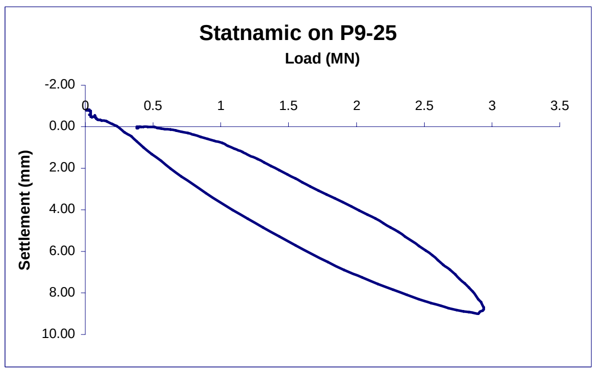

Diagram 9 : Load Settlement Diagram For Pile No. P9-25 For Statnamic Test

3.0.3 Comparison of Static and Stanamic Load Tests results

The comparison here is on the three piles where both Static test and Statnamic test were performed on them. The piles are P2-25, P6-32 and P12-27 respectively. In our case we are comparing the settlement recorded and prediction of ultimate load. The comparison of settlement recorded are shown in Diagram 10, 11 and 12.

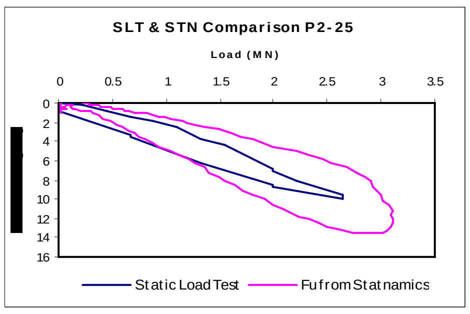

Diagram 10 : Comparison Of Static And Statnamic Test For Pile No. P2-25

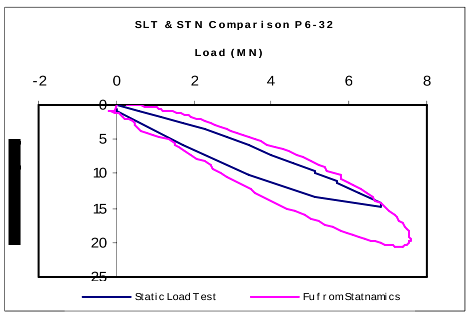

Diagram 11 : Comparison Of Static And Statnamic Test For Pile No. P6-32

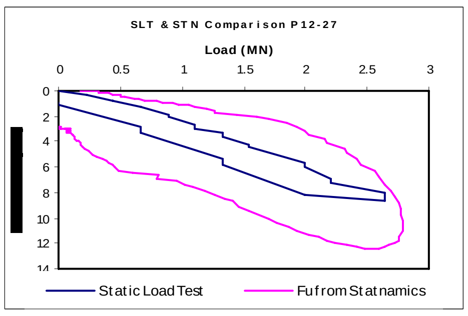

Diagram 12 : Comparison Of Static And Statnamic Test For Pile No. P12-27

We can observe that higher settlements were recorded from all the Statnamic tests when compared to the settlements recorded from the Static tests. During the Static tests, we also observed significant increase of settlement for each increment of load. This may indicate that for marine clay which has an under lying of sand has poor response to instantaneous loading.

Our ultimate load prediction is based on Chin Kondner Method. Results of the prediction are shown in Table 4.

Table 4 : Ultimate Load Prediction

Location	Static Test	Statnamic Test
Pier 2-25	3681 kN	3896 kN
Pier 6-32	8950 kN	8902 kN
Pier 12-27	3079 kN	3082 kN

The predicted ultimate load from the Static test and Statnamic test for pile no. P2-25, P6-32 and P12-27 were reasonably close. From the load settlement diagram, we can observe that all the three piles have quite similar load settlement behavior between Statnamic test and Static test, thus contributing to the favorable comparison.

4.0.0 Conclusion

In the construction of the new concrete bridge across Sungai Kurau at Kuala Kurau connecting Federal Route 75 (FT075) to Perak State Route 100 (A100) in the District of Kerian, Perak Darul Ridzuan, Statnamic test performed satisfactorily when compared to the Static test. The piles' capacity derived from the Unloading Point Method developed by TNO can be used to determine the static capacity of piles. Settlements were recorded from the Statnamic tests were higher when compared to the settlements recorded from the Static tests. Correlation of the ultimate load prediction using data from both Statnamic and Static test were reasonably close.

References

M. Janes, A. Sy & R. G. Campanella 1995. A Comparison Of Statnamic And Static Pile Load Tests On Steel Pipe Piles In The Fraser Delta. Proceedings First International Statnamic Seminar, Vancouver, B. C., Canada.

Y. K. Chow, S. H. Chew, W. M. Chow, L. S. Chuah 1998. Case Histories of Statnamic Pile Load Tests. 13th Southeast Asian Geotechnical Conference, Taipei, Taiwan, R.O.C..