Comparison of Dynamic and Static Pile Testing, a Case Study

Comparaison des tests dynamique et statique sur des piliers. Une étude de cas

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ABSTRACT

Pile capacities can be estimated basically with two different kind of load test: dynamic and static load test. The comparison between these test results is often impossible to do, because usually only one method is used per site. This paper presents a case study where both methods were used and results compared. The test results showed that the dynamic test with or without CAPWAP analysis correlated very well with static load test results. Test results proved that it is possible to use end bearing small diameter steel pipe piles in the area and dynamic pile load test is cost efficient compared to the static load test.

RÉSUMÉ

Dans la pratique, il existe deux tests de charge différents pour estimer la capacité des piliers: le test dynamique et le test statique. La comparaison des résultats de ces deux types de tests s'avère souvent impossible du fait que, normalement, seul l'un ou l'autre est pratiqué sur un site donné. Cet article présente une étude de cas où les deux méthodes ont été utilisées, et leurs résultats comparés. Les résultats font apparaître que le test dynamique, avec ou sans analyse CAPWAP, correspond parfaitement aux résultats de tests de charge statiques. Les résultats montrent qu'il est possible d'utiliser des piliers de tube d'acier de faible diamètre supportant les extrêmités, et que le rapport coût-efficacité du test dynamique de charge de pilier est supérieurs à celui du test de charge statique.

Keywords : Piles, dynamic load test, static load test

1 INTRODUCTION

The most common foundation type in the area of Pärnu in Estonia is to use cast-in-place concrete piles carrying the load with shaft. The quality and capacity of the piles are usually tested with static load test.

In this case the original design for the new Rannila factory building was to use D=450 mm cast-in-place concrete piles. Rannila is part of the Ruukki which manufactures also steel pipe piles and Ruukki decided to use small diameter steel pipe piles instead of cast-in-place concrete piles. The capacity of the test piles were tested with dynamic load test by Tampere University of Technology.

The dynamic testing is not a commonly used practise to test the load bearing capacity of piles in Estonia, and as a result static load tests were also performed to same test piles which were at first tested dynamically. The test was performed by Estonian company REI Geotehnika OÜ.

2 SOIL CONDITIONS

The soil conditions at the test pile location consist of 4-5 m of granular fill/sand followed by approximately 18 m thick clay layer. At approximately 22 m depth the soil type changes to stiff silty till and finally at depth 23-24 m starts a very dense sandy till layer. The soil conditions close to the test piles are shown in figure 1.

In the original design maximum load for the cast-in-place concrete piles were 800 kN and the estimated pile length was about 21 to 22 m and the piles were designed to work as friction piles. In the changed design the cast-in-place concrete piles had been replaced with RR170/10 steel pipe piles (diameter of the pile D=168,3 mm and wall thickness t=10 mm, steel grade S440J2H) with same design load and the estimated pile length was about 23 to 24 m and the piles were working as end bearing piles (pile toe in very dense sandy till).

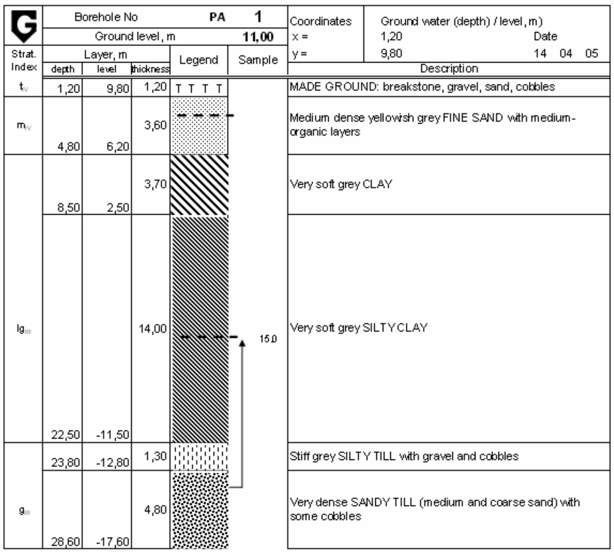

Figure 1. Soil layers close to the test piles.

3 PILE DRIVING

The pile driving were made by using Junttan HHK-5A (weight of the ram 5 ton, which is accelerated hydraulically during the drop) hydraulic hammer mounted to the Liebherr RH piling rig.

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Penetration through the 4-5 m thick granular fill/sand layer was quite easy and the number of blows per one meter penetration was between 20-50 by using 0,20 m stroke. After that, both piles penetrated to 20 m depth nearly by the weight of the hammer and only few blows were needed for the installation. Between 20-21 m and 21-22 m the number of blows per one meter penetration were approximately 50 and 100 by using 0,20 m stroke. This soil layer (at depth 21-23 m) represents probably loose silty till. The required blow count between 22-23 m increased to over 200 blows per meter by using 0,2 m stroke and finally at approximately at 24 m depth the driving resistance was 10 mm per 10 blows by using 0,40 m stroke.

4 DYNAMIC LOAD TESTS

At the site two piles were tested dynamically at the end of the driving. Dynamic measurements were taken with 2 accelerometers and 2 strain transducers attached to the pile. Analog signals from the transducers were conditioned, digitized, stored and processed with a Pile Driving Analyzer®-Model PAK. The pile capacities were estimated by using maximum Case-Goble capacity (RMX) and damping factor Jc=0,5. In the dynamic test piles were given few blows by using 1,0 m stroke in order to cause several millimeters permanent settlement and to mobilize the full toe resistance.

Test piles were restriked after one day of the installation. There seemed no significant changes in capacities of the piles after one day waiting.

The typical measured stress waves (force, velocity- and wave up, wave down-graphs) from tested piles at the end of driving are shown in figure 2 and 3.

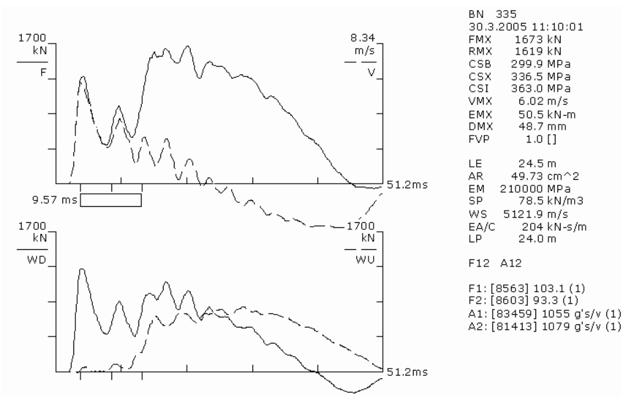

Figure 2. Measured stresswaves of the pile 1, permanent settlement 8 mm with 1,0 m blow.

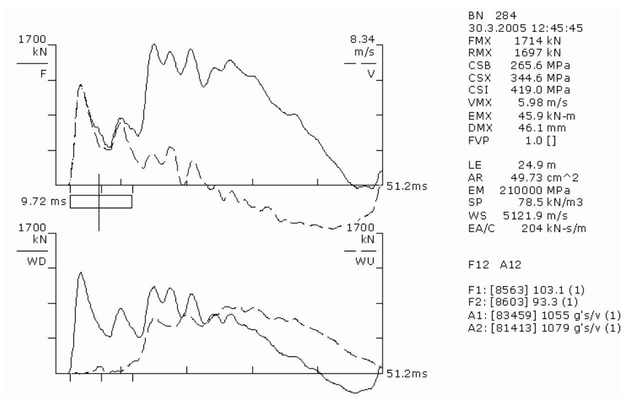

Figure 3. Measured stresswaves of the pile 2, permanent settlement 5 mm with 1,0 m blow.

In figures 2 and 3 used symbols:

FMX:	Maximum compressive force at sensors
RMX:	Maximum Case-Goble capacity (mobilized static resistance)
CSB:	Calculated stress in the pile toe
CSX:	Maximum average axial compression stress at gage (FMX/AR)
CSI:	Maximum individual compression stress for either transducer
VMX:	Maximum velocity at sensors
EMX:	Transferred energy to the pile
DMX:	Maximum displacement at sensors
FVP:	Force / velocity proportionality
LE:	Pile length below sensors
AR:	Area of the pile
EM:	Elastic modulus of the pile material
SP:	Specific weight density of the pile material
WS:	The wave speed in the pile
EA/C:	The impedance of the pile

F1234 A1234 Used sensors: F=Force=strain transducers 1-4, A=Acceleration=Accelerometers 1-2

Dynamic tests with assumed damping factor Jc 0,5 gave capacity (RMX) for testpiles 1620 kN (pile 1) and 1690 kN (pile 2).

5 CAPWAP ANALYSIS

The PDA-signals were later also matched with CAPWAP analysis to determine the correct CASE damping factor for the piles in the site. CAPWAP analysis showed that the damping factor chosen was quite reasonable for tested piles. Usually when piles are working as end bearing piles, the influence of damping factor Jc is minor to the calculated static resistances.

CAPWAP analysis gave a result of ultimate capacity Ru about 1660 kN (pile 1) and 1690 kN (pile 2). Piles are working as end bearing piles shaft resistance 10-20% of total resistance.

6 STATIC LOAD TESTS

The same piles were tested about week later with static load test. Piles were tested as required by EVS-EN1997-1 in accordance with the recommendations of the International Society for Soil Mechanics and Geotechnical Engineering. Duration of a load step was 1 hour and load step magnitude was 200 kN and the readings were taken 1, 5, 10, 15, 30, 45 and 60 minutes after applying the load, maximum load – 1900 kN. The unloading was performed by 400kN steps; each load step was maintained for 15 minutes. Load settlement graphs are shown in figures 4-5.

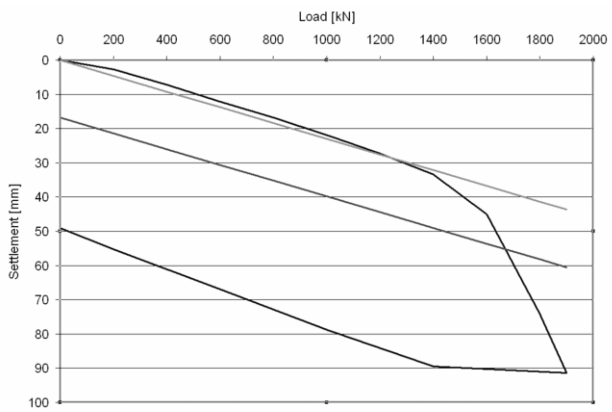

Figure 4. Measured load settlement curve of the pile 1. Green line – elastic compression of the pile, red line 0,1xD settlement and blue line load settlement curve.

According to static load tests the ultimate state limit (settlement of the pile top equal to 10% of the pile base diameter according to EN1997-1: 7.6.1.1) Rcm was 1670 kN.

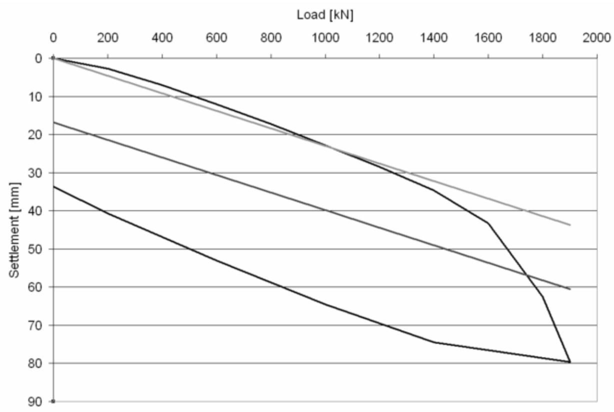

Figure 5. Measured load settlement curve of the pile 2. Green line – elastic compression of the pile, red line 0,1xD settlement and blue line load settlement curve.

According to static load tests the ultimate state limit (settlement of the pile top equal to 10% of the pile base diameter according to EN1997-1: 7.6.1.1) Rcm was 1740 kN.

7 COMPARISON OF RESULTS

The results between static and dynamic test varies only 3%, which can be a consequence of the time between tests. There were no significant changes in capacities of the piles after one day waiting in the dynamic tests, but in the week it is possible that pile will gain some shaft resistance. The capacities of piles from dynamic and static load tests are collected to the table 1.

Table 1. The capacities of the piles with different method.

Test pile number	Dynamic load test with Jc 0,5 RMX, kN	CAPWAP analysis Ru, [kN]	Static load test Rcm [kN
1	1620	1660	1670
2	1690	1690	1740

8 CONCLUSION

The test results showed that the dynamic test in this case with or without CAPWAP analysis correlated very well with static load test results. The damping factor Jc 0,5 is quite reasonable for end bearing piles to estimate the pile capacity. Dynamic load test is cost efficient compared to the static load test.

Piles were working as end bearing piles and the waiting time does not improve the capacity of the piles significantly. Test results proved that it is possible to use end bearing small diameter steel pipe piles in the area.

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