Chapter 1

Belgian national project on screw piles – Overview of the comparative load testing program

N. Huybrechts
Belgian Building Research Institute (BBRI), Brussels, Belgium

J. Maertens
Jan Maertens bvba & Catholic University of Leuven (KUL), Belgium

A. Holeyman
Catholic University of Louvain, Louvain-La-Neuve (UCL), Belgium

SUMMARY

The Belgian Building Research Institute (BBRI) organized, with the financial support of the Belgian Federal Ministry of Economical Affairs, a research project concerning ground displacement screw piles (BBRI 1998–2000 & 2000–2002). This contribution gives a general overview of the research program, and the different load test types that have been performed.

The authors express their points of view regarding the application of kinetic load test and the establishment of a guideline and/or a test standard.

1 INTRODUCTION

The "*ground displacement screw pile*" is a Belgian technology, of which the market share has increased enormously over the last years and which is still increasing. Also on an international level the interest is growing. This success can partially be explained by the ground displacement characteristics of these piles (no soil removal) and their high installation speed. On the other hand the vibration-free and the low-noise installation method play a very important role, especially in densely populated and urban areas.

In order to calibrate the semi-empirical calculation methods, which are mostly based on CPT tests in Belgium, to investigate more in detail the behaviour of this pile type, and to apply and analyse alternative (and cheaper) test methods to deduce the static pile behaviour, i.e. dynamic and kinetic load testing, the BBRI carried out a major research project addressing cast in-situ ground displacement screw piles during the period 1998–2002 (BBRI 1998–2000 & 2000–2002).

The project took place with the financial support of the Belgian Federal Ministry of Economical Affairs and was carried out in collaboration with five Belgian piling companies: De Waal Palen, Franki Geotechnics B, Fundex, Olivier and Socofonda. A National Advisory Committee under supervision of prof. A. Holeyman (UCL) and prof. J. Maertens (KUL) guided the research program.

2 GENERAL REVIEW OF THE RESEARCH

In the first stage of the project (BBRI, 1998–2000) 5 types of screw piles and driven precast piles were installed on a site in Sint-Katelijne-Waver (B) where the subsoil consists of O.C. tertiary Boom clay. Pile loading tests were executed on 30 test piles: 12 static load tests, 2 series of twelve dynamic load tests and 6 Statnamic tests. The results of this test campaign were extensively reported during the first symposium *"Screw piles – Installation and Design in Stiff Clay"*, which was held on 15 March 2001 in Brussels. The proceedings of this symposium have been published in English by Swets & Zeitlinger (Balkema), ISBN 90 5809 192 9 (editor A. Holeyman).

In the second stage (2000–2002), a test campaign of similar extent was organised on a site in Limelette (B), where the subsoil consists of quaternary silty layers (loam) and tertiary Ledian-Bruxellian sand. The results of the second test campaign were reported during a second symposium *"Screw Piles in Sand – Design and Recent Developments"* that took place on 7 May 2003. The proceedings of this 2nd symposium have as well been published in English by Swets & Zeitlinger (Balkema), ISBN 90 5809 578 9 (editors J. Maertens & N. Huybrechts).

Both volumes contain all details about the test campaign (geologic background, soil investigation program, test results, outcome of an international prediction event, …)

A typical CPT of both test sites is given in Figure 1.

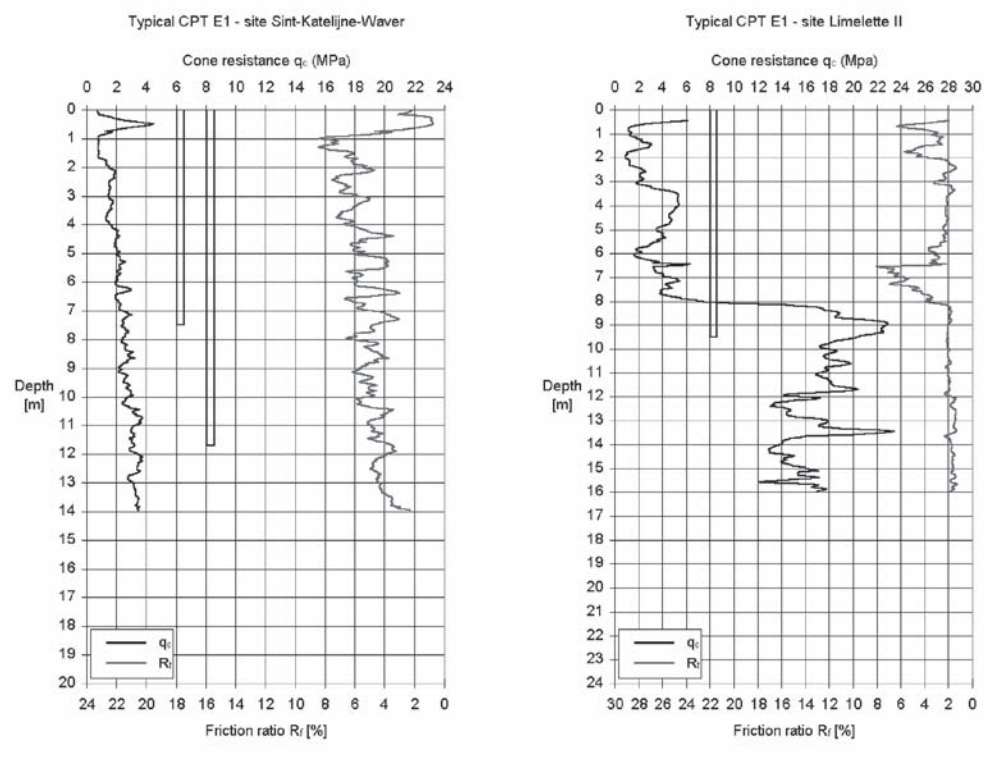

Figure 1 Typical CPT E1 on the site Sint-Katelijne-Waver (left) and Limelette (right).

3 DESCRIPTION AND RESULTS OF THE RESEARCH

On both test sites, different types of load tests were performed: static load tests (maintained load test procedure), dynamic load tests and kinetic (Statnamic) load tests.

In order to compare the results of the static load tests with the static behaviour deduced out of analysis of the dynamic and kinetic load tests, an international prediction event was organised. The details of this comparative analysis was published in contributions by Holeyman *et al.* (2001 & 2003) in the previously mentioned volumes.

Figure 2 and 3 illustrate an example of the results of that prediction event for the clay and sand site respectively.

With regard to the results of the kinetic load tests the following general conclusions were reported:

For the *clay* site, the Statnamic (STN) predictor used the Unloading Point Method (UPM) to predict the static load-settlement behaviour. It was mentioned by the predictor that, due to strain rate sensitivity of clayey soils, a 30% reduction coefficient had to be applied on the usual UPM method. A hyperbolic approximation of that reduced function was then calculated. This is the reason why those predictions are reported "0.7 STN" (see figure 2). Even with this reduction of 30% the "0.7 STN" prediction overestimated the ultimate pile capacity (defined as the load corresponding with a pile displacement of $10\%D_b$) by 25% in average, which means that the results obtained by the UPM overestimate pile capacity by ±50%.

This clayey soil seem extremely sensitive to pile rate effects. The generated pile velocity during the kinetic load tests seems the governing factor that determines the mobilised pile resistance. Applying a simple reduction factor in order to fit ultimate load, is not an acceptable approach as it would generate deviations of the load settlement curve in the initial part of the curve (working load range).

It should also be remarked that in these clay layer even different procedures applied for static load testing (duration of load steps) might significantly influence the static pile capacity deduced from these tests.

For the *"dry" sand* site (the sand was not actually dry, since it was in the vadose zone, but the sand is referred herein as dry for simplicity, while indicating it was not located below the water table) the mobilised static resistance deduced by the Statnamic (STN) predictor was in average 11% higher than the resistance mobilised during static load tests, and this for a pile head settlement of 10 mm ($2.5\%D_b$). This overestimation apparently corresponded well with the expectations of the STN predictor (influence strain rate effects).

With regard to the pile load tests campaigns at Sint-Katelijne-Waver and Limelette, it is especially the results of the static pile load tests that have been extensively exploited within the framework of the establishment of the Belgian National Annex of the Eurocode 7. Up to know the results of the kinetic load tests have not been analysed further in detail by BRRI.

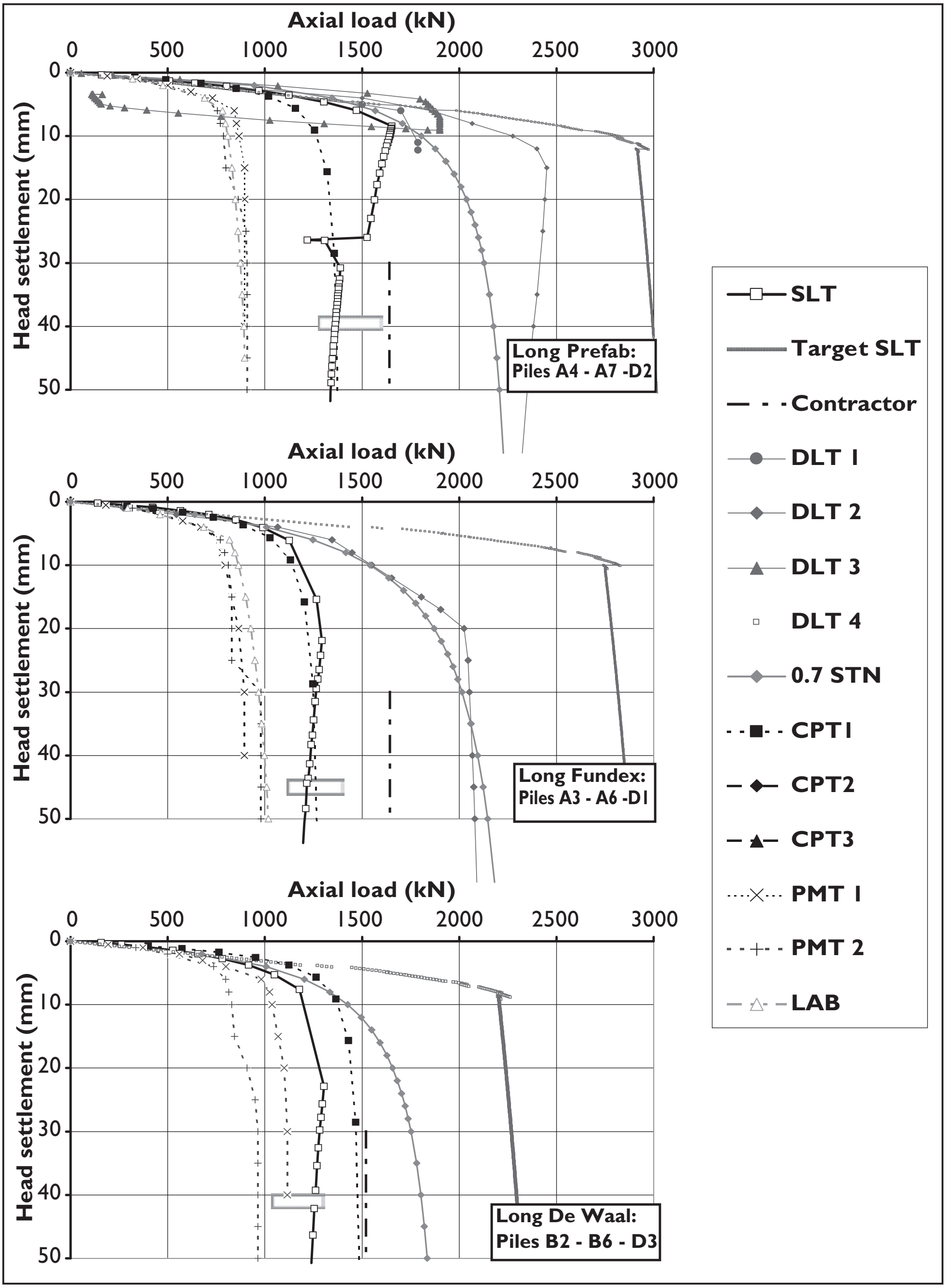

Figure 2 Examples of the result of the prediction event at the clay site (Sint-Katelijne-Waver).

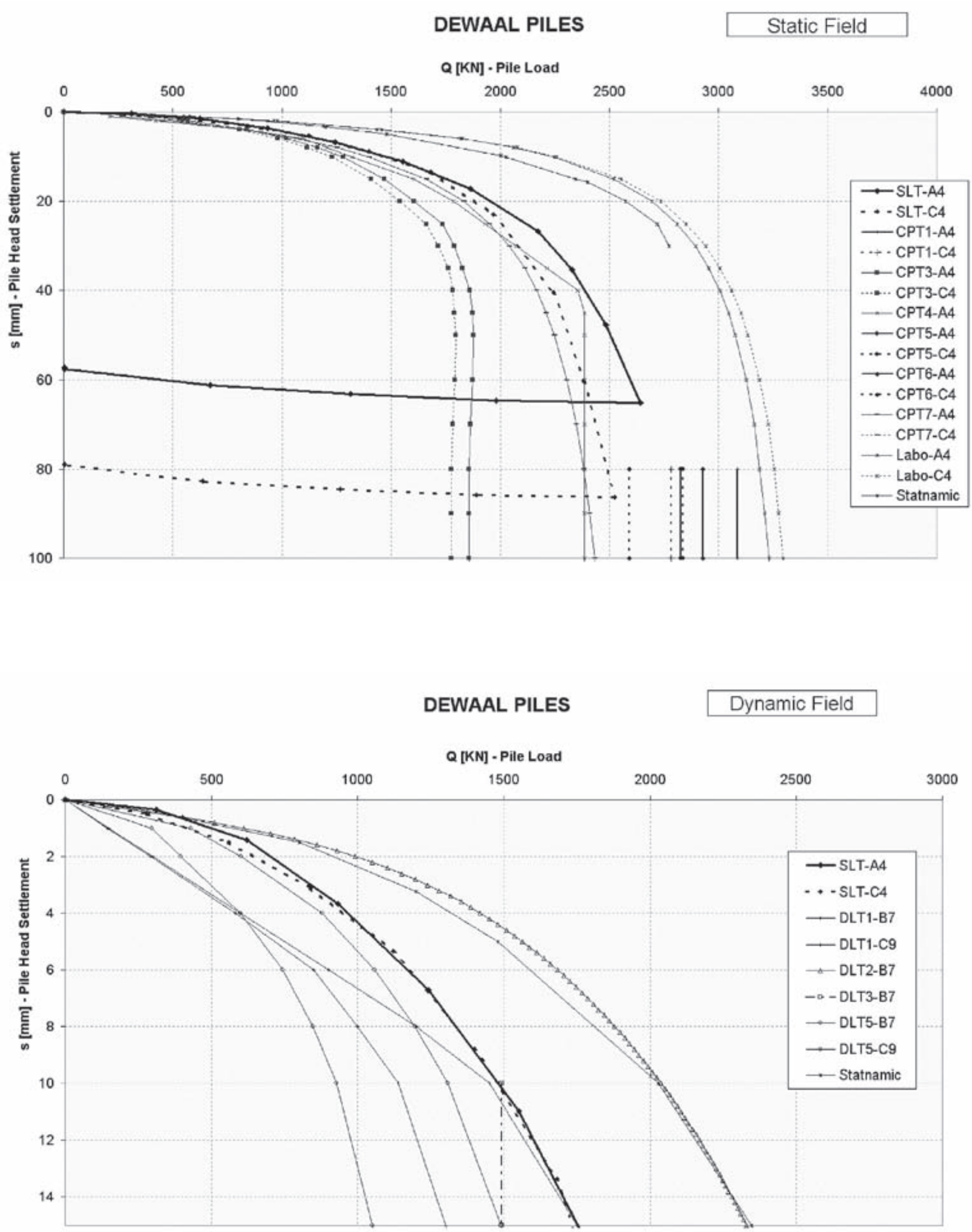

Figure 3 Example of the result of the prediction event at the sand site (Limelette).

4 CONCLUSION

Up to now, no further detailed analysis of the results of the kinetic load tests in Sint-Katelijne-Waver and Limelette have been performed. Some (non-limiting) suggestions for supplementary analysis of these tests are listed below:

- Detailed analysis of velocity-pile resistance effects (especially for the clay site)
- Comparing different types of load tests on different test piles implies that (local) site heterogeneity might have an influence. This effect might be quantified for both test sites as CPT-E have been performed in the axis of each tested pile.
- Analysis of the instrumentation of the kinetic test piles at the clay site (for the clay site the kinetic test piles were instrumented with strain gauge transducers placed just above the pile tip; although measurements were performed during the kinetic tests, no results neither analysis have been reported).

5 CONSEQUENCES OF THE RESULTS FOR THE STANDARD AND THE GUIDELINES

With regard to the application of kinetic load test and the establishment of a guideline and/or a test standard, the authors wish to put forward the following (Belgian) viewpoint and requirements:

Kinetic load tests in general

- Soil mechanics research at high strains and granular matter computational physics show that rate dependency is neither monotonous, nor reversible.
- Avoid single blow RLT: site-specific experimental derivation of displacement, velocity, and acceleration dependence of results needs to be ascertained: demonstrate stability of prediction through multiple blows tests.
- An extensive and demanding test procedure (minimum number of blows, minimum pile head displacement, …) to perform kinetic load testing on piles is necessary. The test procedures need to be standardized taking into account the aim of the test (either control, design, or research).
- The influence of the load test procedure (a.o. number of blows) needs to be studied and more widely ascertained. Especially in clayey subsoil a possible influence of the number of cycles (pore water pressures) is to be considered.
- Comparative load test procedures (static versus kinetic) have to be encouraged within a probation period. When or under which conditions would RLT become a single reliance for pile acceptance. How should we deal with different type of load tests on the same test pile (how can interference between different load tests be mitigated?), and/or how should we deal with different tests types performed on separate test piles (local heterogeneity might interfere with direct comparison). Also the existence of different static load test procedures, which might influence the 'reference' static load settlement behaviour, should be taken into account.
- For comparative analysis, the static pile behaviour deduced from kinetic load testing should only be compared with the results of static load tests (see also

remarks previous point) and not (only) with semi-empirical design methods based on CPT e.g.

Kinetic load test as control test

- Kinetic load testing seems to have a potential to be applied as an alternative for static pile load tests (up to 1.5 design load).
- More extended investigation is however needed to perform comparative analysis in the working load range and this for different soil types (especially in cohesive soils and in saturated soils).
- In certain conditions (e.g. specific subsoil conditions, no comparable experience available, considerable variation of the results, …) a higher load mobilization should be enforced (say 2 or more times the design load), in order to cover some additional uncertainty.

Kinetic load test as design test

- One of the methods that is allowed by Eurocode 7 for pile design, is the design bases on preliminary load tests. The design load is then deduced from the test results (in principle the ultimate static pile load) by applying ξ factors (depending on the number of tests, stiffness of the structure) and γ factors (partial safety factors).
- It is the authors' opinion that these factors (especially the safety factors) can not be the same as the factors to be applied for static load tests. These factors need to be reviewed in detail, based on extended comparative load test data in different soil types. Possibly an extra safety (model) factor should be integrated in this procedure.
- Based on the actual available data resulting from tests in Sint-Katelijne-Waver, the application of the kinetic load as design test in clayey subsoil seems for the moment to be highly questionable. Also for saturated sand no comparative analysis is available in Belgium until now.

REFERENCES

BBRI (1998–2000 and 2000–2002). Soil displacement screw piles – calibration of calculation methods and automatisation of the static load test procedure: stage 1 – friction piles & stage 2 – end-bearing piles. Research programs subsidised by the Belgian Federal Ministry of Economical Affairs, convention numbers CC-CIF-562 and CC-CI-756.

Holeyman, A., Couvreur, J.M. and Charue, N. (2001). Results of dynamic and kinetic pile load tests and outcome of an international prediction event, Proceedings of the symposium Screw piles – installation and design in stiff clay, March 2001, Brussels.

Holeyman, A. and Charue, N. (2003). International pile capacity prediction event at Limelette, Proceedings of the 2nd symposium on screw piles, May 2003, Brussels.

Middendorp, P. (1999). Statnamic test results Sint-Katelijne-Waver. Profound Report 99-PROF-R0014 (Draft version).

Middenddorp, P. and Keindorf, C. (2001). Statnamic load testing – 2nd phase site of the project in Limelette. Profound Report 2001-PROF-R0012.

Swets and Zeitlinger (2001). Holeyman, A. (ed.). Screw Piles: installation and design in stiff clay, Lisse (NL).

Swets and Zeitlinger (2001). Maertens, J. and Huybrechts, N. (eds.). Belgian screw pile technology – Design and recent developments, Lisse (NL).