Ground displacement screw piles project in Belgium – 72-pile load testing program on two different sites

Projet de Recherche Belge relatif aux pieux vissés à refoulement de sol – Programme de 72 essais de mise en charge sur deux sites différents

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ABSTRACT: 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 aims to give a general overview of the research program, and to present some global results of the static pile load tests.

RESUME: Le Centre Scientifique et Technique de la Construction (CSTC) a organisé, avec le support financier du Ministère Fédéral des Affaires Economiques, un programme de recherche concernant les pieux vissés à refoulement de sol (BBRI, 1998-2000 & 2000-2002). L'objectif de cette contribution est de donner un aperçu général du programme de recherche, et de montrer quelques résultats d'essais de mise en charge statique.

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. 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.

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

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 will be reported at a second symposium *"Screw Piles in Sand – Design and Recent Developments*" that takes place on 7 May 2003 (this event is being organised at the time of preparation of this paper).

2 PILE TYPES

Six different types of ground displacement piles were installed and tested: one prefab and five cast-in-place screwed types:

- Atlas pile, installed by the company Franki Geotechnics B
- De Waal pile, installed by the company De Waal Palen
- Fundex pile, installed by the company Fundex
- Olivier pile, installed by the company Olivier
- Omega pile, installed by the company Socofonda

A detailed description and illustration of the installation procedure for the different pile types is given in the proceedings of the first symposium by Huybrechts (2001).

3 TEST SITES & SOIL INVESTIGATION

For the first test campaign a site in Sint-Katelijne-Waver (B) was selected. At this site the stiff fissured tertiary clay, known as Boom clay, almost outcrops. The piles, of which the bearing capacity mainly comes from shaft resistance, were installed at two different depths of 7.5 and 11.7 meters. A typical cone penetration test, with indication of the pile installation depths is given in Figure 1 (picture at the left). The groundwater level at that site was found at a depth of 1 meter.

For the second test campaign a site in Limelette (B) was selected. At this site the subsoil between the soil surface and a depth of 8 meter consists of quaternary silty layers, mainly loam. From that depth on a tertiary compact sand layer, the Ledian-Bruxellian sand formation, occurs. The piles were installed at a depth of 9.5 meter below soil surface. It was aimed to obtain piles of which the total bearing capacity can be attributed to pile base resistance for minimum 50 %. A typical CPT carried out on the terrain is given in figure 1 (picture at the right). The groundwater at this site can be found at great depth.

In order to enhance the international spreading of the test results, an extensive soil investigation campaign was conducted for both test sites. An overview of the basic soil investigation program is given in table 1. Besides the basic soil investigation program, different companies that perform cone penetration testing were invited to carry out additional tests. On both sites more than 40 supplementary cone penetration tests were performed. The objective to perform these tests was to characterize the scatter of results between the basic or reference tests and the tests performed by other companies. For the Sint-Katelijne-Waver site the results of the soil investigation program are given by Mengé (2001).

Table 1. Overview basic soil investigation program at the Sint-Katelijne-Waver and the Limelette test sites

	Sint-Katelijne-Waver	Limelette
In-situ soil investigation		
CPT-E1 (electr. cont. CPT)	30 (in the axis of each test pile)	32 (in the axis of each test pile)
CPT-M1 (mech. disc. CPT)	27	21
CPT-M4 (mech. disc. CPT	4	8
Pressuremeter borings	2	2
SPT	2	3
DMT	4	6 before pile installation 5 after pile installation
Boring with undisturbed sampling	1	1
Sesimic refraction	3	-
SASW	5	5
Seismic cone – CPT S	3	3
Laboratory tests		
Grain size distribution	at 4 depths	at 3 depths
Plasticity Limits	at 4 depths	at 3 depths
UU triaxial tests	at 4 depths	-
CU triaxial tests	at 4 depths	at 3 depths
CD triaxial tests	-	at 3 depths
Triaxial tests with bender elements	at 4 depths	

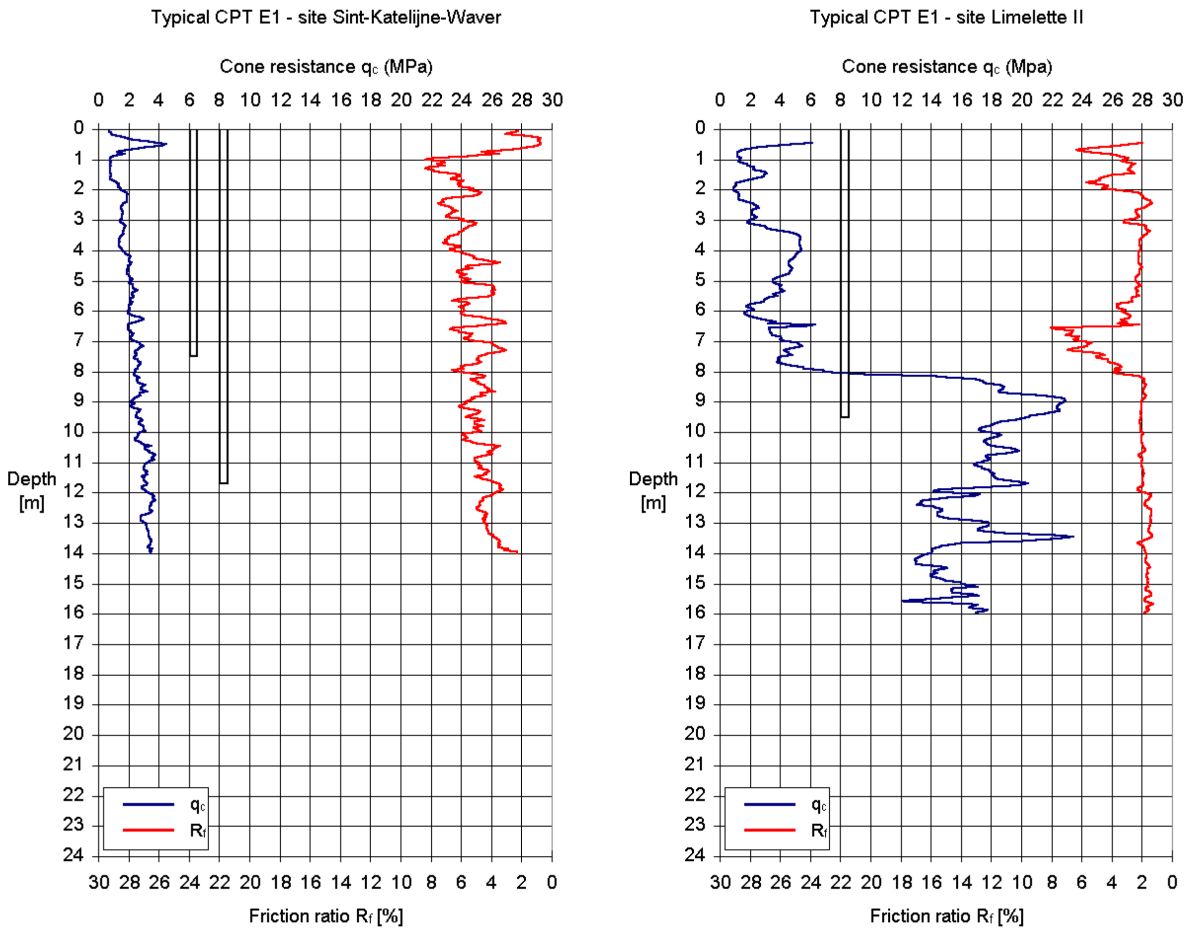

Figure 1. Typical CPT E1 on the site Sint-Katelijne-Waver (left) and Limelette (right)

4 LOAD TEST PROGRAM

For each test site a series of static, dynamic and kinetic pile load tests were performed:

- Twenty four (24) instrumented static load tests carried out upon failure of the piles (two tests per pile type on each site);
- Thirty six (36) dynamic pile load tests (two tests per pile type on each site and a second series of twelve pile load tests after one year on the Sint-Katelijne-Waver test site, in order to study the time effect);
- Twelve (12) kinetic load tests of the Statnamic type (one test per pile type on each site)

  The results of the static pile load tests are summarized in figures 2 and 3 for the Sint-Katelijne-Waver and the Limelette test site, respectively.

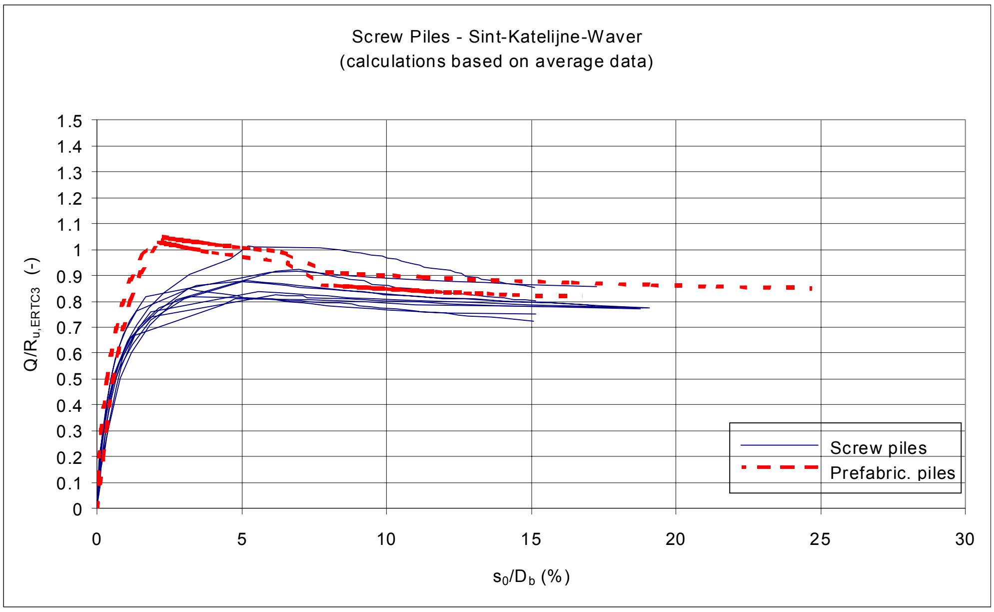

Figure 2. Normalised load settlement curves static pile load tests Sint-Katelijne-Waver

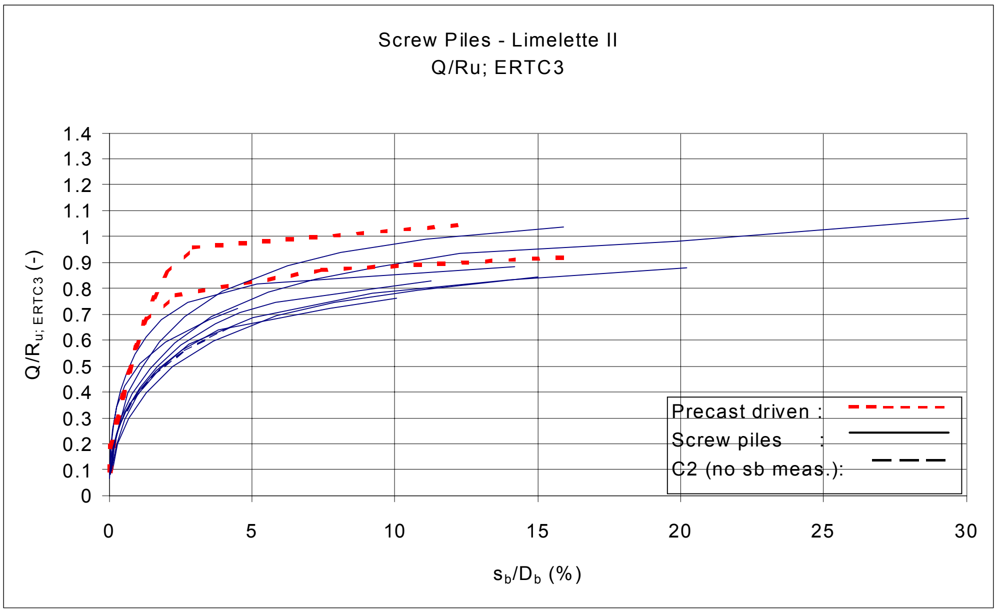

Figure 3. Normalised load settlement curves static pile load tests Limelette

These figures provide the "normalized" load settlement curves of the static pile load test. On the horizontal axis the pile settlement is expressed relative to the pile base diameter. On the vertical axis the measured load Q during the pile load test is expressed relative to the value of the reference calculated ultimate pile bearing capacity. These reference calculated ultimate pile bearing capacities, $R_{u,ERTC3.}$ have been calculated by means of the semi-empirical calculation methodology based on CPT data as formulated in Holeyman et al. (1997), all the empirical factors have been supposed to be equal to one.

Out of these curves a global empirical factor, that takes into account the pile installation method, the nature of the pile shaft material and roughness, and the soil type can be deduced. If it is supposed that the measured ultimate pile bearing capacity is the load corresponding with a settlement of 10% of the pile base diameter (conventional rupture load Q_{conv}), then the global semi-empirical coefficients of table 2 are obtained: global coefficient = $Q_{conv}/R_{u,ERTC3}$.

Table 2. Range of global coefficients obtained at the Sint-Katelijne-Waver and Limelette test site

Pile type	**Sint-Katelijne-Waver**	**Limelette**
Soil displacement screw piles	0.77 – 0.97	0.76 – 0.97
Driven Precast piles	0.85 & 0.90	0.89 & 1.02
Driven tubular pile – 1995/1996	-	0.79
Driven precast pile – 1995/1996	-	0.90
Franki pile – 1995/1996	-	0.90

In figure 4 the results of the static load tests obtained at the Limelette test site are compared with the results of an earlier test campaign at Limelette in 1995/1996 on different types of driven displacement piles, e.g. a driven tubular pile, a driven precast pile, and a driven Franki pile with slightly enlarged bottom plate. The global coefficients that can be deduced from figure 4 for these driven piles are also given in table 2.

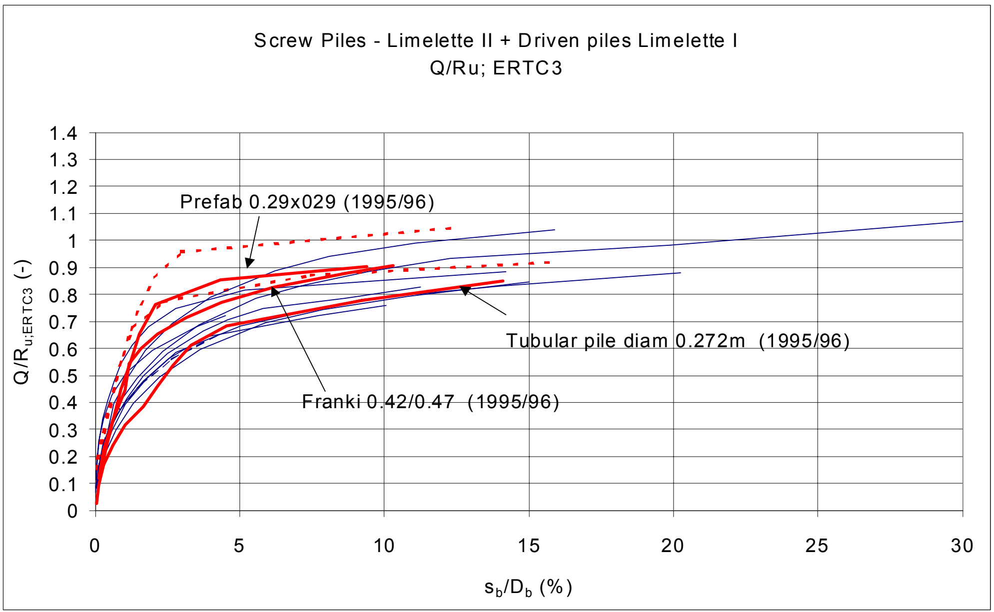

Figure 4. Normalised load settlement curves static pile load tests Limelette including results of an earlier test campaign (1995-1996) on driven displacement piles.

For the Sint-Katelijne-Waver test site more details of the results of the static load tests and the comparison of the test results with the semi-empirical calculation methods applied in Belgium are given in Maertens et al. (2001). The results of the dynamic and kinetic load tests were interpreted by Holeyman et al. (2001).

At the moment of the preparation of this paper, the results of the pile load tests on the Limelette test site are not yet published. The results will be published at the occasion of the second symposium on "Screw piles in sand – design and recent developments", that takes place in Brussels on 7 May 2003.

5 CONCLUSIONS

An overview has been given of the Belgian research program addressing soil displacement screw piles which was executed in the period 1998-2002, and during which 72 pile load tests have been performed.
The first stage of the project that was performed on the stiff fissured clay site at Sint-Katelijne-Waver has already extensively been reported in the proceedings of the symposium "*Screw piles installation and design in stiff clay"*.
The results of the pile test campaign performed during the second stage of the project are being reported at the moment of the establishment of this paper and will be presented at a second symposium on *"Screw piles in sand – design and recent developments"* that will take place on May 7, 2003 in Brussels.
Until now the results of these pile load test campaigns have especially been compared with the design methods based on CPT, which are currently used in Belgium, and are being taken in consideration by the Belgian working group charged with the establishment of the Belgian National Annex of the Eurocode 7.

Based on the actual test results it can be concluded that the soil displacement screw pile types have several excellent qualities: the pile installation method is fast, without soil removal, vibration free and the produced noise is limited. In general a good and constant pile quality with depth is obtained and the total pile bearing capacity of the soil displacement screw piles, which participated at the research project, is in general close to that of driven piles.

REFERENCES

BBRI (1998-2000 & 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., Bauduin, C., Bottiau, M., Debacker, P., De Cock, F., Dupont, E., Hilde, J.L., Legrand, C., Huybrechts N., Mengé P., Simon G. (1997). Design of axially loaded piles – Belgian practice. Proceedings of the ERTC3 seminar, Brussels.

Holeyman, A., Couvreur, J.M., 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

Huybrechts, N. (2001). Test campaign at Sint-Katelijne-Waver and installation techniques of screw piles, Proceedings of the symposium Screw piles – installation and design in stiff clay, March 2001, Brussels

Maertens J. , Huybrechts N. (2001). Results of the static pile load tests, Proceedings of the symposium Screw piles – installation and design in stiff clay, March 2001, Brussels

Mengé, P. (2001). Soil investigation results at Sint-Katelijne-Waver (Belgium), Proceedings of the symposium Screw piles – installation and design in stiff clay, March 2001, Brussels

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