Application of Stress-Wave Theory to Piles, Niyama & Beim (eds) © 2000 Balkema, Rotterdam, ISBN 90 5809 150 3

Preparation of an international pile dynamic testing prediction event

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ABSTRACT: An international prediction event could be carried out on the basis of an extensive pile testing program organized in Belgium. Five units of six pile types were installed, allowing various testing methods to be applied: instrumented static load tests carried up to failure, Statnamic testing, and dynamic testing. This paper provides the project background information that was required to prepare the prediction event. The pile types are fully described while the results of the extensive soil investigation program are summarized. A companion paper reports on the received predictions and results obtained from the static pile load tests.

1 INTRODUCTION

A national research project promoted by the Belgian Building Research Institute (BBRI) has been conducted in order to establish the performance of different types of cast-in-place ground displacement screwed piles. A national advisory committee under chairmanship of the first two authors directed the program, which included installation and testing of 30 test piles. The program has also been followed by an international panel of experts selected amongst members of ITC 18 (International Committee on Pile Foundations, of the International Society of Soil Mechanics and Geotechnical Engineering).

A total of 30 loading tests could be performed at a site located in Sint-Katelijne-Waver, some 20 km north of Brussels, according to the following schedule:

- 6 Statnamic tests and 12 dynamic tests took place within the first and second week of August 1999;
- 12 Static pile tests were performed between September 2nd and October 12th 1999.

That timing allowed the organization of a Class-A type prediction event (Lambe, 1973), with the view to document the profession's ability to estimate those new piles behavior based on standard investigation means as well on dynamic testing.

An extensive soil investigation was performed as part of the research project, including in situ tests (CPT, PMT, SPT, DMT, SASW, ...) and laboratory tests on undisturbed samples. Whereas the present paper provides a description of the pile types and subsurface conditions, its companion (Holeyman et al, 2000) focuses on load tests results and their comparison.

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 Franki Co.
- De Waal pile, installed by De Waal Co
- Fundex pile, installed by Fundex Co.
- Olivier pile, installed by Olivier Co.
- Omega pile, installed by Socofonda Co.

Figures 1 through 5 illustrate the installation process of the five ground displacement screwed piles and define the pile toe level relative to the geometry of the auger/screw tip.

Five piles of each type have been installed on the test site to accommodate the following conditions for each pile type:

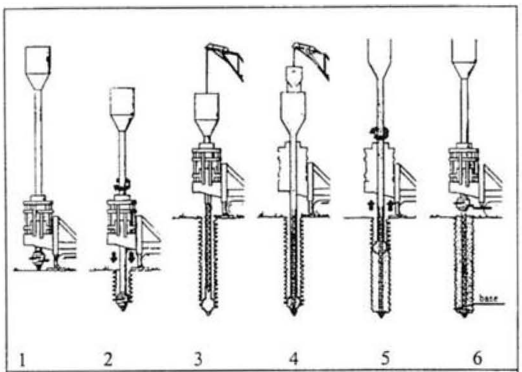
- One short pile for static load testing
- One long pile for static load testing
- One short pile for dynamic load testing
- One long pile for dynamic load testing
- One long pile for Statnamic testing

The short and long piles had an approximate depth of 7.5 m and 11.7 m, respectively.

The different pile types, their testing destination, their nominal shaft and base diameters for geotechnical bearing capacity calculations, and their measured pile base depths are listed in Table 1.

A total number of 30 piles were thus installed according to the pile layout shown on figure 6. The following load tests were to be performed on the following piles referenced according to their grid line locations :

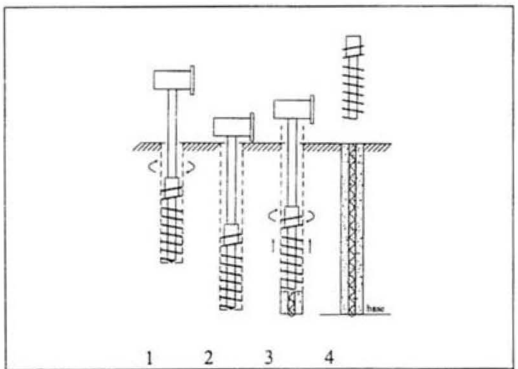
- 12 static load tests on piles A1, A2, A3, A4, B1, B2, B3, B4, C1, C2, C3, and C4
- 12 dynamic load tests on piles A5, A6, A7, A8, B5, B6, B7, B8, C5, C6, C7, and C8; and
- 6 Statnamic load tests on piles D1, D2, D3, D4, D5, and D6.



1. Setting up rig.
2. Screwing in the displacement auger head.
3. Screwing until base level and bringing in reinforcement.
4. Filling tube and funnel with concrete.
5. Screwing out and concreting the pile. Lost point at pile base
6. Finished pile.

Toe level determined by the level of the top of the screw blade on the screw auger

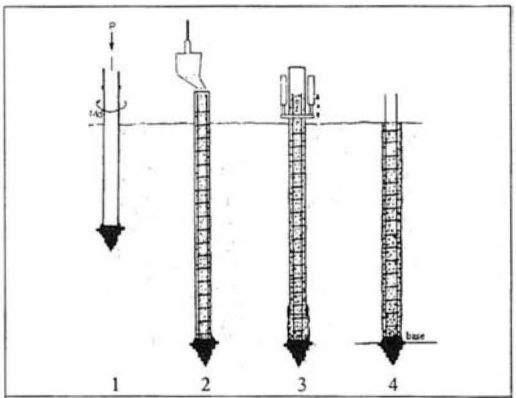
Figure 1. - Installation process of Atlas Pile



1. Screwing in displacement auger head.
2. Bringing in reinforcement
3. Injecting concrete and pulling out auger head, still rotating clockwise. Lost point at pile base.
4. Finished pile.

Pile toe determined by the level of the top of the lost bottom point

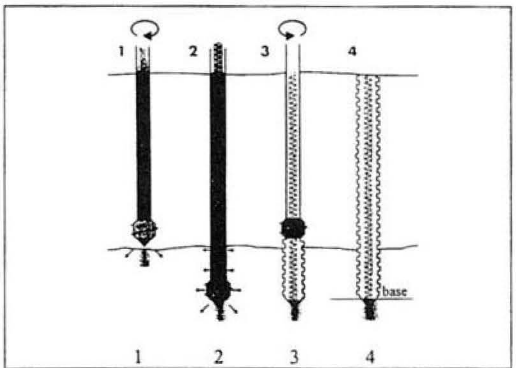
Figure 2. - Installation process of De Waal Pile



1. Screwing in tube, closed at the bottom with displacement auger tip.
2. Bringing in reinforcement and concreting.
3. Pulling out of tube under vertical oscillations. Lost auger head forms enlarged base.
4. Finished pile.

Toe level determined by the level of the max. diameter of the screw blade on the lost auger head

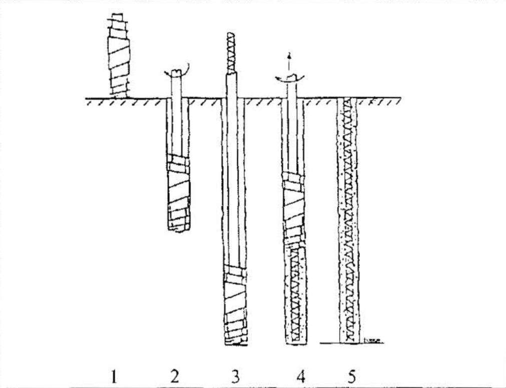
Figure 3. - Installation process of Fundex Pile



1. Screwing in displacement auger head.
2. Bringing in reinforcement.
3. Filling tube and funnel with concrete. Screwing out and concreting pile. Lost point at pile base.
5. Finished pile.

Toe level determined by the level of the top of the lost bottom point

Figure 4. - Installation process of Olivier Pile



1. Setting up rig.
2. Screwing in displacement auger tip, optimally with vertical pressure.
3. Bringing in reinforcement (eventually after concreting).
4. Injecting concrete and pulling out auger head, while pursuing clockwise rotation. Lost point at pile base.
5. Finished pile.

Toe level determined by the level of the top lost bottom point

Figure 5. - Installation process of Omega Pile

3 SOIL INVESTIGATION

3.1 *Overview*

The extensive soil investigation performed as part of the research project included the following in situ tests and laboratory tests, the locations of which are shown on figure 7:

In-situ tests

- 30 CPT(Cone Penetration Test)-E with electric cone in the axis of each test pile
- 27 CPT-M1 with mechanical M1 cone (standard discontinuous penetration)
- 3 CPT-M1 with mechanical M1 cone (alternate continuous penetration)
- 4 CPT-M4 with mechanical M4 cone
- 4 DMT (Dilatometer test)
- 2 borings with PMT (Pressuremeter test) tests at 1 m intervals
- 2 borings with SPT (Standard Penetration Test) tests at 1.5 m intervals
- 1 boring for undisturbed soil samples
- SASW (Spectral Analysis of Surface Waves) tests
- Seismic Refraction Tests
- Seismic Cone tests

Laboratory tests at several depths:

- Grain size distribution
- Atterberg Limits
- CU – Triaxial tests (consolidated, undrained)
- UU – Triaxial tests (unconsolidated, undrained)
- Triaxial tests with Bender Elements

3.2 *Subsurface geology and properties*

Borings B1, SPT1 and SPT2 revealed the following succession of soil layers :

0 – 0.40 m	: rubble
0.40 – 0.65 m	: Quaternary loamy sand
0.65 – 13.90 m	: Tertiary o.c. Boom Clay

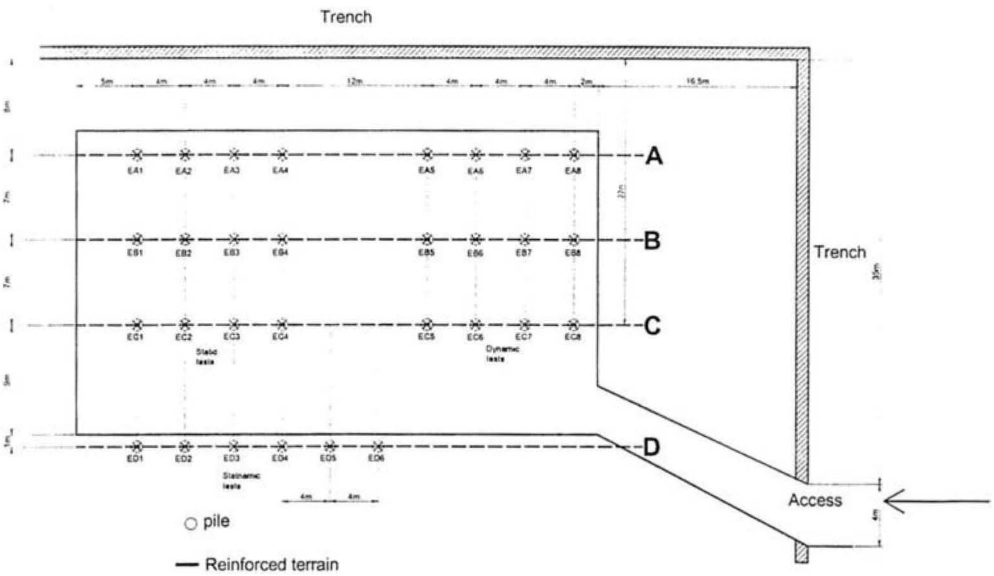


Figure 6 - Test Piles Layout

Table 1 – Features of installed piles

Pile	TEST	Pile type – Nominal dimensions [cm]	Shaft Diameter (1) (m)	Base Diameter (m)	Pile base depth (1) (m)	Excavation level (2) [m]	End level pile head (2) [m]	Top level pile head (2) [m]
A1	Static	Prefab. 35x35	0.395	0.395	-7.39	-1.04	-0.84	+0.22
A2	Static	Fundex 38/45	0.380	0.450	-7.38	-1.07	-0.87	+0.27
A3	Static	Fundex 38/45	0.380	0.450	-11.50	-1.02	-0.82	+0.29
A4	Static	Prefab. 35x35	0.395	0.395	-11.58	-0.98	-0.78	+0.36
A5	Dynamic	Fundex 38/45	0.380	0.450	-7.39	-0.81	-0.60	+0.91
A6	Dynamic	Fundex 38/45	0.380	0.450	-11.56	-0.75	-0.53	+0.97
A7	Dynamic	Prefab. 35x35	0.395	0.395	-11.63	-0.75	Continuous	+1.37
A8	Dynamic	Prefab. 35x35	0.395	0.395	-7.44	-0.71	Continuous	+0.56
B1	Static	De Waal 41/41	0.410	0.410	-7.53	-1.07	-0.87	+0.25
B2	Static	De Waal 41/41	0.410	0.410	-11.73	-1.07	-0.87	+0.28
B3	Static	Olivier 36/51	0.510	0.510	-11.68	-0.97	-0.77	+0.31
B4	Static	Olivier 36/51	0.510	0.510	-7.43	-0.90	-0.70	+0.39
B5	Dynamic	De Waal 41/41	0.410	0.410	-7.48	-0.76	-0.58	+0.92
B6	Dynamic	De Waal 41/41	0.410	0.410	-11.74	-0.76	-0.52	+0.94
B7	Dynamic	Olivier 36/51	0.510	0.510	-11.77	-0.79	-0.46	+1.06
B8	Dynamic	Olivier 36/51	0.510	0.510	-7.90	-0.75	-0.58	+0.94
C1	Static	Omega 41/41	0.410	0.410	-7.67	-1.08	-0.88	+0.32
C2	Static	Omega 41/41	0.410	0.410	-11.83	-1.02	-0.82	+0.35
C3	Static	Atlas 36/51	0.510	0.510	-11.76	-0.95	-0.75	+0.37
C4	Static	Atlas 36/51	0.510	0.510	-7.72	-0.96	-0.76	+0.39
C5	Dynamic	Omega 41/41	0.410	0.410	-7.53	-0.84	-0.57	+0.95
C6	Dynamic	Omega 41/41	0.410	0.410	-11.78	-0.84	-0.53	+0.96
C7	Dynamic	Atlas 36/51	0.510	0.510	-11.61	-0.74	-0.35	+1.01
C8	Dynamic	Atlas 36/51	0.510	0.510	-7.68	-0.82	-0.48	+0.99
D1	Statnamic	Fundex 38/45	0.380	0.450	-11.54	-0.84	-0.66	+0.30
D2	Statnamic	Prefab. 35x35	0.395	0.395	-11.67	-0.87	-0.57	+0.38
D3	Statnamic	De Waal 41/41	0.410	0.410	-11.58	-0.75	-0.49	+0.43
D4	Statnamic	Olivier 36/51	0.510	0.510	-11.55	-0.80	-0.66	+0.38
D5	Statnamic	Omega 41/41	0.410	0.410	-11.71	-0.78	-0.52	+0.48
D6	Statnamic	Atlas 36/51	0.510	0.510	-11.68	-0.76	-0.48	+0.44

(1) Diameter governing soil failure along the shaft

(2) Measured pile base depth relative to original soil surface level and according to the definition of the pile base level (figures 1 to 5)

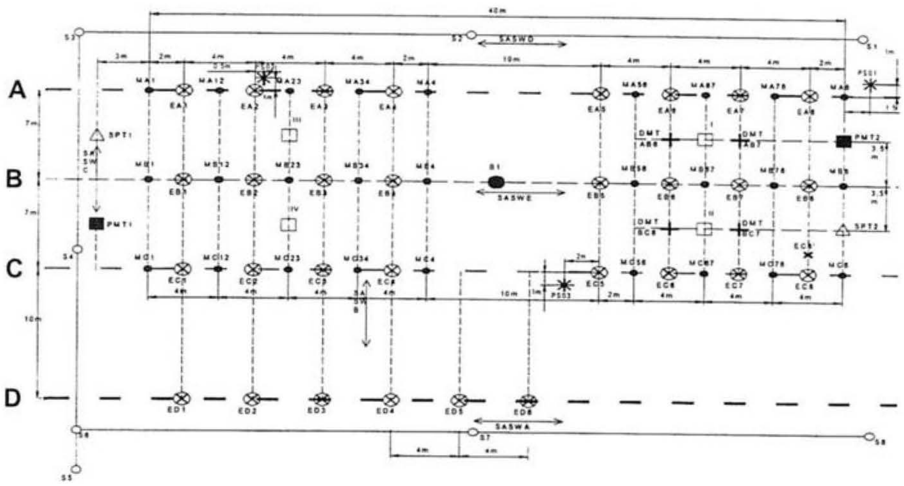


Figure 7 - Site Investigation Plan O Pile ★ CPT M1-cont. × CPT E ←→ SASW
• CPT M1-disc. □ CPT M4-dis. ✚ DMT Δ SPT •Boring ■ PMT o---o Seis. Refract

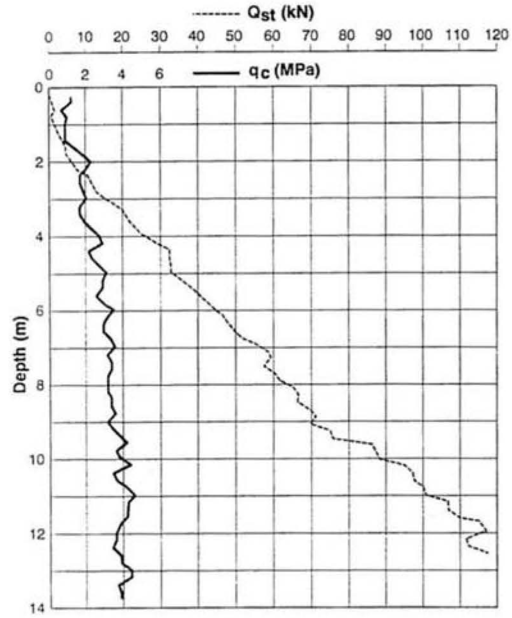


Figure 8 – Typical CPT-M1 Log (MA 78 Location)

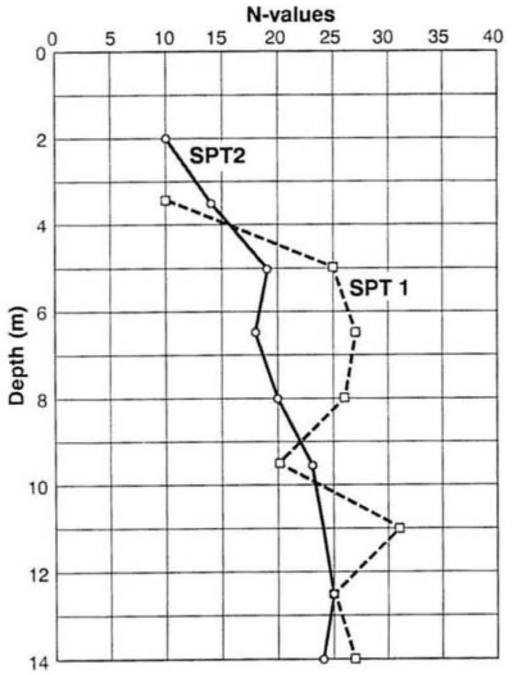


Figure 10 – SPT N – Values profiles at SPT1 and SPT2

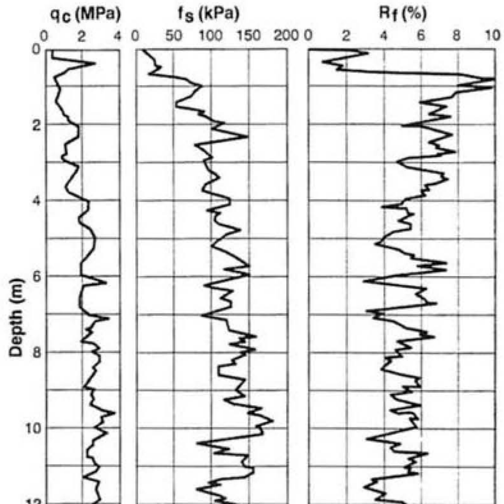


Figure 9 – Typical CPT-E Log (EB5 Location)

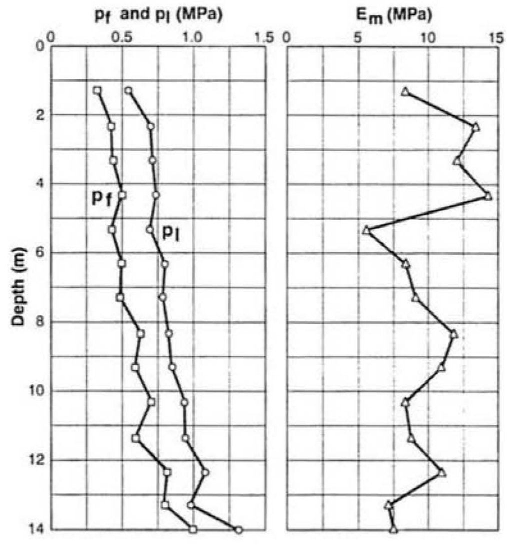


Figure 11 – PMT profiles of creep and limit pressures and pressiometric modulus (PMT2 Location)

The properties of Boom clay, a stiff fissured and stratified clay belonging to the Oligocene, are well documented in the vicinity (De Beer et al, 1977):

Natural water content: w = 22 to 31%

Liquid limit:	$w_L = 84$ %
Plastic Limit:	$w_P = 27$ %
Clay fraction	55 %
Permeability	10^{-10} m/s

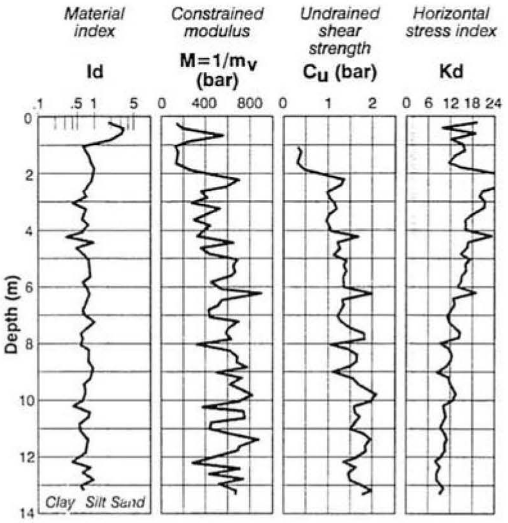


Figure 12 – Typical DMT profiles (BC 6 Location)

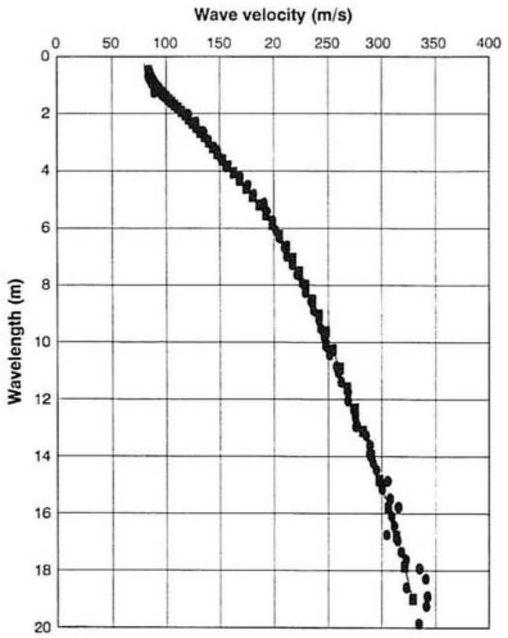


Figure 13 – Typical SASW profile (SASW D Trace)

According to geologists, Boom clay was covered, prior to the Continental Pleistocene erosion, by a layer of Neogene sand with a thickness of approximately 40 meters. That layer has been completely eroded at Sint-Katherlijne-Waver.

UU triaxial tests performed for the research program confirmed the local variability of the properties resulting from the layered and fissured nature of Boom clay: C_u varied between 80 kPa at 4.7m depth to approximately 150 kPa in the 8.5 to 13.9 m depth range. Those results confirmed the trend established by De Beer et al (19977) at the near-by Kontich site:

$$C_u\,[\text{kPa}] = 84 + 6.5\,z\,[\text{m}]$$

More discrepancy was found between the two sites regarding effective strength parameters derived from consolidated undrained triaxial tests conducted with pore pressure measurements: $\phi' = 27°$ and $c' = 30$ kPa for this testing program versus $\phi' = 18°$ and $c' = 11$ kPa at the Kontich site.

3.3 *In situ testing*

The bulk of the investigation effort was directed towards in situ geotechnical testing, which are generally recognized as the "ad hoc" testing for pile design in Belgium (Holeyman et al, 1997). The site was investigated using the several testing tools available to the profession, with a view to accommodate various geotechnical design cultures around the world. The site is herein characterized from the following angles:

CPT-M1, as shown in Fig. 8
CPT-E, as shown in Fig. 9
SPT N-values profiles, as shown in Fig. 10
PMT, as shown in Fig. 11
DMT, as shown in Fig. 12
SASW, as shown in Fig. 13

4 PREDICTION ORGANIZATION

4.1 *Prediction preparation*

On August 20th 1999, a reference document was distributed internationally among interested parties, and in particular to members of ITC 18 (International Committee on Pile Foundations of ISSMGE) and APTLY (Association of Pile Testing LaboratorY) to enable them to:

- predict the load-bearing behavior of the piles based on the results of the dynamic pile load tests, and
- predict the static ultimate pile bearing capacity and the load-bearing behavior of the piles by means of the ground investigation results.

A project synopsis had been prepared to invite interested parties to make those predictions (Holeyman et al, 1999a). It included a description of the pile types, site characterization, the static load test procedure, the dynamic load test procedure and the format of the prediction.

Interested predictors were asked to fill in an invitation document to accept the information release conditions associated with this prediction event. In particular any publication using part of the data herein and public release of any of the research measurements warranted the prior permission of the BBRI. Once this was done, they were sent the complete information, available as laboratory and in situ investigation and dynamic load test results (Holeyman et al, 1999b).

4.2 *Prediction Format*

It was requested that the prediction submittal include:

- A description of the used model(s), with a list of governing parameters,
- The type of soil investigation method on which the calculations were based,
- A detailed calculation methodology, with specific references (data provided, standards, publications, ...) and derivation of governing parameters,
- A separation between pile base resistance and shaft resistance;
- A criterion for the ultimate pile bearing capacity

The predicted static load-settlement behavior of the piles was to be summarized into a table providing the loads corresponding to the following settlements: 1, 2, 4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 150, and 200 mm.

Predictions could be established based on dynamic load tests, detailed geotechnical information (boring+lab tests, CPT, PMT,...), experience, or a combination of the above.

5 CONCLUSION

The soil investigation performed as part of the program was extensive and included enough elements to allow most geotechnical engineering cultures to have a fair chance in the prediction event. Pile types were varied. Although ground displacement screwed piles are not widely known, the program included a prefabricated concrete pile as a more widely known reference pile. Conditions were set to assess the bearing capacity of those pile types and compare them with international predictions.

6 ACKNOWLEDGMENTS

The authors would like to acknowledge the Belgian Ministry of Economic Affairs for its financial support of the testing program (Convention CC CIF - 562). The testing site was made available by the 'De Nayer' Institute at Sint-Katelijne-Waver. Contractors installation their own piles free of charge, is also very much appreciated.

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