FDP

Full Displacement Pile System
Process and equipment

Process

BAUER

FDP Full Displacement Pile System

Soil displacement piles are bored cast in-situ concrete piles constructed by advancing a displacement boring tool into the ground with a rotary drilling rig using both torque and crowd force.

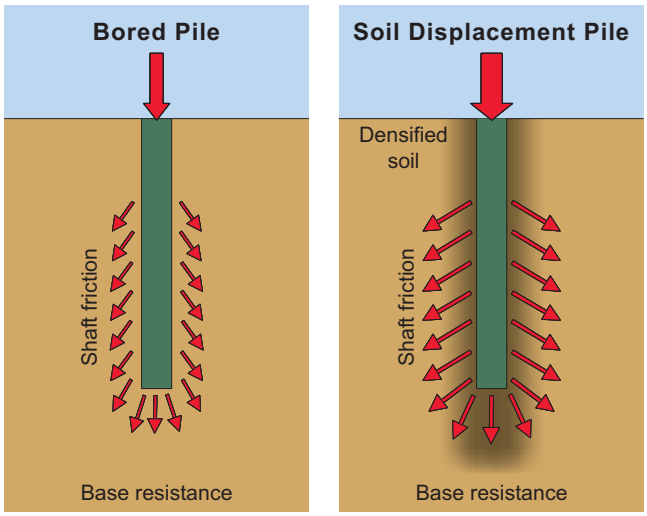
The precondition for the successful deployment are modern rotary drilling rigs offering high levels of torque, downward thrust and retraction force, as well as a tall torsion-resistant drill mast.

The technique is ideally suited for a wide spectrum of soil conditions ranging from sandy gravel, sand, silt and clay to soft organic soils, so long as the soil is displaceable. The following general rule of thumb applies:
SPT < 30 or CPT < 10 MPa.
By using displacement tools with an extended starter auger section, it is possible to drill through thinner non-displaceable formations or socket displacement piles into these.

Advantages of the Displacement Pile System

High Bearing Capacity

Displacement of the volume of soil into the surrounding soil formation produces a highly densified body of soil. This effect results in an increase in shaft friction and base resistance (in relation to the nominal diameter).



Minimal Amount of Spoil Material

During drilling and pushing the displacement tool into the ground, the displaced volume of soil is pushed fully into the surrounding soil material by the displacement body. In the absence of soil being conveyed to the surface, this system is suited particularly well for operating in contaminated soils. The absence of any significant amounts of spoil also provides a greater freedom of manoeuvrability on site for the drilling rig.

Continuous conveyance of spoil with CFA (as a comparison)

Negligible conveyance of spoil with FDP

Reduced Concrete Consumption

Compared with other auger bored piling systems, concrete overbreak is significantly lower.

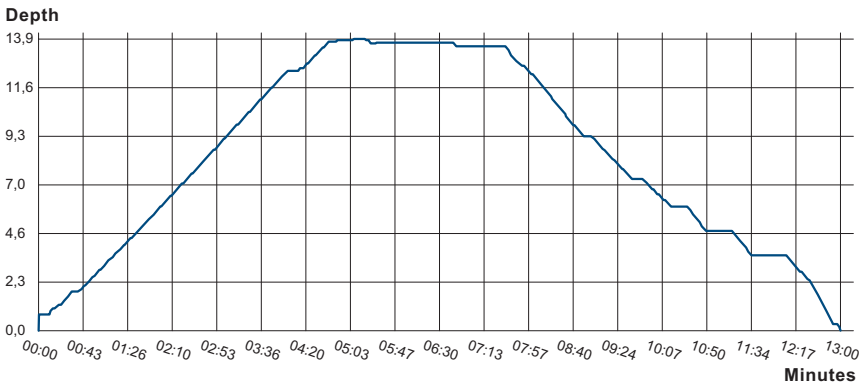
Vibration-free Installation Process

Drilling the displacement tool into the ground by the rotary drilling technique with additional downward thrust does not induce vibrations on adjacent buildings.

High Level of Productivity

The productivity of pile installation is dependent on:

- Pile diameter
- Torque and crowd force of the drilling rig
- Density of the subsoil
- Displaceability of the subsoil
- Capacity of the oncrete pump



Example:

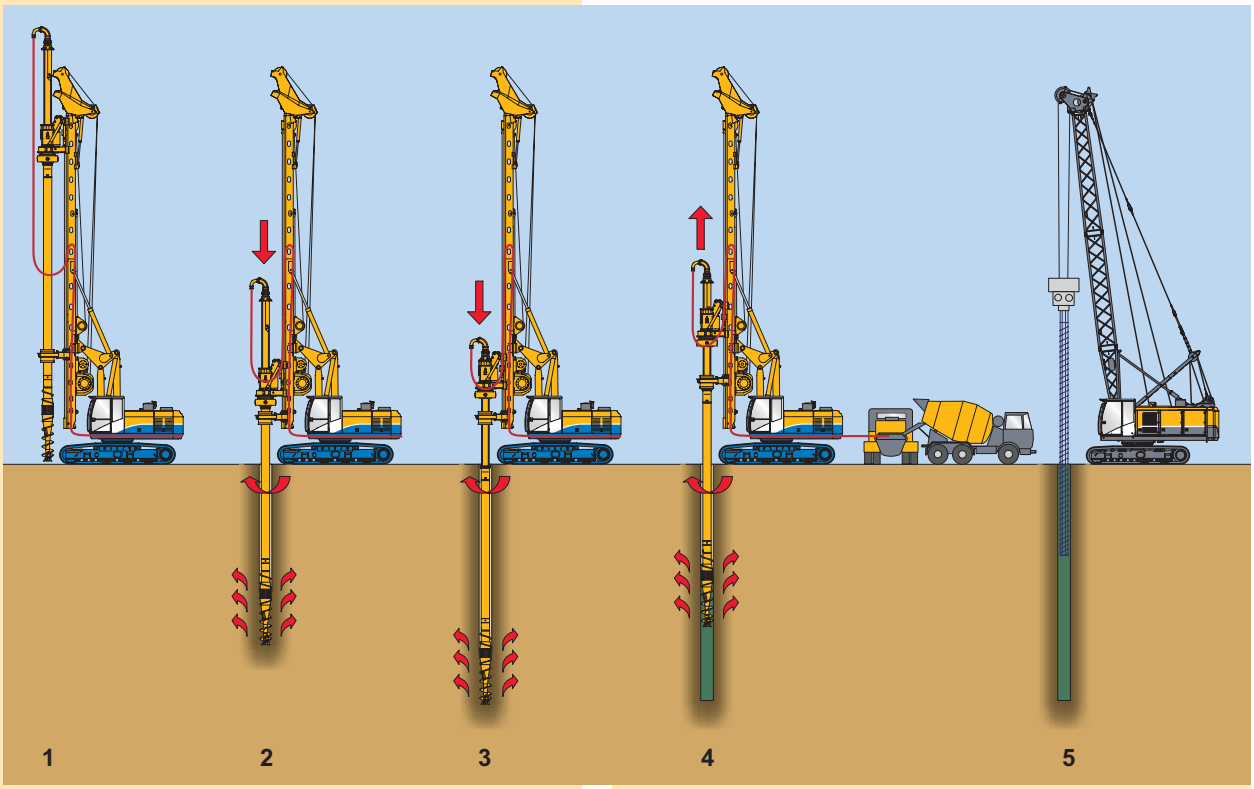
FDP Pile	**13,9 m**
Drilling down	5,5 min
Concreting	7,5 min
Reposition & set up	3 min
Total time	**16 min**
Max. daily production	**36 Piles (430 m)**

FDP
Standard Technique

FDP – Standard Technique
Operating Sequence

Step 1:
Positioning and setting up drilling rig over pile position.

Step 2:
Drilling of the displacement tool into the ground by rotating and pushing of the tool. The soil is loosened by the starter auger and then pushed laterally into the surrounding soil by the displacement body.



Step 3:
Drilling down to the final depth. The installation depth is limited by the height of the drill mast, but it can be extended by between 6 – 10 m, depending on the type of rig, by using a kelly extension.

Step 4:
On reaching the final depth the displacement tool is extracted and concrete is simultaneously pumped through the hollow drill stem into the void created by the tool. During extraction, the displacement tool is rotated in drilling direction and densifies any soil material that may have fallen into the bore or any loosened borehole wall areas with the counter-rotating flight section above the displacement body.

Step 5:
The reinforcement cage is pushed into the fresh concrete supported, if necessary, by a small vibrator.

FDP – Standard Technique
Displacement Tool

Post-densification during extraction
Counter-rotating flight on a conical body for densification of any loose soil areas during extraction of the tool

Stabilisation
Cylindrical displacement body for stabilisation of the displaced soil material

Densification
Conical shape of the hollow stem induces horizontal forces in the soil conveyed upwards by the flight (horizontal densification energy)

Loosening
The soil is loosened by the starter auger section and conveyed upwards by the flights

FDP – Standard Technique
Drilling Depths and Drilling Diameter

Drilling rigs of the BG-Series and universal base machines of the subsidiary company, RTG Rammtechnik (RG rigs) are ideally suited as base carriers for the FDP piling technique.
Rig selection is dependent on the required drilling depth and necessary torque.
The drilling depth can be increased by equipping the base machines with optional equipment (kelly extension and lattice boom extension).

Drilling depth (m)

Ø D1	**360 mm**			**440 mm**			**440 mm**			**510 mm**			**510 mm**			**620 mm**		
Ø D2	254 mm			254 mm			368 mm			254 mm			368 mm			368 mm		
	STM	**KV**	**GMV**	**STM**	**KV**	**GMV**	**STM**	**KV**	**GMV**	**STM**	**KV**	**GMV**	**STM**	**KV**	**GMV**	**STM**	**KV**	**GMV**
BG 12 H	11,0	15,0	–	11,0	15,0	–	–	–	–	–	–	–	–	–	–	–	–	–
BG 15 H	12,0	18,0	–	12,0	18,0	–	–	–	–	–	–	–	–	–	–	–	–	–
BG 18 H	–	–	–	13,5	21,5	–	13,5	21,5	–	13,5	21,5	–	–	–	–	–	–	–
BG 20 H	–	–	–	14,5	22,5	–	14,5	22,5	–	14,5	22,5	–	14,5	22,5	–	–	–	–
BG 24 H	–	–	–	–	–	–	15,0	23,0	25,5	–	–	–	15,0	23,0	25,5	15,0	23,0	25,5
BG 28	–	–	–	–	–	–	–	–	–	–	–	–	18,0	26,0	28,5	18,0	26,0	28,5
BG 28 H	–	–	–	–	–	–	–	–	–	–	–	–	17,5	25,5	28,0	17,5	25,5	28,0
BG 30	–	–	–	–	–	–	–	–	–	–	–	–	18,0	26,0	31,5	18,0	26,0	31,5
BG 30 H	–	–	–	–	–	–	–	–	–	–	–	–	19,3	27,3	32,3	19,3	27,3	32,3
BG 39	–	–	–	–	–	–	–	–	–	–	–	–	19,0	27,0	31,0	19,0	27,0	31,0
BG 40	–	–	–	–	–	–	–	–	–	–	–	–	18,5	26,5	30,5	18,5	26,5	30,5
BG 42	–	–	–	–	–	–	–	–	–	–	–	–	20,0	28,0	32,0	20,0	28,0	32,0
BG 46	–	–	–	–	–	–	–	–	–	–	–	–	22,5	30,5	34,5	22,5	30,5	34,5
BG 50	–	–	–	–	–	–	–	–	–	–	–	–	30,0	38,0	42,0	30,0	38,0	42,0
RG 18 S	18,0	22,0	–	18,0	22,0	–	18,0	22,0	–	18,0	22,0	–	18,0	22,0	–	–	–	–
RG 22 S	22,0	26,0	–	22,0	26,0	–	22,0	26,0	–	22,0	26,0	–	22,0	26,0	–	–	–	–
RG 25 S	–	–	–	–	–	–	24,5	32,0	–	24,5	32,0	–	24,5	32,0	–	24,5	32,0	–

Ø D1 = Drilling diameter
Ø D2 = Drill string diameter
Ø Hollow drill stem diameter 120 mm for all drilling diameters

Standard mast
Kelly extension
Kelly extension + lattice boom extension
STM **KV** **GMV**

BG 28 with standard mast

BG 40 with kelly extension

BG 30 with kelly extension and lattice boom extension

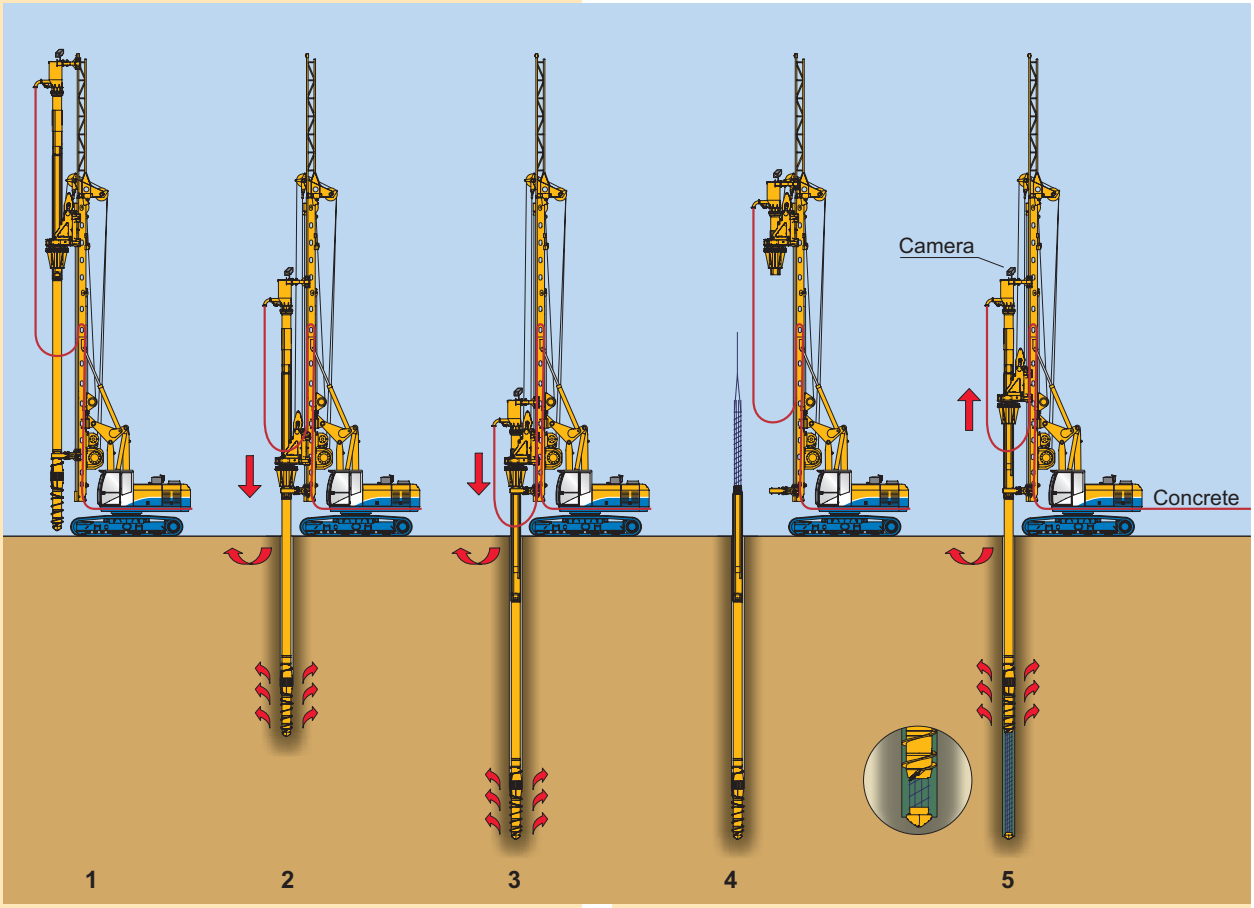
FDP "Lost Bit" Technique

As a variant, the FDP soil displacement pile system can also be deployed with a sacrificial drill bit. It differs from the standard technique by a detachable full-face drill bit, a hollow drill stem with a larger internal diameter and a concrete hopper that is mounted at the top of the hollow stem. With this set-up concrete can be placed in the pile by gravity feed alone without the application of pressure.
Due to the "unpressurised" placement of the concrete, excessive consumption of concrete is kept to a minimum particularly in soft soils. It also reduces the risk of the displacement body becoming jammed during concreting.

FDP – "Lost Bit" Technique
Operating Sequence

Step 1:
Positioning and setting up drilling rig over pile position, attaching sacrificial drill bit.

Step 2:
Drilling of the displacement tool into the ground by rotating and pushing of the tool. The soil is loosened by the starter auger and then pushed laterally into the surrounding soil by the displacement body.



Step 3:
Drilling down to the final depth. The installation depth is limited by the height of the drill mast, but it can be extended by up to 6 – 10 m, depending on the type of rig, by using a kelly extension. The drilling depth can also be extended by the addition of jointed drill string sections.

Step 4:
On reaching the final depth the rotary drive is disconnected from the hollow drill string and the full-length reinforcement cage is inserted into the hollow drill stem with the use of the auxiliary winch or an attendant crane.

Step 5:
During extraction of the displacement tool, concrete is simultaneously discharged by the concrete hopper and placed "unpressurised" in the pile through the hollow drill stem. The fill level in the concrete hopper can be monitored continuously by the rig operator via a camera mounted on top of the hopper. As with the standard technique, the displacement tool is rotated in drilling direction during extraction and densifies any soil material that may have fallen into the bore or any loosened borehole wall areas with the counter-rotating flight section above the displacement body.

FDP – “Lost Bit” Technique Equipment

Drive assembly with concreting equipment

1 Concrete hopper
2 Concrete hose pipe
3 Camera
4 Rotary drive
5 Hydraulic guide
6 FDP drill string

“Lost Bit”

Standard: Steel or cast iron drill bit

Drill bits made of ultra high-strength concrete are in the experimental phase

“Lost Bit” drill string

Comprising lost drill bit, starter auger, auger lead section, displacement body, drill string

The auger lead section is used for loosening hard soils. It is available in different lengths. In normally displaceable soils the auger lead section is omitted.

FDP – "Lost Bit" Technique
Drilling Depths and Drilling Diameter

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Rig selection is dependent on the required drilling depth and necessary torque.
The drilling depth can be increased by equipping the base machines with optional equipment (kelly extension and lattice boom extension).

Drilling depth (m)

Ø D	440 mm		510 mm		550 mm		620 mm		710 mm	
	STM	GMV	STM	GMV	STM	GMV	STM	GMV	STM	GMV
BG 18 H	13,5	21,0	13,5	21,0	–	–	–	–	–	–
BG 20 H	14,0	21,5	14,0	21,5	–	–	–	–	–	–
BG 24 H	15,0	25,0	15,0	25,0	15,0	25,0	15,0	25,0	–	–
BG 28	–	–	18,0	28,0	18,0	28,0	18,0	28,0	18,0	28,0
BG 28 H	–	–	17,5	27,5	17,5	27,5	17,5	27,5	17,5	27,5
BG 30	–	–	18,0	31,0	18,0	31,0	18,0	31,0	18,0	31,0
BG 30 H	–	–	19,3	32,3	19,3	32,3	19,3	32,3	19,3	32,3
BG 39	–	–	19,0	30,5	19,0	30,5	19,0	30,5	19,0	30,5
BG 40	–	–	18,5	30,0	18,5	30,0	18,5	30,0	18,5	30,0
BG 42	–	–	20,0	31,5	20,0	31,5	20,0	31,5	20,0	31,5
BG 46	–	–	22,5	34,0	22,5	34,0	22,5	34,0	22,5	34,0
BG 50	–	–	30,0	41,5	30,0	41,5	30,0	41,5	30,0	41,5
RG 18 S	18,0	–	18,0	–	–	–	–	–	–	–
RG 22 S	22,0	–	22,0	–	–	–	–	–	–	–
RG 25 S	24,5	–	24,5	–	24,5	–	24,5	–	24,5	–

Standard mast

Kelly extension + lattice boom extension

STM **GMV**

Drilling diameter D (mm)

	440	510	550	620	710
Drill string diameter (mm)	368	368	445	445	445
Hollow drill stem diameter (mm)	220	220	327	327	327

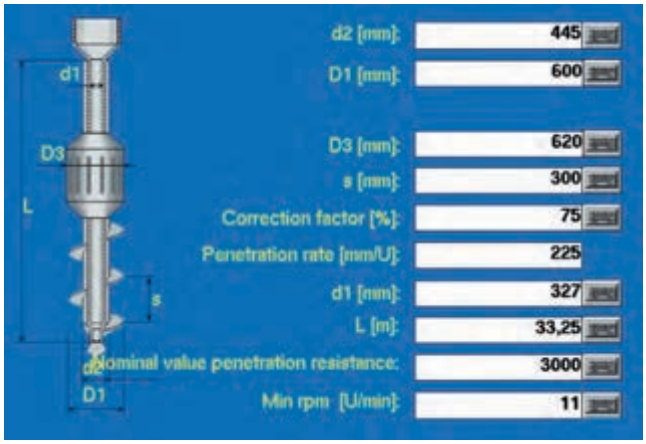
BG 28 with standard mast

BG 28 with kelly extension and lattice boom extension

Control and modulation with electronic “assistants”

Most of the Bauer rigs can be equipped with electronic software programmes for use with the FDP Soil Displacenment Pile System (“Drilling Assistant”), which modulate the optimal rate of penetration and crowd force during the drilling process for an optimal speed of rotation of the displacement tool. The desired initial parameters can be input by the rig operator with the help of simple onscreen menues.
By using a programmable “extraction assistant”, the speed of extraction and volume of concrete can be modulated. This involves measuring the volume of concrete continuously throughout the concreting process and automatically adjusting the speed of extraction based on the flow rate of the concrete.

The “Assistants” are integrated into the general electronic monitoring and control system B-Tronic. They ensure the piles are installed to a high and consistant quality standard.



Onscreen input menu for the initial parameters for “Automatic Drilling”

Touchscreen with display of essential parameters in automatic drilling mode.

Drilling speed, depth, torque, crowd force, alpha value, etc. are displayed and recorded.

B-Tronic display in automatic extraction mode.

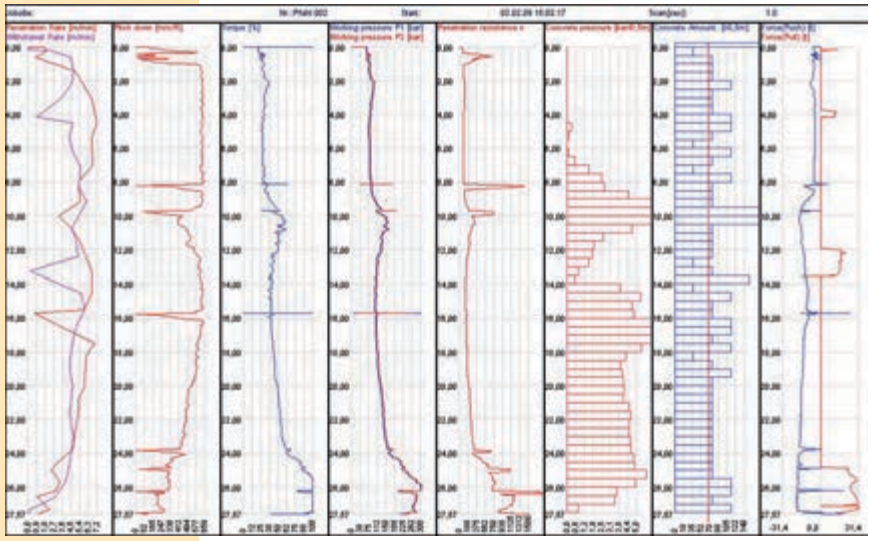
During concreting the volume of concrete is measured continuously. Based on the flow rate of the concrete the speed of extraction is automatically adjusted.

B-Report

The recorded data can be evaluated in the B-Report add-on either in their entirety or in selected groups and be printed out in the form of a pile installation record or as a quality assurance record.

Legend:

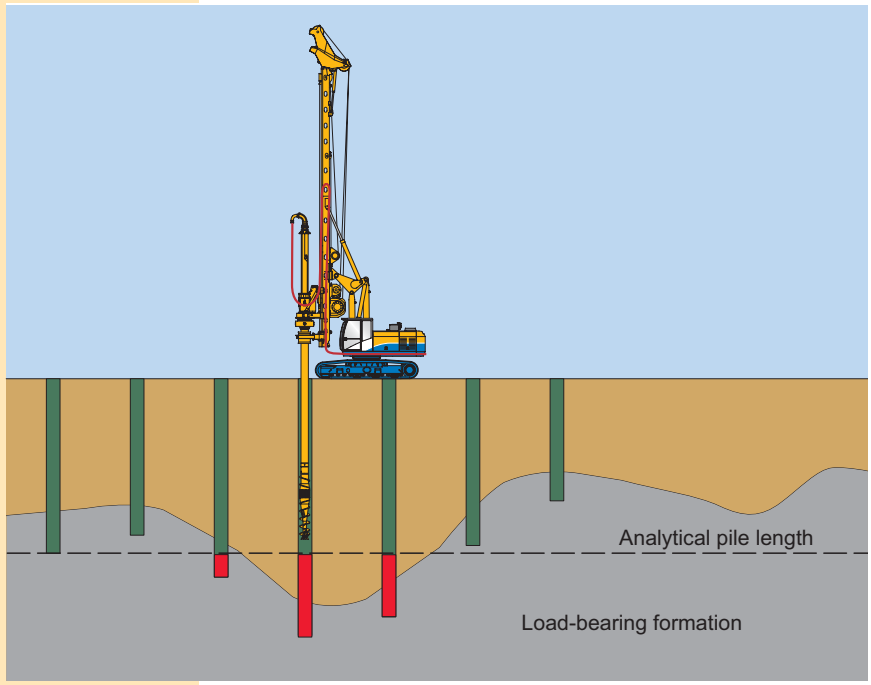
1 Penetration rate
2 Pitch down value
3 Torque
4 Hydraulic pressure
5 Alpha value
6 Concrete pressure
7 Concrete volume
8 Crowd force



α-Value (alpha-value)

During drilling the rate of penetration (m per tool rotation) and torque (kNm) are measured.
Using these data the computer then calculates the α-value.
This dimensionless value is used as an indicator of the strength or density of the prevailing soil formation. It provides an indication that the required load bearing horizon of a pile is being reached and can, therefore, be used to optimise the pile length.
Prior to starting the pile installation, an α-value record is determined and compared with borehole logs in one or more trial borings.
The working piles must be drilled using the “Drilling Assistant” for ensuring the reproducibility of defined stop criteria.

Self-exploratory system for flexible pile lengths which can be adapted to the geological conditions.

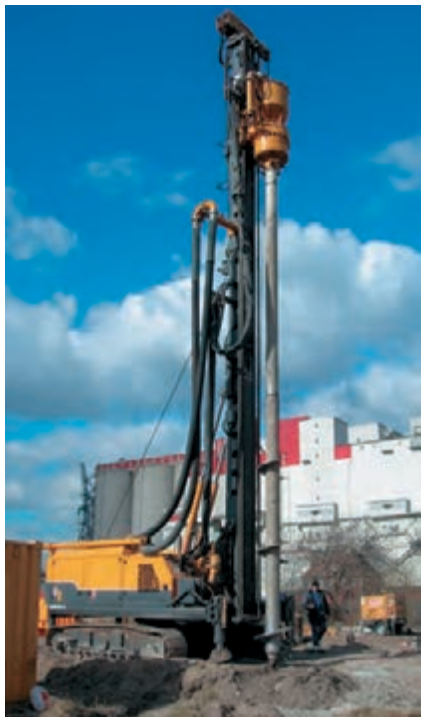


FDP Displacement Pile System – Pile Bearing Capacity

Static pile load tests on special test piles or working piles are the most reliable method for determining the bearing capacity of piles. Test piles constructed in advance of the actual construction works can be loaded to failure and provide, therefore, the most accurate data regarding load-bearing capacity, safety and settlement behaviour.

BAUER Maschinen has developed a simple modular system for rapid pile testing. Four steel screw piles are installed as reaction piles and connected to a purpose-built load frame. As there is no need to wait for the reaction piles to cure, the pile test can be carried out instantly. On completion of the pile test, the screw piles can be recovered and used for the next pile test.

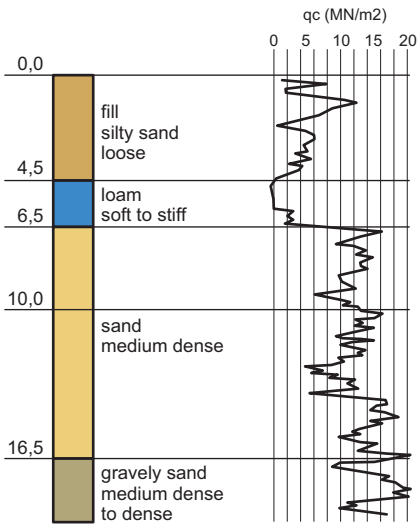
Pile load test reaction beam for a maximum test load of 3200 kN

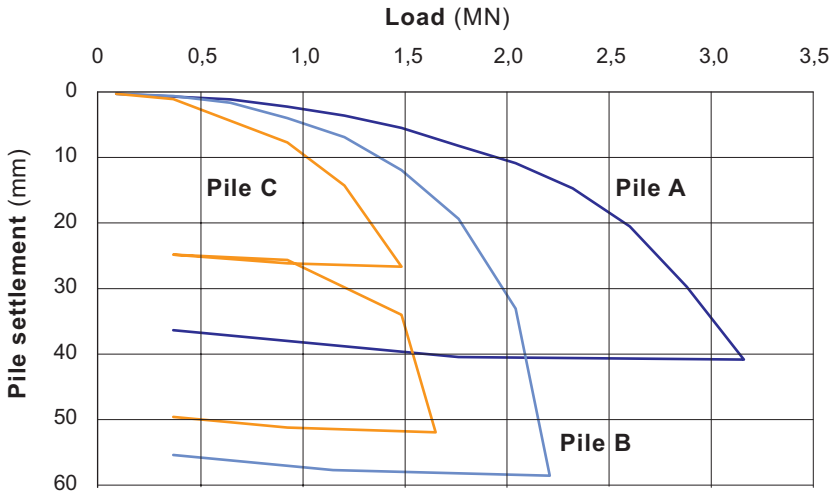


Installation of temporary tension piles

Pile Test: Hamburg

A series of pile load tests was carried out in co-operation with the university of Hamburg-Harburg as part of a fundamental research programme, for which a total of 17 piles were constructed with length ranging from 8 to 16 m . The load settlement curves below show the results of three load tests carried out on three different types of pile.

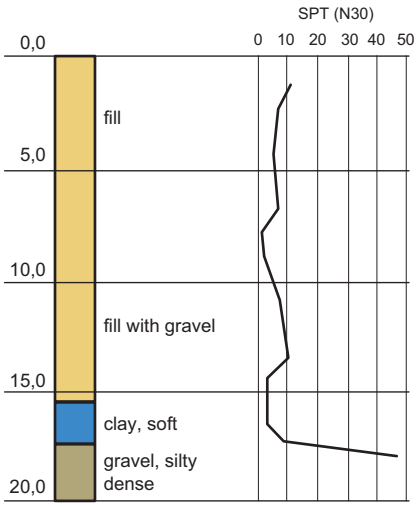


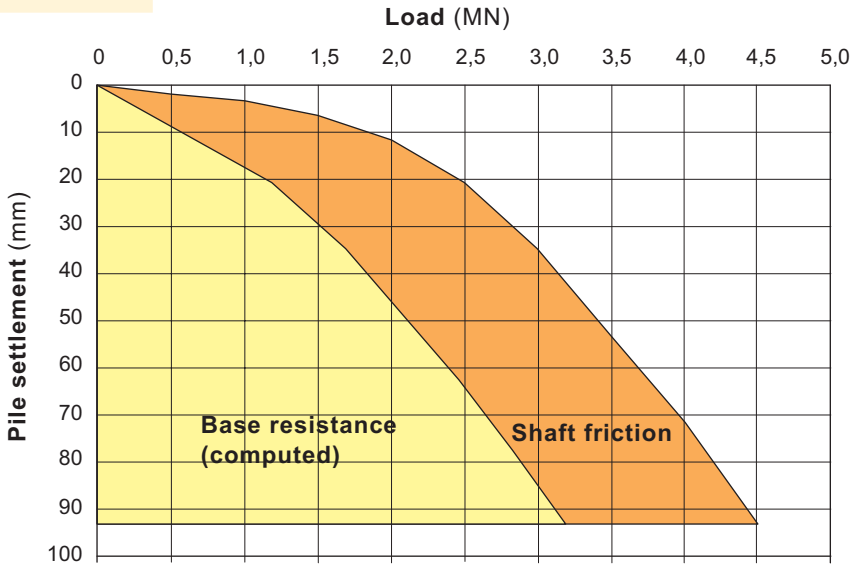


	Pile A	Pile B	Pile C
Drilling system:	FDP lost bit	FDP lost bit	CFA (comparative pile)
Pile diameter	510 mm	440 mm	500 mm
Pile length	10,0 m	8,4 m	10,0 m

Pile Test: Japan

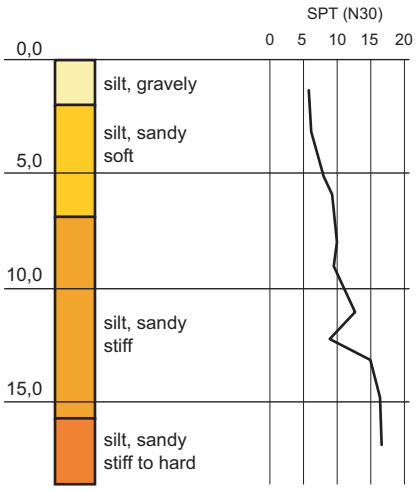
Drilling rig:	BG 28
Drilling system:	FDP, lost bit
Pile diameter:	620 mm
Pile length:	18,6 m

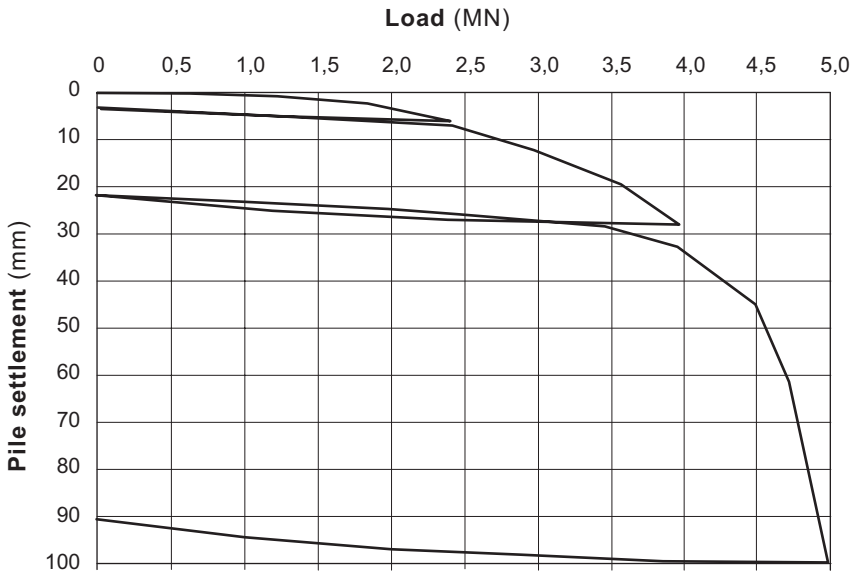




Pile Test: Malaysia

Drilling rig:	BG 40
Drilling system:	FDP Standard
Pile diameter:	600 mm
Pile length:	13,0 m





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