

Bored cast-in-place concrete piles



The Task

High structural loads

Difficult ground conditions

Excavation close to existing buildings

In the past the position of a building was generally chosen according to the suitability of the ground. Nowadays difficult ground or the presence of existing buildings close to the site boundaries are no longer considered as obstacles. Whether it is a question of making the most economic use of a site, the need for new traffic routes through difficult terrain, the need for the maximum use of expensive land, design engineers are increasingly confronted with one or more of the following circumstances:

- Shallow foundations are ruled out because settlements will be too great or the subsoil cannot take high loads without lateral yielding.

- Large point loads have to be transferred into the subsoil.
- The subsoil is contaminated from past industrial pollution.
- Deep basements have to be excavated close to the existing buildings which must be protected against damage.
- The excavation extends below the groundwater table.

Front cover:
Tunnel project in Lugano, Switzerland

Back cover:
Top left:
Construction of a pile wall for the BMW-Welt, Munich, Germany

Top right:
EUROVEA International Trade Centre in Bratislava, Slovakia

Bottom left:
Bored pile foundation for the Tampa Museum of Art, USA

Bottom right:
Construction of bored piles in rock for a new building of SWR in Stuttgart, Germany



Pasing Arcaden, Munich, Germany

The Solution

Deep foundations to support structures

Bored pile retaining walls for deep excavations

Deep foundations

These are several ways of transferring structural loads into the subsoil on sites where ground conditions are unfavourable.

The bearing capacity of the subsoil can be increased by ground improvement techniques such as:

- Replacement of non-load bearing layers of soil close to the surface
- Soil consolidation using pre-loading or vertical drains
- Soil compaction using grout injection, deep vibration or stone columns.

Alternatively, structural loads can be transferred to stronger competent strata at depth by the use of

- Bored piles
- Diaphragm wall elements
- Mixed in place (MIP) piles
- Piles reinforced by steel bars
- Vibrated concrete columns.

Technical literature on all these special alternative construction techniques is available on request from Bauer Spezialtiefbau.

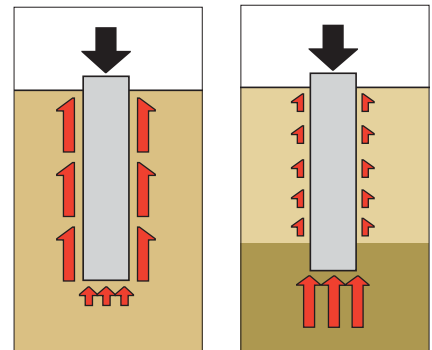
Retaining walls

The problem of providing stable retaining structures close to existing buildings or of constructing watertight excavation pits can be solved in a number of ways. However, the most appropriate solution is almost always the installation of a bored pile retaining wall.

Bored piles

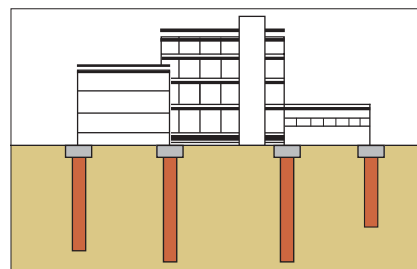
In general bored piles offer the most economical foundation as they can be constructed in a wide choice of diameters, typically ranging from 300 to 1,800 mm, and to depths of up to 70 m at rakes of up to 1:4. They can thus be tailored precisely to the particular requirements of the building or excavation. This flexibility means that bored piles can provide solid foundation elements suitable for almost all site conditions.

Bored piles can be classified into two main groups, according to their load bearing behaviour: friction piles, which transfer load mainly by frictional resistance along the shaft; and endbearing piles in which load is primarily transferred to the surrounding soil of through the pile base. Depending on the structural requirements, bored piles may be constructed singly, in groups or as walls using secant, contiguous or king piles, with or without infill.

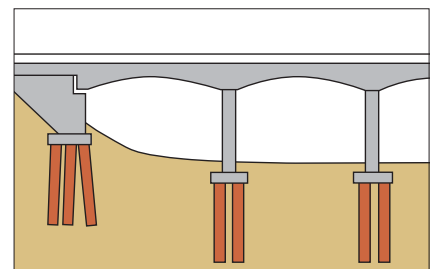


"Friction pile"

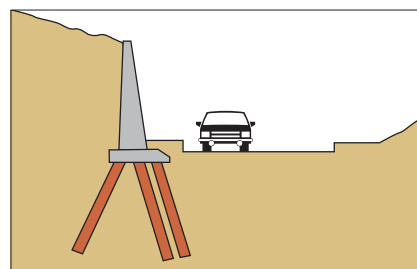
"End bearing pile"



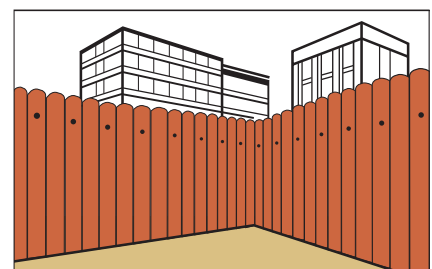
Single piles



Pile groups



Vertical and raked piles



Piled wall

Techniques

Cast-in-place concrete piles

Piling systems differ in respect of the techniques used (e. g. grab, rotary drill, direct circulation drill); the method used to support the borehole (with or without drill casing, dry, hydrostatic pressure, slurry stabilisation), and method of concreting (poured or injected). Pile construction comprises

three main steps, drilling, placing reinforcement and concreting. Some of these stages may be carried out simultaneously. Selection of the most appropriate piling technique depends on the prevailing soil conditions, the technical specifications relating to the site and the overall cost.



Reichenbachbrücke, Munich, Germany



Wedding Towers, Moskau, Russia



Airport Wien, Austria

Rotary drilling with kelly

a) Cased

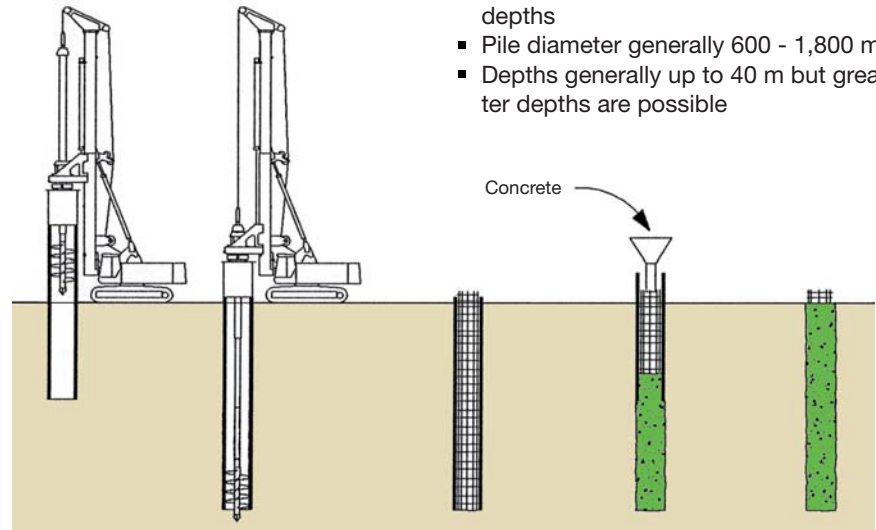
Standard cast-in-place pile

Main applications:

- All types of soil
- Where site conditions are restricted

Special features:

- Vibration free drilling
- High output with casings installed by rotary drive
- Casing oscillator can be used for larger pile diameters and greater depths
- Pile diameter generally 600 - 1,800 mm
- Depths generally up to 40 m but greater depths are possible



Install casing tubes by rotating and crowding using rotary drive
 Remove spoil with drilling tools attached to kelly bar with borehole stabilisation by temporary casing
 Insert reinforcing cage into borehole
 Place concrete by tremie and withdraw casing using rotary drive
 Completed pile

b) Borehole supported by hydrostatic pressure

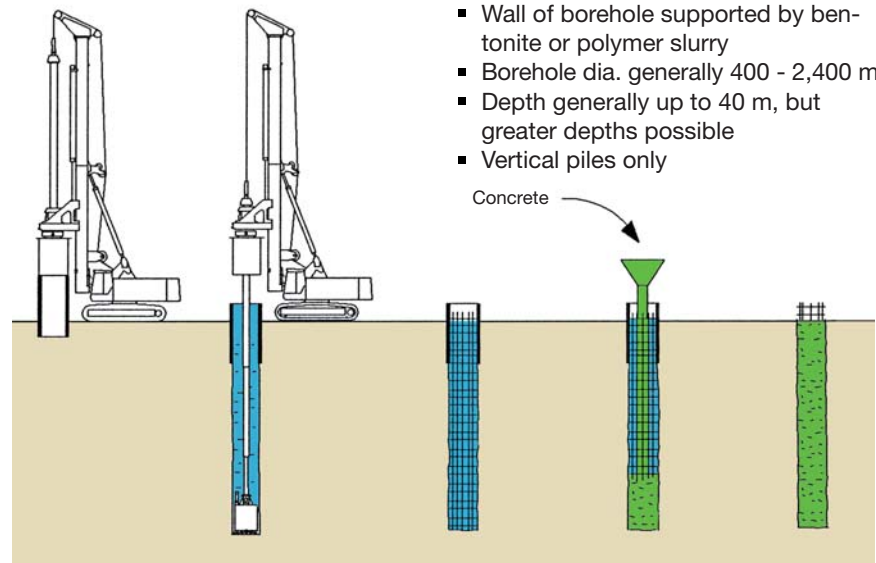
Standard cast-in-place pile

Main applications:

- In all kinds of soil, for large pile diameters and pile depths

Special features:

- Vibration free drilling
- No casing required
- Starter casing used for top section only
- Wall of borehole supported by bentonite or polymer slurry
- Borehole dia. generally 400 - 2,400 mm
- Depth generally up to 40 m, but greater depths possible
- Vertical piles only



Rotate starter casing to depth
 Remove drilling spoil with bucket attached to kelly bar with borehole supported by slurry
 Recycle slurry to remove soil and insert reinforcing cage
 Place concrete simultaneously displacing slurry
 Completed pile

Rotary drilling using twin rotary head

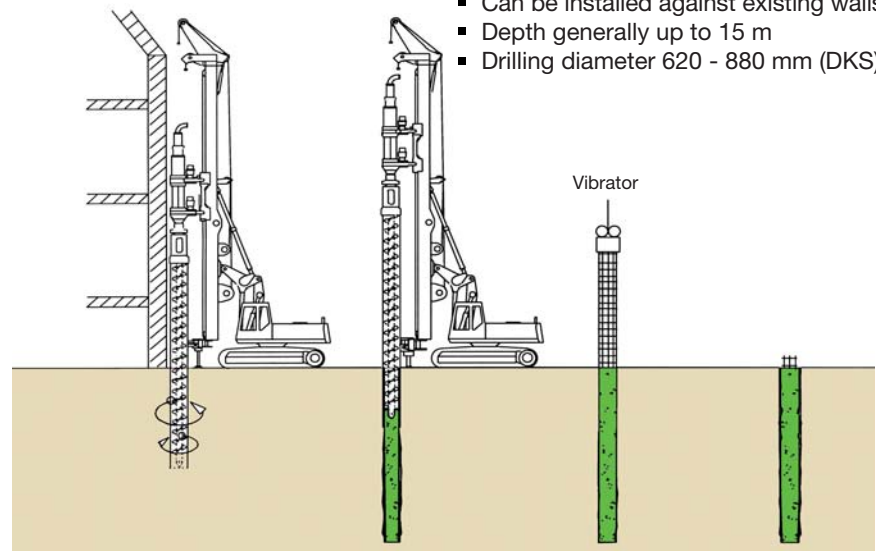
Drilling with double rotary head

Main applications:

- All types of soil
- On restricted sites

Special features

- Vibration free
- Continuous flight auger and casing installed simultaneously by counter rotating twin rotary drives
- Can be installed against existing walls
- Depth generally up to 15 m
- Drilling diameter 620 - 880 mm (DKS)



Install casing and continuous flight auger to required depth using counter-rotating drives

Inject concrete through hollow stem auger, simultaneously withdrawing auger and casing

Insert reinforcement cage into concreted borehole

Completed pile

Auger cast-in-situ pile

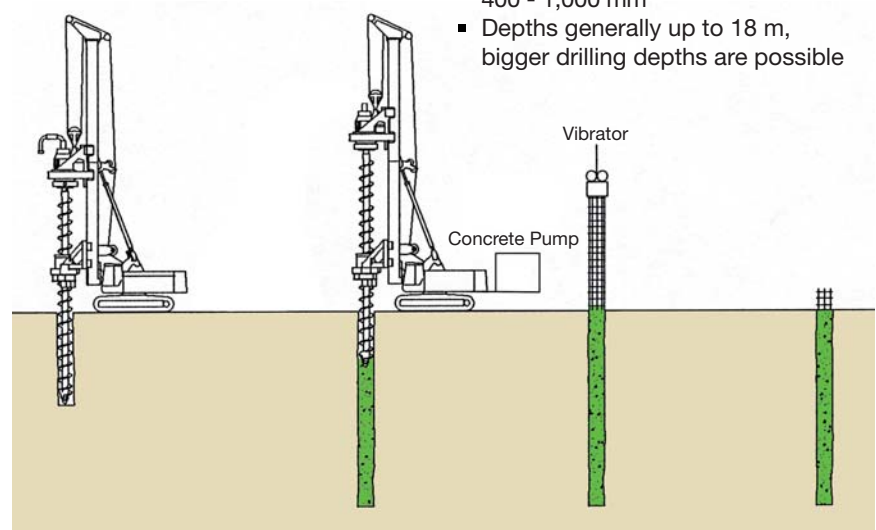
Auger cast-in-situ pile (SOB-pile)

Main applications:

- All types of soil
- Restricted sites

Special features:

- Vibration free
- Reinforcement can be pushed or vibrated into the fresh concrete
- Pile bore diameters from 400 - 1,000 mm
- Depths generally up to 18 m, bigger drilling depths are possible



Rotate continuous flight auger to required depth

Inject concrete through hollow stem, simultaneously withdrawing auger without rotation

Vibrate into place or push reinforcement cage fitted with spacers into fresh concrete

Completed pile

Displacement pile

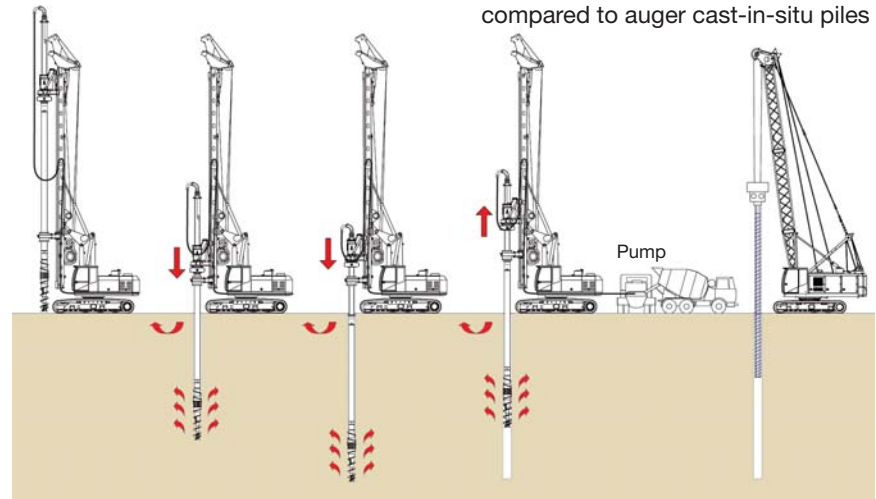
Displacement pile

Main applications:

- Contaminated soils to avoid disposal of drill spoil
- Limited space, e. g. track construction
- Soft soils

Special features:

- High bearing capacity through highly compacted skin area
- Avoiding drill spoil
- High performance
- Drilling diameter 420, 510, 610 mm
- Drilling without tremors
- Drilling depth up to 34 m
- Reduced concrete consumption compared to auger cast-in-situ piles



Set up at drilling point

Turning in and pressing of drilling tools

Following up kelly extension. Drilling up to final depth

Continued pulling and turning during the concreting process

Subsequent installation of reinforcement cage with additional crane

Grab construction Cased

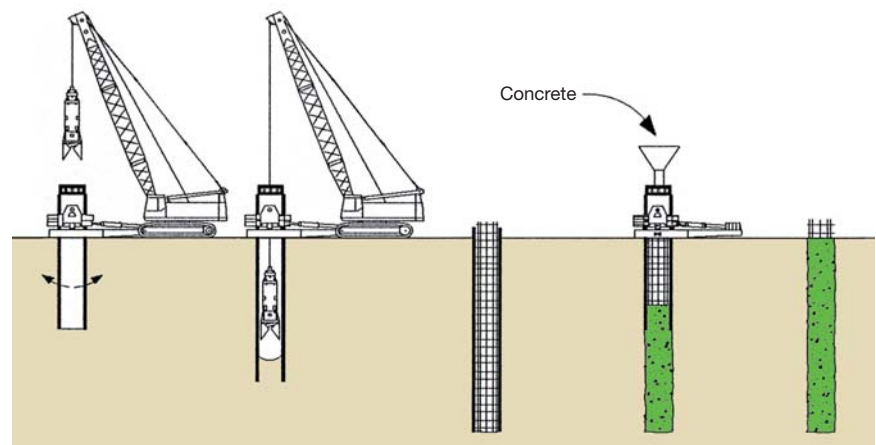
Using crawler crane and casing oscillator

Main applications:

- Soil such as sand and gravels with high demands on casing technology
- Where it is economically viable to use chisels to break up bedrock and boulders

Special features:

- Minimum distance to existing buildings is required
- Pile diameters generally ranging from 620 - 2,000 mm
- Depths generally up to 50 m



Install casing using casing oscillator

Simultaneously remove drill spoil with grab

Insert reinforcement cage into cased borehole

Place concrete by tremie and withdraw casing using oscillator

Completed pile

Planning considerations



Project Mixed-Use-Development in Abu Dhabi, UAE

Subsoil

Before starting piling operations the subsoil must be fully investigated in accordance with the appropriate standards such as DIN 1054. The stratification of the subsoil and groundwater conditions should be determined by exploratory boreholes and soundings. It is recommended that site investigations are taken to about 6 m below the proposed foundation levels in deep foundations. Based on the results of the site investigations the most suitable type of pile can be selected and the detailed design carried out.



Pile design

The pile design is based on two elements: internal and external bearing capacity. The minimum diameter results from the proof of the inner bearing capacity as stated in the standard DIN 1045. The inner bearing capacity depends on the concrete cross section and the reinforcement content. On the basis of the standard EN 1536 (previously: DIN 4014) the proof of the external bearing capacity results from the minimum embedment length in the bearing soil, taking the loads, the pile diameter and the soil specific bearing parameters (skin friction, pressure peak).

Underground car park Strasbourg Passages de l'Etoile, France

Increasing the bearing capacity of piles

Shaft grouting

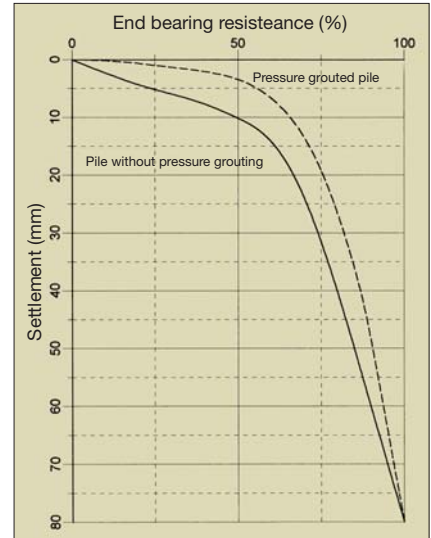
Pressure grouting along the shaft of the pile compresses the soil around the shaft, producing stronger adhesion between the concrete of the pile and the soil. Depending on the type of soil this can result in a considerable increase in shaft friction which enhances the bearing capacity and thus the performance of the pile.

Base grouting

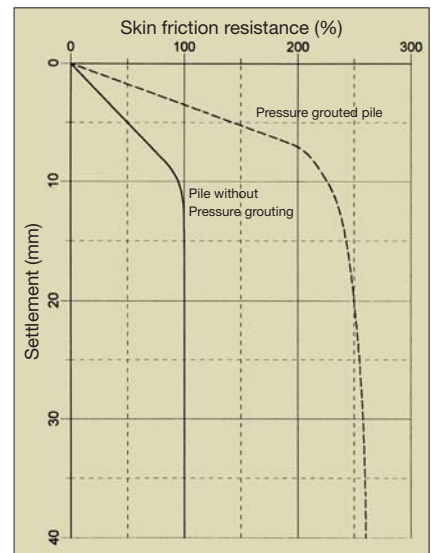
The end-bearing resistance of the pile can also be increased by injecting cement grout under pressure into the contact zone between the toe of the pile and the underlying soil. Base grouting not only offsets the almost inevitable softening of the material at the borehole toe but also reduces some of the early settlement.

Preparatory works for piling

Piled foundations and piled walls require planning approval. The cleared site should be made available in reasonable time before piling starts. Typical preparations would involve searching for underground channels, services, cable ducts and other sub-surface installations, remains of existing foundations, archaeological artifacts, and unexploded bombs or other war material. Authorization for access can be given by utilities, clients, national institutions for the protection of ancient monuments or bomb disposal services. In addition stable and leveled work platforms must be provided where piling rigs will be operating.



100 % end-bearing resistance $\hat{=}$ maximum end-bearing resistance of an ungrouted pile in sand with a settlement $s = d/10$ where (d = pile diameter)



100 % skin friction resistance $\hat{=}$ maximum skin friction resistance of an ungrouted pile in sand



Injection hoses for skin grouting



Bauer Lift-Cell to pre-stress the pile bottom

Pile load tests

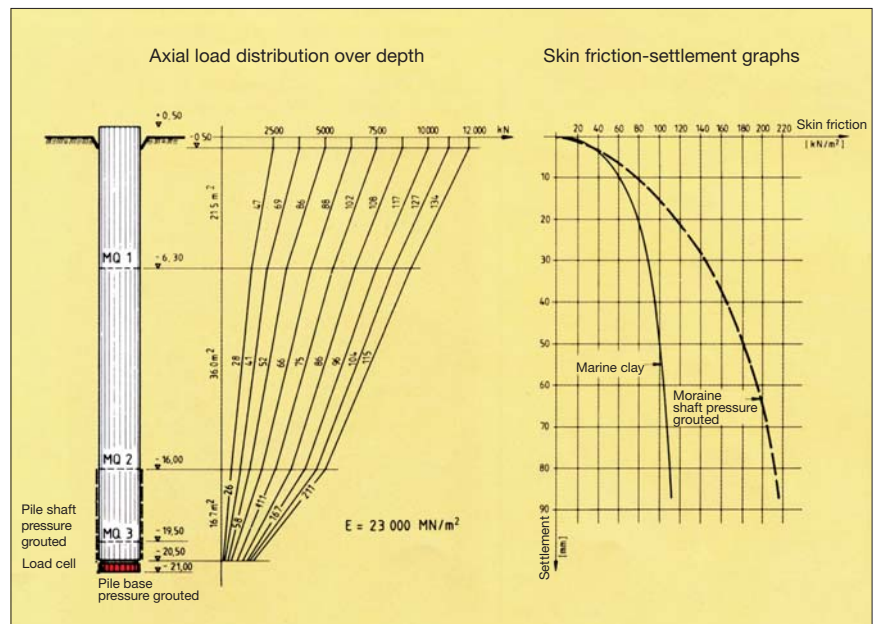
The most cost-effective bored pile designs are those based on load tests on site. They are generally only economic for large construction projects. As a result of the large number of pile load tests we have carried out over many years we are able to design bored piles for all types of ground conditions so as to achieve the greatest possible economy. The diagrams below illustrate typical pile test results.



Pile test below tent at Daun upon Eifel



Pile test in Rotterdam-Maasvlakte, Netherlands for E.ON power station



Distribution of force and skin friction versus settlement chart of a pile diameter 1,180 mm in stiff marine clay, 5 m socketed in moraine

Quality- assurance

Pile installation is carried out by qualified personnel whose technical experience is constantly monitored and improved by in-house seminars and quality audits. To ensure both site safety and optimum production levels, all drilling rigs and tools are regularly tested. All construction materials are selected on the basis of the specified structural and process criteria to maintain quality to the standards required. The pile production is documented according to EN 1536 (previously: DIN 4014). During construction of cast

in place continuous flight auger (CFA), Front of wall (FOW) or mixed in place (MIP) piles, all the parameters relating to construction are displayed for the rig operator on a monitor and are stored in a data logger developed by Bauer Spezialtiefbau. The stored data are computer processed, evaluated for technical content and plotted out in a standardised format. All other processes are recorded by the piling supervisor in accordance with standard procedures.

PRODUCTION LOG, CFA Piles

PRODUCTION LOG, MIP

Job site:	Baden - Baden, Balger Str.	Project No.:	A2310355
Client:	EBUT Baden - Baden	Cut:	S0000002
Operator:	Schreyer Alex	Date:	15.04.2008
Drilling Rig:	RG 25	Wall thickness/Dia.:	0.55 m
I-No.:	45757	Width of cut:	1.7 m
		Drilled depth:	17.27 m
		Number of test cubes:	

MIP recipe:	2.32	Additives	
W/Z:		Grout density:	1.264 - 1.270
		Actual grout con.:	6.446 m³

Beginn:	15:56:08
End:	16:16:16
Total time:	00:20:08

Comments:

Supervisor:

BAUER BST-D-86522 Schrobenhausen Tel. 08252/97-0 Germany

PRODUCTION LOG, CFA Piles

Project No.: 23302610

008
09.07.2007
880 m.m
0 *
11.67 m

11.11.2008

Plan Nr.: 100503001

880 mm Bohrung	<input checked="" type="checkbox"/> verrohrt
500.00 müNN	<input type="checkbox"/> unverrohrt
5.00 m	<input type="checkbox"/> teilverrohrt
18.30 m	
2.40 m	
16.30 m	
0.00 müNN	Verschleiß:
1.70 müNN	4 Stck WS
*	2 Stck RSM
	Stck FZ

Plan Nr.: s.o

in des Bewehrungskorbs:

em Betonieren

den Betonieren

K 1 UK 2

Probewürfel:

ja nein

kg/m³

mm

(-)

0 bs 550 mm

540 mm

der Einbringung:

Schüttrohr

Rumrohr

sondigen (s. Bem.)

Uhrzeit	Wetter
7:00	bewölkt
8:00	bewölkt
9:11	bewölkt
10:50	bewölkt

BSI 11/2007



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