CFA

Continuous Flight Auger Piles

Method Statement

BAUER Maschinen GmbH

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1 Definition and construction principle

CFA piles are cast-in-situ piles, where a hollow-stem continuous flight auger is rotated and driven into the ground at a controlled speed to the specified pile depth. Concrete is then pumped under continuous positive pressure through the hollow stem of the auger to fill the borehole as the auger is withdrawn.

Once the auger is completely out of the borehole a reinforcing cage can be inserted and driven into the fresh concrete to the designed depth.

Following the development of high torque rotary heads and drilling rigs with extended masts and high crowd and extraction forces, the range of diameters and depths for CFA piles has increased significantly and it is possible to install CFA piles through a wide variety of soils including clays, silts, peat, sand and sandy gravels. It is possible, using the high crowd forces that the Bauer rigs can - together with new, automatic control systems - install CFA piles through stiff soil layers and to socket them into rock.

The method is suitable for cohesive, non-granular soils:

- Undrained shear strength: $c_u > 15$ kN/m²
- No boulder presence

2 Construction procedure

The working sequence for the construction of CFA piles comprises the following key steps:

- Preparation of the site and setting up the rig,
- Drilling and concreting the piles.
- Inserting the reinforcing cage.

2.1 Preparation of the site and setting up of the rig

A level, stable working platform must be prepared at the pile position to support the weight and pressures imposed by the drilling rig. The inclination of the working platform should not exceed 3%.

The drilling rig is placed in position so that the tip of the CFA is exactly on the pile position. The mast is then levelled using the automatic levelling device included in the Bauer base carrier.

The bottom end of the hollow shaft is sealed with a disposable tip.

2.2 Drilling and concreting the pile

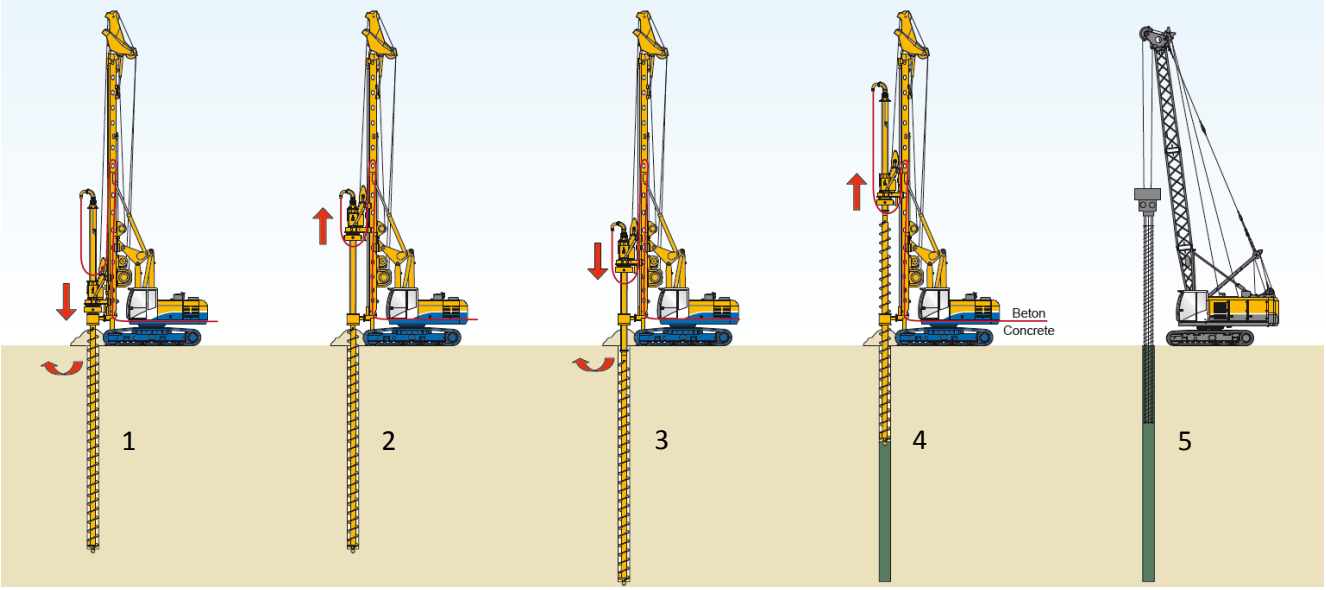

Fig 1: Construction steps

Once the drilling rig is set up over the pile position, the CFA drill string is drilled into the ground to the required depth, extended by optional Kelly extension (**2**), by the torque generated by the rotary drive of the drilling rig and the crowd pressure generated by the crowd winch (**1 & 3**).

During this operation care must be taken to ensure that the speed of rotation of the auger is not excessive in respect to its rate of penetration. If the speed of rotation is too high there is a risk of "Overflighting" i.e. the removal of soil from the sides of the borehole and moving this to the surface, thus reducing the geotechnical characteristics of the pile/soil interface. This phenomenon becomes especially important when the CFA meets hard layers of soil or rock and the speed of penetration slows. The speed of rotation must be adjusted accordingly.

If the rig is fitted with the "Drilling Assistant" module, after having entered the geometric dimensions of the auger, the computer will regulate automatically the speed of rotation with respect to its penetration speed.

Once the founding level is reached, the concrete pump is activated and concrete is pumped through the swan neck and swivel to fill the hollow shaft of the CFA. A pressure sensor on the swan neck measures the concrete pressure. An additional sensor records the pump strokes. The volume per stroke (determined by calibration) is typed into the B-Tronic, so that the flow rate is known. Concrete pressure and concrete volume are displayed on the B-Tronic screen. As soon as the entire hollow shaft is filled up with concrete, extraction of the auger will start (**4**).

The extraction speed controlled by the “pulling assistant”. It depends either on the flow of concrete or on the concrete pressure.

During the concreting and extraction phase the auger is normally not made to rotate. Nevertheless some project specifications permit rotation of the auger during extraction. In this case care must be taken to ensure that the auger is made to rotate in the drilling direction otherwise it will discharge soil and contaminate the concrete.

Fig 2: Pressure sensor

It is strongly recommended to activate the auger cleaner during the concreting and extraction phase. Cleaning of the flights prevents spoil dropping from height and possibly causing injury to nearby personnel.

Fig 3: Auger cleaner

2.3 Inserting the reinforcement cage

In the CFA method, contrary to other piling methods, the reinforcing cage is installed after the borehole has been concreted (**4**). Depending on its design the pile can be reinforced over part of its depth or, with limitations, to its full depth.

In order to ensure that the cage will penetrate easily into the fresh concrete, particularly at depth, a number of characteristics need to be ensured:

- The reinforcing cage must be designed and built stiff.
- The concrete mix must be designed to ensure that it will remain fluid for a period of time sufficient to ensure insertion of the cage, particularly where the cage is long or is inserted in more elements that need to be spliced together.
- In permeable soils – especially in sand - there will be a loss of fluid from the concrete mix over a short period of time and the mix will become stiff and resist penetration of the cage. The concrete mix must therefore be designed accordingly.
- Installation of the reinforcement cage should start immediately after the concreting phase.

The reinforcing cage will normally penetrate under its own weight, or with a little manual help, to depths of about 6 – 10 m. Beyond this depth, the use of a vibrator (Fig.4) is needed to push the cage to its designed depth. For that case it is essential that the rebar cage sections are welded.

Fig 4: Rebar installation with vibrator

Fig 5: Rebar installation with drawdown beam and vibrator

When cages are long, they become slender and tend to buckle when pushed into the concrete mix. In these cases it is better to fit the cage with a central driving element (normally a large diameter steel tube or I-beam) with a bayonet connection at the bottom of the cage. A vibrator is fitted to the top of the driving element and the cage is drawn into the concrete mix from the bottom rather driven from the top. (Fig. 5)

This method of operating ensures that the cage does not buckle and enables cages to be inserted to depths beyond 20 m.

3 Drilling Rig and Drilling Equipment

3.1 Drilling rig

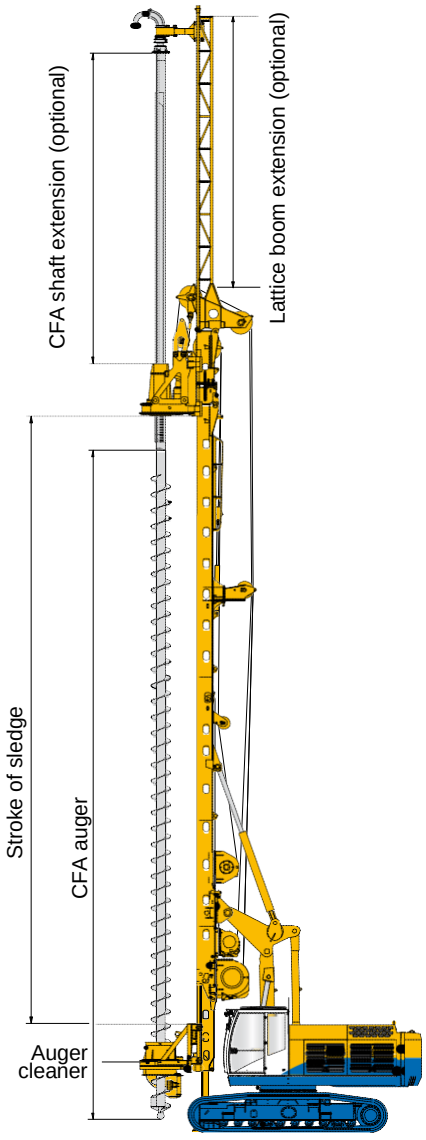

Fig 6: BG with drill shaft extension

All Bauer BG drilling rigs with a crowd winch can be easily converted to the CFA mode. They are all fitted with CFA crowd systems and high extraction force capabilities.

The CFA depth capability of the rig is determined by the stroke of the rotary head. On some rigs mast extensions are available to increase the stroke and therefore the depth capability of the machine (The Bauer technical department must be consulted to determine limitations to the mast lengths).

Care must be taken however, when using CFA drill shaft extensions, as the upper part of the borehole, in correspondence with the shaft extension, is not supported and may collapse causing extra resistance to the extraction of the tool during the concreting phase.

For an optimized extraction force various winch combinations are available depending on the type of rig.

3.2 Tools

CFA´s are available in diameters ranging from 400 mm to 1200 mm. The bottom end of the CFA can be fitted with different starters to suit the predominant ground formation on the project (See the Bauer catalogue for the design of different starters).

4 Material Specifications

4.1 Reinforcement

All steel shall be in accordance with the specifications set out in the contract documents.

Reinforcing cages must be designed and built stiff to prevent them from buckling when driven into the freshly concreted borehole.

Reinforcing cages must be fitted with appropriate spacers to guarantee the design cover. Their lower part should be tapered inwards to keep the cage central in the borehole during insertion.

4.2 Concrete

The concrete and its components shall comply with the specifications set out in the contract documents.

The maximum size of aggregates should not exceed 16 – 20 mm, but it is fundamental when constructing CFA piles that the mix be fluid enough to facilitate insertion of the reinforcing cage. This fact becomes particularly critical when piles are long or when they are built in permeable soil where there is the risk of loss of fluid and stiffening of the mix.

The design strength class of the concrete shall be at least of grade C 20/25 or C 30/37. For reasons of workability and its self-compacting properties the following criteria should be met (even if they are higher compared to the requirements of the contract specifications)

- Cement content (placement - dry) > 325 kg/m^3
- Cement content (placement - submerged) > 375 kg/m^3
- Water/cement ratio < 0.6
- Slump flow (consistency classification F 5) 560 – 620 mm (slump 160 – 180 mm)

Prior to starting works trial mixes should be prepared to check suitable mix proportions, workability and strength.

5 Quality Control and Quality Assurance

The use of a reliable monitoring and data recording system during the whole construction process is fundamental.

All Bauer drilling rigs are fitted with automatic verticality control systems to ensure that the masts and tools are kept vertical at all times thereby assisting the operators to drill properly aligned holes.

The Bauer B-Tronic system will record all parameters during the construction process. These can be reproduced and printed for QA/QC assurance.

The use of the Bauer "Drilling and Pulling Assistants" will further guarantee quality and the good behavior of the pile.

Fig 7: B-Tronic screenshots – left: Drilling Assistant – right: Pulling Assistant

The use of this equipment is highly recommended

For QA/QC work all drilling and concreting data are available in real time.

6 Safety

To avoid any danger or injury during the piling works the following measures may be taken:

- When extracting the soil-filled continuous flight auger a (hydraulically operated) auger cleaner should be used.
- Protect all working and storage areas that are to be off limits to the public, by temporary site fencing clearly marked with hazard or danger signs.
- During rest days and rest hours cover up or protect all open bores with fencing at least 1.5 m in height.
- During rest days and rest hours store safely and lock all tools & machines.
- When working at night provide adequate platforms and lighting.
- When carrying out maintenance on machines and equipment follow strictly the manufacturer's recommendations.
- Proper working attire should be worn by all persons engaged on site, inclusive of safety appraisals such as helmets, proper shoes or boots safety harnesses etc.
- Comply with all other safety measures prescribed by the general conditions of contract.

7 Annexes

7.1 List of Equipment

The following is a list of typical equipment required to construct CFA piles

Nos.	Description
1	Bauer BG drilling rig with CFA kit and auger
1	Concrete pump with capacity between 60 to 120 m^3/h
1	Vibrator for rebar installation with top cage bell or drawdown beam
1	Excavator for moving drill spoil and for assistance during cage installation
1	Optional: Service crane (handling of reinforcement cage)

7.2 Recommended Manpower

The following manpower chart is based on 1 shift per day at peak performance.

Drilling operation:	Number
Foreman / Engineer	1
Operator	1
Frontman	1
Reinforcement and Concreting	
Concrete pump operator	1
Excavator operator	1

8 Disclaimer

The purpose of this Method Statement is to generally describe the Continuous Flight Auger Piling Method and the sequence of activities required to execute the method. It describes also the main equipment which will be needed to execute the work.

We emphasize that this Method Statement is a description of events given at the planning stage. Varying soil conditions or differing site conditions may result in a modification of the construction methodology.

All data used are either data gathered from various documents or verbal information provided by the customer or assumed by Bauer to be able to complete the MS.

The MS is provided to the customer free of any consideration and as a guide only.

The customer shall check all the data used and recommendations made and come to their own conclusion as to adopt the system proposed or use other or improved methods.

Under no circumstances shall Bauer or the persons preparing this MS accept any type of liability to the same unless agreed through written contract.