EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1536

February 1999

ICS 93.020

English version

Execution of special geotechnical work - Bored piles

Exécution des travaux géotechniques spéciaux - Pieux forés

Ausführung spezieller geotechnischer Arbeiten (Spezialtiefbau) - Bohrpfähle

This European Standard was approved by CEN on 1 June 1997.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 1536:1999 E

Contents

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 288 "Execution of special geotechnical works", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 1999, and conflicting national standards shall be withdrawn at the latest by August 1999.

The remit of TC 288 is the standardisation of the execution procedures for geotechnical works (including testing and control methods) and of the required material properties. WG 3 has been charged with the subject area of bored piles, including barrettes but not "mini piles" of diameter less than 0,3 m.

For bored piles not included in this European Standard, the construction should follow, as far as applicable, the general principles of this EN 1536.

The document has been prepared to stand along side with ENV 1997-1: Eurocode 7: Geotechnical design - Part 1: General rules. Clause 7 "Design related considerations" of this European Standard expands on design only where necessary (e.g. the detailing of reinforcement) but provides full coverage of the construction and supervision requirements.

It has been drafted by a working group comprising delegates from 11 countries and against a background of more than 30 pre-existing piling standards and codes of practice both national and international. In view of different construction methods used internationally and the respective experience it can be necessary to supplement this European Standard or parts of it by a National Foreword to cater for specific or local situations.

In accordance with the CEN/CENELEC Internal Regulations, the following countries are to bound to implement this European Standard: Austria, Belgium, Czechovakia, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

1 Scope

1.1 This European Standard establishes general principles for the construction of piles

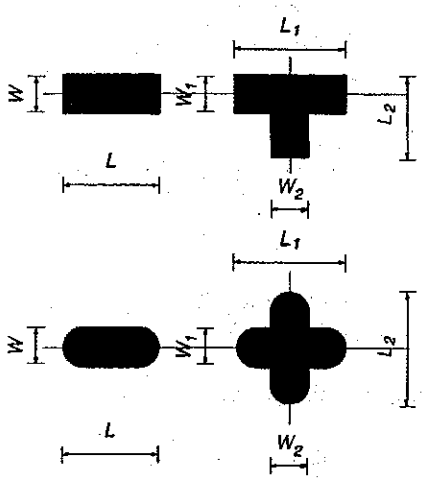
- which are formed in the ground by excavation and
- which contain a structural member to transfer loads and or limit deformations.

1.2 This European Standard covers

- piles with circular shape (see figure 1) and
- piles with barrette shape, provided the section is concreted in a single operation.

D: Pile diameter

Figure 1 : Circular bored pile



L: Barrette length
W: Barrette thickness
A: Cross-sectional area of the shaft

Figure 2 : Examples of barrette piles and dimensions

1.3 The barrette shapes covered are rectangular, **T**- or **L** shaped in plan or any other similar configuration (see figure 2).

1.4 This European Standard covers piles with:

- uniform cross-section (straight shaft);
- telescopically changing shaft dimensions;
- excavated base enlargements; or
- excavated shaft enlargements

(see figure 3).

NOTE : The shape of the pile base and of an enlargement can depend on the tool used for the excavation.

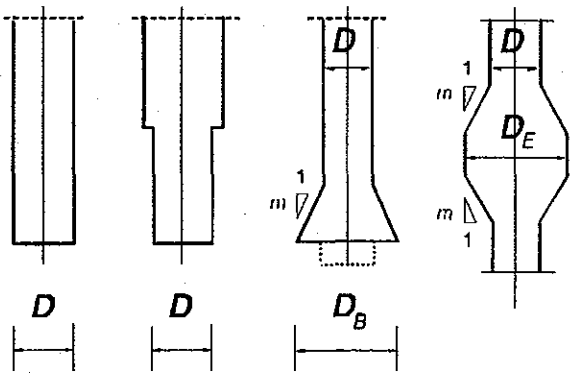


Figure 3 : Examples for straight shaft piles and piles with shaft and base enlargement

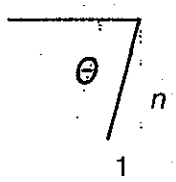


Figure 4 : Definition of the rake

1.5 The provisions of this European Standard apply to piles with the following dimensions :

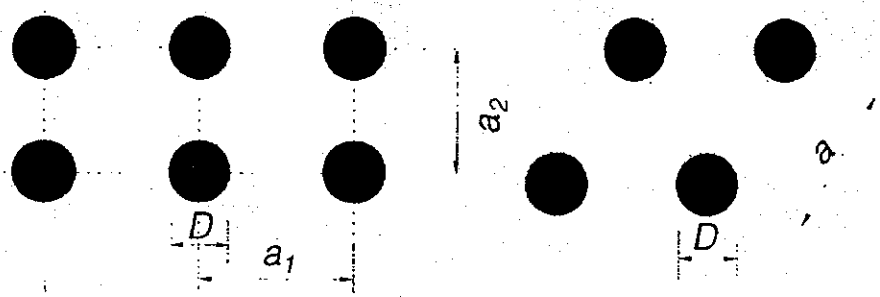
- shaft diameter : $0,3 \leq D \leq 3,0$ m (see figure 1 and figure 3);
- dimension for cast-in-place barrette piles :
  $W_i \geq 0,4$ m (see figure 2);
- ratio between the dimensions : $L_i / W_i \leq 6$
  where:
  L_i is the largest dimension of a cast-in-place barrette pile and
  W_i is the least dimension of a cast-in-place barrette pile
  (see figure 2);
- least dimension ≥ 0,3 m for precast elements used in barrette piles or piles:
  $D_P \geq 0,3$ m and
  $W_P \geq 0,3$ m respectively
  where:
  D_P is the diameter of a circular precast element;
  W_P is the thickness of a rectangular precast element;
- rake generally : $n \geq 4$ ($\Theta \geq 76°$) (see figure 4) ;
- rake for permanently cased piles : $n \geq 3$ ($\Theta \geq 72°$);
- base enlargements or cross-sectional area of barrette piles: $A \leq 10$ m² ;

1.6 Shaft or base enlargements covered by this European Standard are:

- base enlargements in non-cohesive ground :
  $D_B / D \leq 2$ and
  in cohesive ground : $D_B / D \leq 3$;
- shaft enlargements in any ground : $D_E / D \leq 2$;
- slope of the enlargement in non-cohesive ground :
  $m \geq 3$ and
  in cohesive ground : $m \geq 1,5$
  (see figure 3).

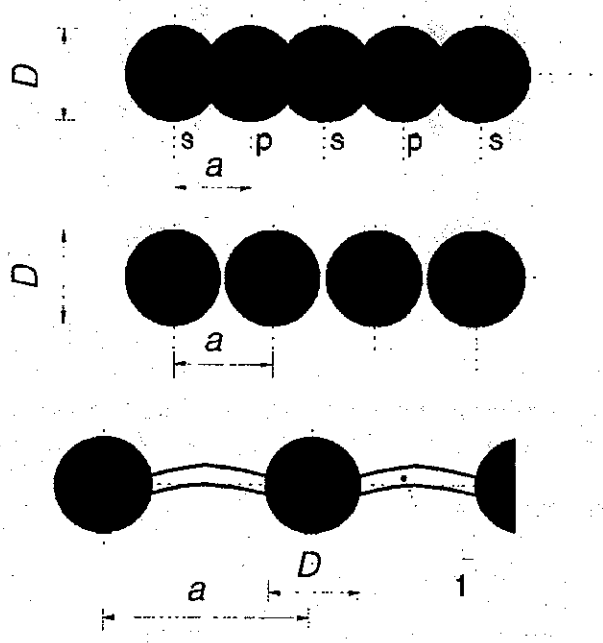
1.7 The provisions of this European Standard apply to :

- single piles;
- pile groups (see figure 5);
- walls formed by piles (see figure 6).



D: Shaft diameter
a: Distance of the piles according to design

Figure 5 : Examples of pile groups



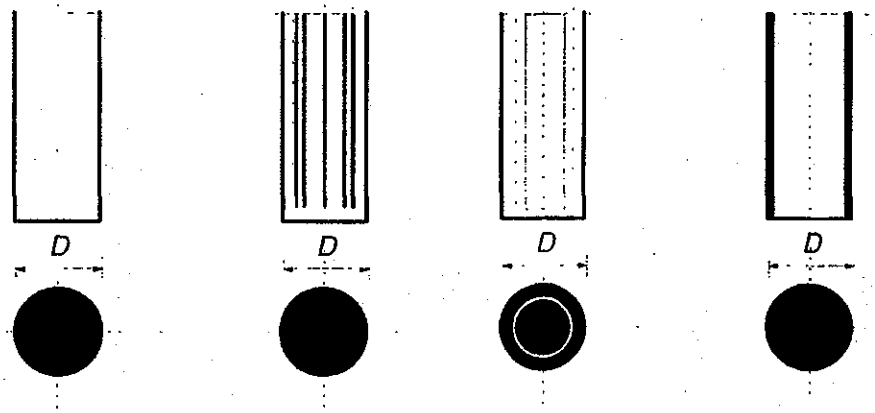
Secant bored pile wall:
$a < D$
p: primary piles
s: secondary piles

Contiguous bored pile wall:
$a \cong D$

Widely spaced bored pile wall:
$a > D$

a: Distance of the piles
1 : Lagging

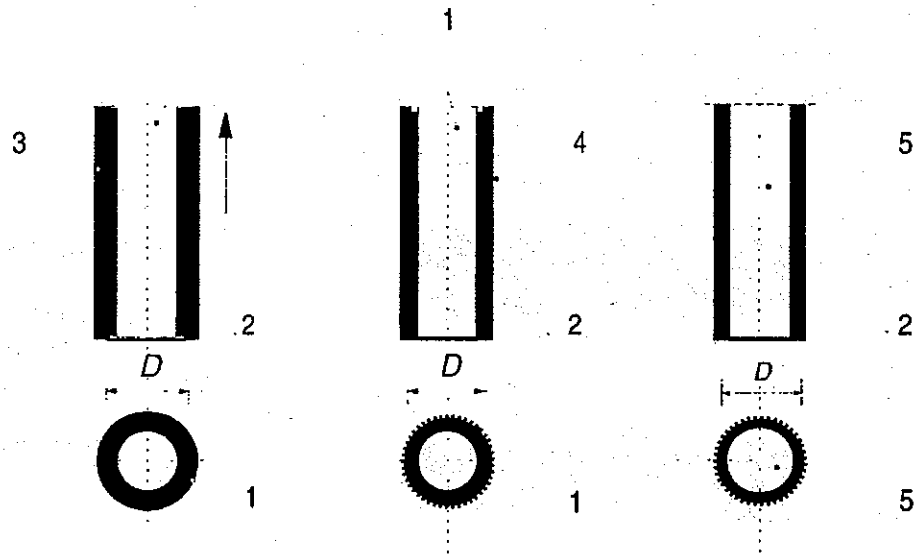
Figure 6 : Examples of bored pile walls



Use of plain concrete

Use of concrete with bar reinforcement

Use of special reinforcement (steel section or tube)



Use of precast concrete element as main or supplementary structural member

Use of steel tube as main or supplementary structural member

1 : Precast concrete element
2 : Grout
3 : Temporary casing (extracted)
4 : Uncased excavation
5 : Unreinforced or reinforced concrete or cement grout
D: Shaft diameter

Figure 7 : Examples of circular piles

1.8 The piles which are the subject of this European Standard can be excavated by continuous or discontinuous methods using support methods for stabilizing the excavation walls where required.

1.9 This European Standard applies only to construction methods that allow the designed cross-sections to be produce.

1.10 The provisions apply to piles where the bearing member is constructed

- of unreinforced (plain) concrete,
- of reinforced concrete,
- of concrete reinforced by means of special reinforcement such as steel tubes, steel sections or steel fibres,
- of precast concrete (including prestressed concrete) elements or steel tubes where the annular gap between the element or tube and the ground is filled by concrete, cement or cement-bentonite grout

(see figure 7).

1.11 Micropiles, mixed-in-place columns, columns constructed by jet grouting, ground improvement for piling, mixed-in-place pile bases and diaphragm walls are not covered by this European Standard.

2 Normative references

NOTE 1 : This European Standard incorporates by undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

NOTE 2 : Exceptionally, the list of normative references contains also European Standards and Prestandards which are at the draft stage. If one of those documents has become a European Standard, the references shall be checked.

2.1 Users of this European Standard shall satisfy themselves that the standards and other references used are current issues and that there is compatibility between the reference documents employed.

2.2 List of documents to which normative reference is made in the text :

ENV 197-1	1992	Cement - Composition, specifications and conformity criteria - Part 1: Common cements
ENV 206	1990	Concrete - Performance, production, placing and compliance criteria
EN 791	1996	Drill rigs - safety
prEN 1008	1997	Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including wash water from receycling installations in the concrete industry as mixing water for concrete
EN 1538	1998	Execution of special geotechnical works - Diaphragm walls
ENV 1991-1	1994	Eurocode 1 : Basis of design and actions on structures - Part 1: Basis of design
ENV 1992-1-1	1991	Eurocode 2 : Design of concrete structures - Part 1-1 : General rules and rules for buildings
ENV 1994-1-1	1992	Eurocode 4 : Design of composite steel and concrete structures - Part 1-1: General rules for buildings
ENV 1997-1	1994	Eurocode 7 : Geotechnical design - Part 1: General rules
EN 10025	1990	Hot rolled products of non-alloy structural steels - Technical delivery conditions
ENV 10080	1995	Steel for reinforcement of concrete, weldable ribbed reinforcing steel B 500 - Technical delivery conditions for bars, coils and welded fabric
EN 10210-1	1994	Hot finished structural hollow sections of non-alloy and fine grain structural steels - Part 1: Technical delivery requirements
prEN 12620	1996	Aggregates for concrete including those for use in roads and pavements

3 Definitions

NOTE : The following definitions are used for the construction of bored piles covered by this European Standard. Additional explanations of piling terms are listed in Annex A. For the purposes of this European Standard, the following definitions apply.

3.1 pile **fr : pieu** **de : Pfahl**

Slender structural member in the ground for the transfer of actions. For the purpose of this European Standard the slenderness ratio is not limited.

3.2 bored pile **fr : pieu foré** **de : Bohrpfahl**

Pile formed with or without a pile casing by excavating or boring a hole in the ground and filling with plain or reinforced concrete.

3.3 barrette

fr : barrette
de : Schlitzwandelement

Discrete length of diaphragm wall, usually short, or a number of interconnecting lengths cast simultaneously (e.g. **L**-, **T**- or cruciform shapes), used to support vertical and/or lateral loads.

3.4 compression pile

fr : pieu en compression
de : Druckpfahl

Pile to resist compressive forces.

3.5 continuous flight auger pile (CFA-pile)

fr : pieu à la tarière continue creuse (CFA)
de : Schneckenbohrpfahl

Bored pile formed by means of a hollow stemmed continuous flight auger through the stem of which concrete or grout is pumped as the auger is extracted (see figure A.9).

3.6 end bearing pile

fr : pieu travaillant en pointe
de : Spitzendruckpfahl

Pile transmitting forces to the ground mainly by compression on ist base.

3.7 enlarged base

fr : base élargie
de : Fußaufweitung

Base of a pile formed to have an area greater than that of ist shaft. For bored piles, normally constructed by the use of special underreaming or belling-out tools (see figure 3).

3.8 friction pile

fr : pieu flottant
de : Reibungspfahl

Pile transmitting actions to the ground mainly by friction and adhesion between the lateral surface of the pile and the adjacent ground.

3.9 prepacked pile

fr : pieu ballasté injecté
de : Prepacked-Pfahl

Pile where the completed excavation is filled with coarse aggregate which is subsequently injected with cement mortar from the bottom up.

3.10 shaft diameter

fr : diamètre du fût
de : Pfahldurchmesser

Diameter of the part of the pile between the pile head and the pile base :

a) for bored piles constructed with casings: equal to external diameter of the casing ;
b) for bored piles constructed without a casing: equal to the maximum diameter of the boring tool.

3.11 tension pile

fr : pieu en traction
de : Zugpfahl

Pile designed to resist tensile forces.

3.12 preliminary pile

fr : pieu préliminaire
de : Probepfahl (1)

Pile installed before the commencement of the main piling works or section of the works for the purpose of establishing the suitability of the chosen type of pile and/or for confirming the design, dimensions and bearing capacity.

3.13 trial pile

fr : pieu de faisabilité
de : Probepfahl (2)

Pile installed to assess the practicability and suitability of the construction method for a particular application.

3.14 test pile fr : **pieu d'essai**
de : **Probepfahl (3)**

Pile to which loads are applied to determine the resistance deformation characteristics of the pile and the surrounding ground.

3.15 working pile fr : **pieu de fondation**
de : **Bauwerkspfahl**

Pile for the foundation of a structure.

3.16 static pile test fr : **essai de chargement statique de pieu**
de : **statische Probebelastung**

Loading test where a pile is subjected to chosen axial and/or lateral forces at the pile head for the analysis of its capacity.

3.17 maintained load pile test fr : **essai de chargement par palier**
de : **lastgesteuerte Probebelastung**

Static loading test in which a test pile has loads applied in incremental stages, each of which is held constant for a certain period or until pile motion has virtually ceased or has reached a prescribed limit (ML -test).

3.18 constant rate of penetration test fr : **essai de chargement à vitesse d'enfoncement constante**
de : **weggesteuerte Probebelastung**

Static loading test in which a test pile is forced into the ground at a constant rate and the force is measured (CRP-test).

3.19 dynamic pile test fr : **essai de chargement dynamique de pieu**
de : **dynamischer Pfahlversuch**

Loading test where a dynamic force is applied at the pile head for assessment of pile capacity.

3.20 integrity test fr : **essai d'intégrité**
de : **Integritätsprüfung**

Test carried out on an installed pile for the verification of soundness of materials and of the pile geometry.

3.21 sonic test fr : **essai d'auscultation sonique par réflexion**
de : **Ultraschallversuch**

Integrity test of a pile where a series of sonic waves is passed between a transmitter and a receiver through the concrete of a pile and where the characteristics of the received waves are measured and used to infer continuity and section variations of the pile shaft.

3.22 sonic coring fr : **essai d'auscultation sonique par transparence**
de : **Ultraschallversuch im Pfahl**

Sonic integrity test of pile concrete carried out from core drillings in a pile shaft or from a pre-placed tube system.

4 Needs for the construction of bored piles

4.1 Any information important for the execution for the works on site should :

a) be provided with the specifications of the works;

b) be available before commencement on site; and

c) include:

- the geotechnical information (see clause 5);
- the site conditions, (e.g. size, site boundaries, topography, slope, access, limitations);
- existence, location and condition of adjacent structures, (e.g. buildings, roads, utilities or services), underground structures and foundations, archaeological remains, headroom restrictions (e.g. power lines);
- underground contamination or hazards that can affect the execution method, the working safety or the discharge of excavation material from the site;
- environmental restrictions (e.g. on noise, vibration or pollution) and any legal or statutory restrictions;
- the design and specifications for the works;
- all necessary or relevant information for the production of the working drawings and method statements (where required);
- previous experience with bored piling or other foundations or underground works on or adjacent to the site;
- concurrent activities which can affect the work (e.g. dewatering, tunnelling, deep excavation);
- additional requirements for the supervision, monitoring or testing of the works;
- functional requirements for water tightness at joints of bored pile walls;
- the location of main grid lines for setting out.

4.2 Necessity, extent, procedure and responsibility for any survey of the conditions of structures, roads, services, etc. adjacent to the works area shall be established. The survey shall be carried out and be available prior to the commencement of the works.

4.3 Bored piling works shall conform with this European Standard provided the criteria and requirements set out in the following clauses have been observed. A suitable quality control system shall be established for supervision and monitoring.

4.4 Any additional or deviating requirements falling within the permissions given in this European Standard shall be established and agreed before the commencement of the works and the quality control system shall be suitably amended.

EXAMPLES : Such additional or deviating requirements can be :

- reduced or increased geometrical construction deviations;
- application of different or varying construction materials;
- precast concrete elements;
- special anchorage or doweling of piles to underlying rock;
- special reinforcement as the use of steel tubes or sections or of steel fibres;
- grouting of pile shafts or bases;
- cutting-off of pile heads by mechanical equipment;
- extensive manual excavation.

5 Site investigation

5.1 General

NOTE : ENV 1997-1, 3 and 7 and the relevant national documents are valid for the general requirements of site investigation (as long as respective European Standards are not available). The provisions of this clause contain additional requirements and recommendations.

5.1.1 The site investigation depth shall be sufficient to identify all ground formations and layers affecting the construction and to recognize the capacity and the deformation properties of the ground.

5.1.2 The extent of the site investigation shall be sufficient for the determination of the characteristic ground conditions of the site in accordance with the requirements of ENV 1997-1

5.1.3 When geotechnical categories as defined in ENV 1997-1 are applied for the foundation, categories 2 or 3 shall be used as appropriate.

5.1.4 If the maintenance of stability of a pile bore is likely to be difficult, a trial bore of relevant dimensions should be carried out.

5.1.5 Relevant experience of the execution of comparable foundation works under similar conditions and/or in the vicinity of the site should be taken into account when determining the extent of site investigation.

5.1.6 Reference to relevant experience is permitted if appropriate means of verification are taken (e.g. by penetration tests, pressuremeter or other tests).

5.1.7 The site investigation report shall be made available together with all relevant data known to affect the choice of method.

5.1.8 Bore holes shall be suitably backfilled to such levels that subsequent pile construction and performance will not be affected.

5.2 Specific requirements

5.2.1 Apart from the general geological description and the details as listed in ENV 1997-1 the site investigation report shall contain the following information :

a) the ground level at any point of investigation or testing relative to the recognised national datum or to a fixed reference bench mark;

b) presence and characteristics of loose or soft soils or ground that is likely to soften, loosen or become unstable during excavation;

c) presence of soil- or rock formations with a tendency to swelling;

d) presence of coarse soils, ground with an open structure (high permeability) or cavities which can cause sudden loss of a stabilizing fluid or a sudden drop of concrete during the placement;

e) presence of cobbles and boulders or other underground obstructions that can cause difficulties for the excavation or could require special methods or tools for their penetration or removal;

f) thickness of any potential bearing stratum;

g) presence, extent and thickness of any strata that can be sensitive to water infiltration or to stress caused by piling tools (e.g. impact, percussion or vibration);

h) piezometric levels of ground-water and its variation, including any artesian ground-water tables;

i) underground strata where high ground-water velocities exist;

j) aggressiveness of ground-water or ground that can affect the properties of a stabilizing fluid or of fresh or hardened concrete (see ENV 206);

k) level and inclination of any relevant underlying rock;

l) thickness and extent of any existing weathered rock;

m) type and quality of rock, especially:

   1) strength;

   2) state of degradation;

   3) cavities;

   4) open or filled joints;

   5) zones of weakness;

n) presence, extent, thickness and nature of contaminated soil or waste, that can influence the disposal of the excavated material;

o) mining beneath the site; and

p) site stability problems.

5.2.2 The site investigation has to demonstrate that, where end bearing is to be relied on, any competent founding stratum is not immediately underlain by a soft stratum where there is a possibility of a punching failure.

6 Materials and products

6.1 General

6.1.1 All materials and products for incorporation into the bored pile shall be in accordance with the relevant European Standards (or, as applicable and as long as respective European Standards are not available, national standards) and with the specifications for the works.

6.1.2 The sources of supply of materials shall be documented and shall not be changed without prior notification.

6.1.3 Rejected materials are to be removed promptly from the site.

6.2 Materials for concrete and grout

6.2.1 Cement

6.2.1.1 Cement for bored piles shall be of the following types as defined in ENV 197-1, 5.1:

- portland cement — CEM I;
- portland slag cement — CEM II/A-S and II/B-S;
- portland silica cement — CEM II/A-D;
- portland fly ash cement — CEM II/A-V and II/B-V;
- blast furnace cement — CEM III/A, III/B and III/C.

6.2.1.2 Other cement types may be used when specified and of proven performance in the specific conditions.

6.2.1.3 Calcium aluminate cement shall not be used.

6.2.1.4 The use of cement containing additions (type II) should be preferred because they have been shown to have beneficial effects on concrete, such as

- improved workability,
- reduced heat generation during setting and
- improved durability.

6.2.2 Aggregates

6.2.2.1 Aggregates shall comply with prEN 12620 and ENV 206, 4.2.

6.2.2.2 The sources of supply of material, the grain size distribution of aggregates, and their mineralogical types shall be agreed prior to commencement of work.

6.2.2.3 Rounded aggregates should be preferred when placing concrete by tremie.

6.2.2.4 The maximum size of the aggregate shall not exceed 32 mm or ¼ of the clear distance of the longitudinal bars, whichever is the less.

6.2.2.5 Frozen aggregate shall be heated so that no adhering ice or hoar frost enters the mix.

6.2.3 Water

6.2.3.1 Mixing water shall comply with prEN 1008 and ENV 206, 4.3.

6.2.3.2 Water may be chilled or may be replaced by up to 50 % of its mass by ice-chips for cooling of fresh concrete at high ambient temperatures.

6.2.4 Additions and admixtures

6.2.4.1 Additions and admixtures shall comply with ENV 206 4.4 and 4.5

6.2.4.2 As long as respective specific European Standards are not available, the use of additions or admixtures shall be in accordance with the national standards and/or regulations in the place of use of the concrete.

6.2.4.3 Additions and admixtures shall be used in accordance with the approval document and the manufacturer's instructions.

6.2.4.4 To provide the properties of the concrete required for the placement process the following admixtures may be used

- water reducing/plasticizing,
- high range water reducing/super-plasticizing and
- set retarding.

6.2.4.5 The mix and the application of the concrete and the specific addition or admixture shall be compatible.

6.2.4.6 Additions and admixtures may be used

- to give a mix of high plasticity and
- to avoid bleeding, honeycombing or segregation that might otherwise result from a high water content
- to prolong the workability as required for the duration of the placement and
- to cater for any interruptions in the placement process.

NOTE: Inappropriate application of additions and admixtures can result into damages.

6.2.4.7 The proportions of admixtures or additions in the mix shall be notified before any concrete is mixed.

6.2.4.8 Where piles are constructed in a cold climate and the ground surrounding the upper part of the pile is to be excavated after concreting, air entraining admixtures may be used in the concrete for the part of the pile to be exposed to frost action.

6.3 Concrete in situ

6.3.1 General

6.3.1.1 The mix composition for concrete for bored piles shall be designed in accordance with ENV 206, unless specified otherwise in this European Standard.

6.3.1.2 Unless otherwise specified, the design strength class of concrete used for bored piles shall range between C 20/25 and C 30/37 with mix proportions and consistency in accordance with tables 1 and 2.

6.3.1.3 For primary piles of bored pile walls a lower strength class of concrete or mortar may be used (see figure 6).

6.3.1.4 If required by the design and compatible with the ground conditions and the construction procedure, higher strength concrete may be used.

6.3.1.5 Concrete for piles shall

- have a high resistance against segregation,
- be of high plasticity and good cohesiveness,
- have good flowability,
- have the ability to self-compact and
- be sufficiently workable for the duration of the placement procedure, including the removal of any temporary casings.

Table 1 : Mix proportions

Cement content: – placement in dry conditions – placement in submerged conditions	≥ 325 kg/m^3 ≥ 375 kg/m^3
Water-cement ratio (W/C)	< 0,6
Fines content $d < 0{,}125$ mm (inclusive of cement) – coarse aggregate $d > 8$ mm – coarse aggregate $d \leq 8$ mm	 ≥ 400 kg/m^3 ≥ 450 kg/m^3

Table 2 : Consistency ranges for fresh concrete in different conditions

Flow diameter range mm	Slump range mm	Typical conditions of use (examples)
$460 \leq Ø \leq 530$	$130 \leq H \leq 180$	– concrete placed in dry conditions
$530 \leq Ø \leq 600$	$H \geq 160$	– placed by pumping or – concrete placed in submerged conditions under water by tremie
$570 \leq Ø \leq 630$	$H \geq 180$	– concrete placed by tremie in submerged conditions under a stabilizing fluid.
Note: The measured slump (H) or flow diameter (Ø) is to be rounded off to the nearest 10 mm.		

6.3.1.6 Where the mix proportions and consistency ranges as set out in tables 1 and 2 do not provide a high density mix, the cement content and the consistency range may be adjusted.

6.3.1.7 Adequate protection against aggressiveness of subsoil and/or groundwater shall be provided, e.g. by mix design or permanent lining.

NOTE :

a) In particularly severe water or ground conditions sufficient protection might not be provided through mix design only.

b) Contaminated ground and water can be additional risks (e.g. retarding influence or changes in the pore-structure of the concrete by heavy metals).

6.3.1.8 Reliable protection for the fresh concrete against rapid groundwater flow that might have a washing-out effect can be achieved by means of a permanent casing or lining.

6.3.2 Mixing

6.3.2.1 The general requirements for the mixing and the accuracy's for batching of constituent materials shall be in accordance with ENV 206, 9.

6.3.2.2 Ready-mixed or site-mixed concrete may be used for the works.

6.3.2.3 Unless otherwise specified, three separate concrete batches shall be prepared for trial mixes.

6.3.2.4 From each trial batch sampling of 6 cubes or cylinders shall be made, two each to be tested after 7 and 28 days respectively and 2 to be kept in reserve for any additional evidence until the results of the 28 day tests are known and the concrete has been accepted.

6.3.2.5 The addition of water to the mixed concrete is prohibited unless where required to permit the correct mixing of additions and admixtures just before placement. The design water-cement ratio shall be maintained.

6.3.3 Sampling and testing

6.3.3.1 Unless it can be shown that the use of the same concrete mix has previously and in similar applications conformed with the requirements, preliminary trial mixes shall be prepared for suitability testing before commencement of concreting, preferably under full scale production conditions. If this is not possible the trials shall be made in an accredited laboratory. The trials shall contain a sufficient number of samples and be representative of the aggregates and cement to be used in pile construction.

6.3.3.2 All sampling and testing of fresh concrete shall be in accordance with ENV 206. In addition, the subsequent provisions apply.

6.3.3.3 The minimum number of cylinder or cube specimens in a sample is four.

6.3.3.4 Sampling of concrete on site for compressive strength testing shall be carried out as follows :

a) one sample for each of the first three piles on a site;

b) one sample for every subsequent five piles (15 piles if the individual concrete volume is 4 m^3 or less) ;

c) two additional samples after interruptions of the works longer than 7 days;

d) one sample for every 75 m^3 of concrete cast on the same day; and

e) at least one sample for every pile cast where concrete stresses require concrete classes C35/45 and above.

6.3.3.5 Where the concrete is produced in a continuous and certified quality assurance system, deviating requirements for concrete sampling on site may be agreed.

6.3.3.6 Additional sampling and testing can be required in special cases.

EXAMPLES :

- End bearing piles on rock;
- single piles;
- high bending stresses.

6.3.3.7 The frequency of testing of

- consistence,
- concrete temperature and
- workability time

shall be in accordance with table 10.

6.3.3.8 A full record of all tests carried out on the concrete shall be kept. Results shall be noted in the concrete placement record.

6.4 Grout

6.4.1 Cement-bentonite grouts and any other grouts shall be prepared, maintained and controlled in accordance with the respective national standards, as long as respective European Standards are not available or, where these do not apply, with other agreed procedures.

6.4.2 Grout composition and the grouting technique and procedure shall be planned and carried out in a manner appropriate to the application (e.g. external grouting around precast elements, base or shaft grouting) and the ground condition.

6.4.3 When selecting the type of cement for grout placed in contact with the ground, account shall be taken of the known or possible presence of aggressive substances.

6.4.4 Water/cement ratios should be appropriate to actual ground conditions.

NOTE :The water/cement ratios may typically range from 0,40 to 0,55 or more, if judged necessary.

6.4.5 Admixtures may be used to create a pumpable grout mix with a low bleed rate.

6.5 Stabilizing fluids

6.5.1 General

6.5.1.1 Stabilizing fluids or drilling mud's shall be a suspension. To differ are

- bentonite suspensions,
- polymer suspensions or
- other suspensions.

6.5.1.2 The fluids shall be prepared by suspending the respective particles in water, with or without the use of admixtures.

6.5.2 Bentonite suspensions

6.5.2.1 Preparation, maintenance and control of bentonite suspensions shall be in accordance with EN 1538 unless stated otherwise in the subsequent subclauses of 6.5.2.

6.5.2.2 Properties of bentonite suspensions, when fresh, ready for re-use and before concrete placement shall be in accordance with table 3.

Table 3 : Characteristics for Bentonite suspensions

	Unit	Suspension		
		fresh	ready for re-use	before concreting
Density	g/cm^3	< 1,10	—	< 1,15
Marsh value	sec	32 to 50	32 to 60	32 to 50
Fluid loss	cm^3	< 30	< 50	—
pH		7 to 11	7 to 12	—
Sand content	% (mass)	—	—	< 4
— : no provision.				

6.5.2.3 The testing procedures for the bentonite suspensions shall follow EN 1538.

6.5.2.4 At the stage before concreting, a value of density up to 1,20 g/cm^3 is permitted for special cases such as in salty water or heavy mud.

6.5.2.5 At the stage before concreting, a value up to 6 % by mass for sand content is permitted for special cases such as friction or unreinforced piles.

6.5.2.6 Where bentonite suspension is also used as a means of transport for the excavated material, higher densities are permitted during the excavation process for the ready for re-use case.

6.5.3 Polymers and other suspensions

6.5.3.1 Other suspensions or drilling mud's, for instance containing

- polymers,
- polymers with bentonite as an admixture,
- other clays

may be used as stabilizing fluids on the basis of experience of

- previous cases in comparable or worse geotechnical conditions or
- full-scale trial excavations on the site.

6.5.3.2 The suspensions shall be prepared, maintained and controlled in accordance with the respective national standards or requirements, as long, as respective European Standards are not available or, where these do not apply, to the manufacturer's instructions.

6.6 Steel

6.6.1 Steel bars, steel wire mesh, steel tubes or sections used for the reinforcement of bored piles shall comply with ENV 10080, EN 10210-1 and EN 10025.

6.6.2 When selecting the type and grade of steel, attention shall be given to the assembly of reinforcement cages and to weldability requirements.

6.6.3 Where steel tubes or sections are used for the reinforcement of piles their design shall be in accordance with ENV 1994-1-1.

6.6.4 Where bored piles are constructed with stabilizing fluids, other metallic elements, such as access pipes for testing purpose, shall, without special precautions, not consist of galvanised steel or other because of the risk for :

- a build-up of filtercake by electrostatic effects , or
- electrochemical corrosion problems of the reinforcement.

7 Design related considerations

7.1 General

7.1.1 The basic European Standards for the design of bored piles shall be :

- ENV 1991-1 Eurocode 1 : Basis of design and actions on structures - Part 1 : Basis of design;
- ENV 1992-1-1 Eurocode 2: Design of concrete structures - Part 1-1 : General rules and rules for buildings;
- ENV 1994-1-1 Eurocode 4: Design of composite steel and concrete structures - Part 1-1: General rules for buildings;
- ENV 1997-1 Eurocode 7: Geotechnical design - Part 1: General rules;

NOTE : Clause 7 relates to matters, resulting from the execution of bored piles which can affect the design.

7.1.2 The design can be affected by

- the specific needs of the project as stated in clause 4,
- the site investigation as described in clause 5 and/or
- the material requirements as set out in clause 6.

7.1.3 The design shall take into account

- the geometrical construction tolerances and
- execution conditions

as set out in 7.2 and clause 8.

7.1.4 A bored pile may be designed as an unreinforced concrete element, if

- the design actions and/or
- actions caused by the construction and/or
- actions resulting from the ground

produce only compressive stresses in the pile and

- the pile foundation is not located in a seismic area.

7.1.5 Reinforcement of pile heads is recommended for unreinforced piles to cater for accidental loads (e.g. resulting from construction works on the site).

7.1.6 Piles should be reinforced over any length through soft or loose soil unless otherwise specified.

7.1.7 Piles designed for bending shall be provided with reinforcement.

7.1.8 Tension piles shall be provided with reinforcement over their whole length.

7.1.9 If there is no design requirement for reinforcement, starter bars should be provided in the pile head for the connection to the superstructure.

NOTE : Base enlargements of piles are usually constructed without reinforcement beyond that required (if any) in the shaft.

7.1.10 Where reinforcement cages are installed after concrete placement, a special and rigid design can be necessary.

7.2 Geometrical construction tolerances

7.2.1 Piles shall be constructed within the following geometrical tolerances:

a) plan location of vertical and raking piles referenced to the working level :
$e \leq e_{max} = 0{,}10$ m for piles with: $D \leq 1{,}0$ m;
$e \leq e_{max} = 0{,}1 \times D$ for piles with: 1,0 m $< D \leq$ 1,5 m;
$e \leq e_{max} = 0{,}15$ m for piles with: $D >$ 1,5 m;

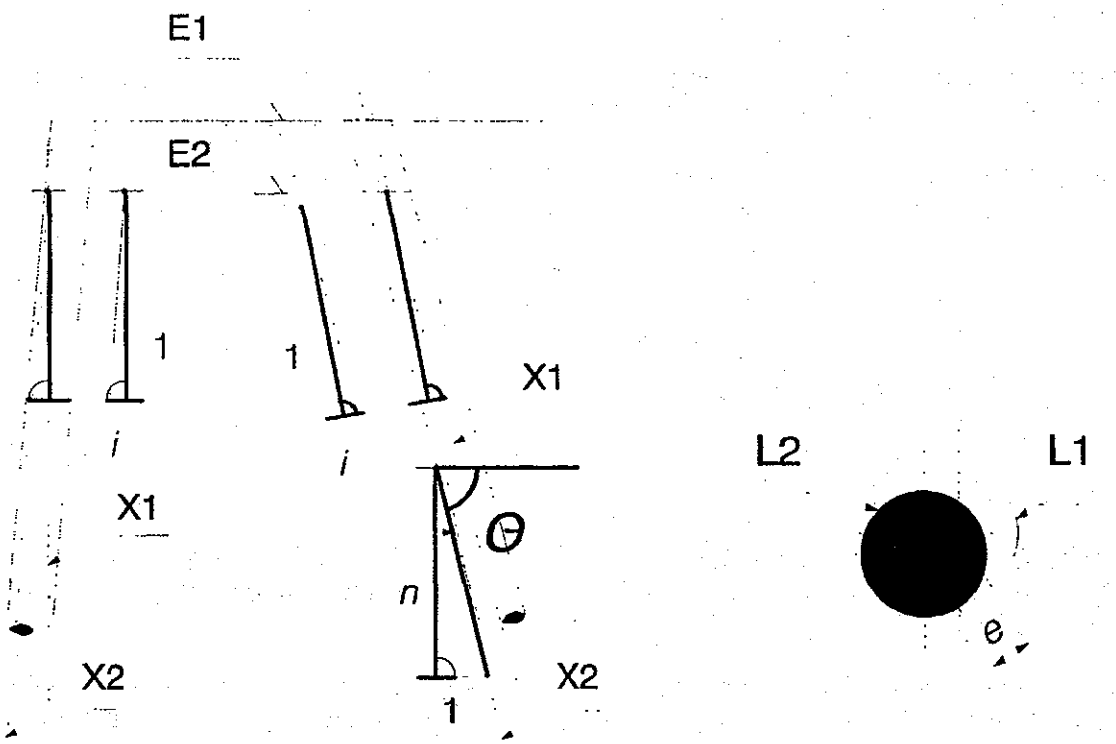
b) deviation of inclination of vertical piles or piles with an inclination of $n \geq 15$ ($\Theta \geq 86°$):
$i \leq i_{max} = 0{,}02$ (0,02 m/m) ;

c) deviation of inclination of piles raking $4 \leq n < 15$ ($76° \leq \Theta < 86°$) :
$i \leq i_{max} = 0{,}04$ (0,04 m/m);

d) deviation in plan of centres of enlargements in relation to the pile axis :
$e \leq e_{max} = 0{,}1 \times D$.

(see figure 8)

NOTE : For the recording of construction deviations the centre of the pile is considered the centroid of the longitudinal reinforcement or, for unreinforced piles the centre of the largest circle which can be drawn within the section at the section at the pile head.



Vertical pile Raked pile Deviation of location

E1 : Working level
E2 : Cut-off level
X1 : Design centre line
X2 : As build centre line
i: Tangent of deviation angle (between the designed and the as built centre line of the pile)
n: Rake of the design centre line against the horizontal
Θ: Angle of the design centre line against the horizontal
L1 : Design location
L2 : As built location
e: Plan deviation at working level

Figure 8 : Definition of geometrical construction deviations

7.2.2 Where tolerances other than those stated are required or allowed in regard to

- constructional demands,
- ground conditions,
- available piling equipment or
- a very deep cut-off level

they shall be agreed before the commencement of the work.

7.3 Piles forming a wall

7.3.1 Piles forming a wall can be designed for axial and/or lateral loads (e.g. in the case of ground or water retaining walls or of underpinning).

7.3.2 The geometrical construction tolerances for piles forming a wall can be more demanding than the values indicated at 7.2.1, in particular when soil or water tightness is required.

7.3.3 The rake, spacing, geometrical construction tolerances, overlap and requirements for water tightness of joints in walls shall be specified.

7.3.4 The rake of a wall shall be $n \geq 8$ ($\Theta \geq 83°$) (see figure 4).

7.4 Excavation

7.4.1 When piles are to be socketed into a bearing stratum or into rock, the design shall specify the shape, the minimum depth of penetration and the quality of the material in which the socket is to be formed.

7.4.2 Where ground conditions differ from those stipulated in the design, the designer shall be notified and appropriate action shall be taken to provide the required bearing resistance of the pile or of the foundation.

7.4.3 Compression piles shall not be founded on obstructions unless

- sufficient bearing resistance is proved,
- full face seating, and
- similar deformation behaviour with respect to adjacent piles can be achieved.

7.4.4 If piles encounter an imenetrable obstruction prior to reaching their designed founding depth, the design shall be reviewed in the light of any available knowledge about the obstruction.

NOTE : Additional or supplementary piles of equivalent performance can be necessary in this case.

7.4.5 Enlargements of a pile base or shaft shall be designed only when the intended shape can be constructed in a controllable way and checked by suitable methods.

7.4.6 Base enlargements shall not be specified in unstable soils such as :

- loose sands;
- uniform sands below the ground-water table;
- soft or sensitive clays.

7.4.7 Shaft enlargements shall be specified only for vertical piles in stable ground.

7.5 Precast concrete elements

7.5.1 The design, execution and supervision of precast concrete elements shall be in accordance with ENV 1992-1-1 and ENV 1994-1-1.

7.5.2 The design shall consider the cases of handling, transportation and installation; any restrictions shall be marked on the element.

7.5.3 The concrete cover shall be in accordance with the requirements for the respective environmental conditions.

7.6 Reinforcement

7.6.1 General

7.6.1.1 Starter bars or dowel bars for connection to a superstructure shall be in accordance with ENV 1992-1-1.

7.6.1.2 Where steel tubes or sections are used for the reinforcement of piles their design shall be in accordance with ENV 1994-1-1.

7.6.1.3 An allowance for corrosion shall be made in the design where a steel reinforcement pipe or a permanent casing is used as a structural member, unless protection is already naturally present or the entire surface is protected by a sufficient concrete or grout cover or other protective measures.

7.6.1.4 All necessary measures to provide cage rigidity should be shown on the working drawings.

7.6.2 Longitudinal reinforcement

7.6.2.1 Where a

- bentonite,
- clay or
- polymer

suspension is used as a stabilizing fluid, only ribbed bars shall be used for main reinforcement.

7.6.2.2 Unless otherwise specified by design the minimum amount of longitudinal reinforcement shall be as indicated in table 4 where reinforcement is required.

Table 4 : Minimum longitudinal reinforcement

Nominal pile cross section: A_C	Area of longitudinal reinforcement: A_S
$A_C \leq 0{,}5\ m^2$	$A_S \geq 0{,}5\ \%\ A_C$
$0{,}5\ m^2 < A_C \leq 1{,}0\ m^2$	$A_S \geq 0{,}0025\ m^2$
$A_C > 1{,}0\ m^2$	$A_S \geq 0{,}25\ \%\ A_C$

7.6.2.3 The minimum longitudinal reinforcement shall be four bars of 12 mm diameter.

7.6.2.4 Spacing of longitudinal bars should always be maximized in order to allow proper flow of concrete but should not exceed 400 mm.

7.6.2.5 The minimum clear distance between longitudinal bars or bundles of bars of one layer shall be not less than 100 mm.

7.6.2.6 The minimum clear distance between longitudinal bars or bundles of bars of one layer may be reduced to 80 mm when using $d \leq 20$ mm aggregate.

7.6.2.7 Concentric layers of longitudinal bars should be avoided where possible.

7.6.2.8 Where concentric bar layers of longitudinal bars are used

- the maximum number of layers shall be two for circular bored piles,
- bars of the layers shall be placed radially behind each other, and
- the minimum clear distance between bar layers shall be equal to 2 times the bar diameter or 1.5 times the size of the coarse aggregate, whichever is the greater.

7.6.2.9 The spacing of the reinforcement may be reduced along the lap length of bars.

7.6.2.10 Where longitudinal bars are not evenly spaced, special methods are required to hold the correct positioning of the reinforcement cage during installation and concrete placement.

7.6.3 Transverse reinforcement

7.6.3.1 Transverse reinforcement is to be designed in accordance with ENV 1992-1-1.

7.6.3.2 The diameters of the transverse reinforcement should be in accordance with table 5.

Table 5 : Recommended diameters of transverse reinforcement

Links, hoops or helical reinforcement	≥ 6 mm and ≥ one quarter of the maximum diameter of the longitudinal bars
Wires of welded mesh transverse reinforcement	≥ 5 mm

7.6.3.3 The minimum clear distance of transverse bars shall not be less than the clear distance as set out for the main reinforcement in 7.6.2.

7.6.3.4 Where the shear stress in a pile exceeds 0,5 times the shear strength of the concrete alone, then the transverse reinforcement should be designed in accordance with the appropriate code practice.

7.6.3.5 Longitudinal bars or longitudinal bar bundles placed in a corner of a reinforcement cage should be restrained by the transverse reinforcement.

7.6.3.6 Stiffening rings or other means of support for the assembly of reinforcement cages may be recognized as a part of the transversal reinforcement only where properly connected to the longitudinal bars.

7.6.4 Concrete cover

7.6.4.1 The cover to all reinforcement in cast-in-place piles shall comply with ENV 1992-1-1 and shall be not less than

- 60 mm for piles with $D > 0{,}6$ m or
- 50 mm for piles with $D \leq 0{,}6$ m

unless otherwise agreed.

7.6.4.2 The minimum cover should be increased to 75 mm where :

- piles penetrate soft soil and are constructed without a casing;
- exposure class 5 in accordance with ENV 206;
- submerged placement of concrete with 32 mm max. aggregate is used;
- reinforcement is installed subsequent to concrete placement; or
- the borehole walls have uneven surfaces.

7.6.4.3 The concrete cover may be reduced to 40 mm to the external face of a permanent casing or lining, where used.

7.6.5 Reinforcement tubes and sections

7.6.5.1 The design of tubes or sections as special reinforcement shall be in accordance with ENV 1994-1-1.

7.6.5.2 The design value for bond stress between the concrete and the embedded section shall have been agreed before the commencement of the works and the concrete cover or thickness shall be specified in the design documents.

7.6.5.3 Site or laboratory tests can be required for this purpose.

7.6.5.4 An installation procedure shall be determined to maintain the alignment of the special reinforcement with the pile axis and the correct concrete cover over its entire length.

8 Execution

8.1 Excavation

8.1.1 General

8.1.1.1 When constructing bored piles measures shall be taken to prevent uncontrolled inflow of water and/or soil into the bore.

NOTE 1 : An inflow of water and/or soil could cause for instance :

- a disturbance to or instability of the bearing stratum or the surrounding ground;
- loss of support by the removal of soil from beneath adjacent foundations;
- unstable cavities outside the pile;
- damage to the unset concrete in the pile or piles recently installed nearby;
- voids in the shaft during concreting;
- washing out of cement.

NOTE 2 : There are increased risks in:

- loose granular ground;
- soft cohesive ground; or
- ground which is variable.

8.1.1.2 In soils liable to flow into the pile bore or where there is a risk of collapse, means of support shall be used to maintain stability and thereby prevent the uncontrolled entry of soil and water.

EXAMPLE :
Common means of support of a pile bore are

- casings,
- stabilizing fluid,
- soil-filled auger flights.

8.1.1.3 Pile bores shall be excavated until they reach

- the specified bearing stratum, or
- the anticipated founding level,

and shall be socketed into the founding material where and as required by the design.

8.1.1.4 In cases of

- unfavourable stratification of the bearing layers,
- founding on bedrock, or
- sloping surface of the bearing layers

the excavation shall be carried down to provide full face contact.

8.1.1.5 In case of an inclined rock surface, the bottom of the excavation should be levelled for fixing of the pile base and for preventing the pile from sliding.

NOTE 1 : In the case of a steep rock surface or other unfavourable stratification it can be necessary to excavate deeper or to provide the pile-bases with fixing dowels.

NOTE 2 : It can be necessary to install a casing down to full contact and to seal it into the rock.

8.1.1.6 Where the ground conditions differ from those stipulated in the design, appropriate action shall be taken in agreement with the designer.

8.1.1.7 Completed excavations shall be left open only for the time necessary to allow

- cleaning and/or desanding,
- the various checks, and
- installation of reinforcement, if any.

8.1.1.8 Where piles are constructed in ground which is likely to deteriorate with time and it is not possible to finish the pile by the end of the working day, a depth equivalent to

- at least twice the shaft diameter but
- not less than 1,5 m

shall be bored the following working day immediately before concrete placement.

8.1.1.9 If a pile bore encounters an impenetrable obstruction prior to reaching its designed founding depth, the designer shall be informed of further actions required to continue the work.

8.1.1.10 The use of explosives

- for removing obstructions, or
- for socketing piles into bedrock

shall not be allowed unless damage will not result to neighbouring piles or structures.

8.1.1.11 The construction sequence of piles shall be chosen so as to avoid damage to neighbouring piles.

8.1.1.12 Disturbed soil, debris or any other material that could affect the pile performance shall be removed from the base prior to concrete placement (cleaning of bases).

8.1.2 Methods and tools

NOTE : Piles can be excavated in an intermittent or continuous process :

a) tools for intermittent excavation are for example: grabs, shells, augers, boring buckets and chisels (see figures A.3 to A.6) ;

b) tools for continuous excavation are for example: augers, drilling or percussion tools for excavation combined with augering or flushing methods for soil removal (see figures A.7 to A.9).

8.1.2.1 The employment of

- temporary or permanent casings
- supporting fluids, or
- soil-filled flights of a continuous flight auger

can be necessary to support the excavation walls.

8.1.2.2 The type of boring tool shall

- be appropriate to the given soil, rock, groundwater or other environmental conditions,
- be selected with a view to preventing loosening of material outside the pile bore and below its base, and
- allow the bores to be excavated quickly.

8.1.2.3 It can be necessary to change the method or tool employed to meet the requirements.

8.1.2.4 Special tools and/or techniques other than those used for excavation may be used for the cleaning of bases.

8.1.2.5 In situations where water or supporting fluid is present inside the bore, the choice and operation of tools shall not impair bore stability.

NOTE : A piston effect with negative influence on the stability of the pile bore walls can occur and the operating speed of the tool should be adapted accordingly.

8.1.3 Excavations supported by casings

8.1.3.1 Raking piles shall be cased over their entire length if their inclination is : $n \leq 15$ ($\Theta \leq 86°$) unless it can be shown that uncased bores will be stable (see figure 4).

8.1.3.2 Casings may be installed during the excavation process using :

- oscillating or
- rotating equipment

or they may be driven prior to the excavation using :

- piling hammers or
- vibrators or other.

8.1.3.3 The casings shall allow their safe installation and subsequent recovery during or after the concreting process, unless casings are required to be permanent.

8.1.3.4 For that purpose

- casings shall be cylindrical and without any significant longitudinal or diametrical distortion,
- casings shall be designed to withstand the external pressure and the forces of installation and recovery,
- temporary casings shall be free of significant internal projections or encrusted concrete,
- casing joints shall permit the transfer of longitudinal forces and torsion moments without significant play.

8.1.3.5 Where a cutting ring projects at the bottom edge of the casing it should be kept as small as possible, but sufficient for the safe installation and recovery of the casing (see figure A.2).

8.1.3.6 Where a pile is excavated

- below the groundwater table in permeable ground, or
- in artesian conditions

an internal excess pressure shall be provided within the casing by a head of water or other suitable fluid of not less than 1,0 m which shall be maintained until the pile has been concreted.

8.1.3.7 The excess pressure may be reduced if

- a sufficient casing advancement is provided, or
- a sufficient head of concrete is achieved during placement.

8.1.3.8 In unstable bores the casing shall be maintained in advance of boring.

8.1.3.9 The advancement in relation to the excavation shall be adjusted to suit the ground and groundwater conditions.

NOTE : The insertion of the casings ahead of boring is necessary to prevent an inflow of soil and disturbance below the pile base which can affect the pile performance ("caving in", "bottom heave"). The creation of a cavity outside the casing can endanger the integrity of a concreted pile if and when the casing is withdrawn ("necking"). Zones of loosening can also move upwards to the surface and can there cause subsidence.

8.1.3.10 The amount of casing advance or the internal excess pressure shall be increased if instability of the bottom of the excavation is likely.

8.1.3.11 Temporary casings shall not be installed into pre-excavations stabilized by supporting fluids unless special precautions are taken to prevent contamination of the concrete by that fluid.

NOTE : Otherwise "locked pockets" of that fluid might form outside the casing and could contaminate the concrete during the placement process.

8.1.4 Excavation supported by fluids

8.1.4.1 The properties of a stabilizing fluid shall be in accordance with subclause 6.5.

8.1.4.2 The fluid shall be completely or partially replaced if one of the properties of the fluid is outside the specified ranges of table 3.

8.1.4.3 Fluid recovered during excavation work or during concrete placement may be re-used, after suitable processing.

8.1.4.4 The upper part of an excavation shall be protected by a lead-in tube or guide wall

- to guide the boring tools,
- rotect the pile bore against collapse of upper loose soils, and
- for the safety of site personnel.

8.1.4.5 The level of the stabilizing fluid shall be such that at all times sufficient internal pressure is provided to maintain the stability of the walls and prevent migration of soil particles into the bore hole.

8.1.4.6 At all times during boring and concrete placement the level of stabilizing fluid shall be maintained

- within the lead-in tube or the guide wall, and
- at least 1,5 m above the external ground-water level.

8.1.4.7 The head of the stabilizing fluid may be reduced based on experience or calculations.

8.1.4.8 An adequate supply of stabilizing fluid shall always be kept available to cater for regular consumption and any potential loss of suspension into the ground.

NOTE : In cases of sudden outflow of fluid from the excavation, it can be necessary to backfill the bore.

8.1.4.9 The operating velocity of the tool shall be controlled and adjusted as necessary in order to avoid a "piston" effect that can affect pile bore stability.

8.1.4.10 Stabilizing fluids should not be used for support of excavations for raking piles with an inclination of $n \leq 15$ ($\Theta \leq 86°$) unless special precautions are taken in installation of reinforcement and concrete placement.

8.1.5 Boring with continuous flight augers

8.1.5.1 Piles may be formed without other means of support of the bore, by using a continuous flight auger in such a way that the stability of the bore is preserved by the material on the flights.

8.1.5.2 Continuous flight auger piles shall not be constructed with inclinations of $n \leq 10$ ($\Theta \leq 84°$), unless measures are taken to control the direction of the excavation and the installation of the reinforcement.

8.1.5.3 Boring with continuous flight augers shall be carried out as fast as possible and with the least practical number of auger rotations in order to minimize the effects on the surrounding ground.

8.1.5.4 Where layers of unstable soil are encountered with a thickness of more than the pile diameter, the feasibility of the construction shall be demonstrated by means of trial piles or local experience before the commencement of the works.

8.1.5.5 Unstable soils are considered to be :

- uniform non-cohesive soils ($d_{60}/d_{10} < 1,5$) below the groundwater table;
- loose non-cohesive soils with relative density $D_r < 0,3$ or having a corresponding pressuremeter results;
- clays with high sensitivity;
- soft soils with undrained shear strength c_u < 15 kPa.

8.1.5.6 During excavation the advance and speed of rotation of the auger shall be adjusted in accordance with the soil conditions so that soil removal is limited to such an extent that

- the lateral stability of the bore wall will be preserved, and
- over-excavation will be minmized.

8.1.5.7 For this the boring tool shall be provided with sufficient torque and traction power.

8.1.5.8 The pitch of the flights shall be constant over the whole length of the auger.

8.1.5.9 A system of closure shall be provided in the hollow auger stem to prevent the entry of soil and inflow of water during drilling.

8.1.5.10 The auger shall be lifted from the pile bore only if

- the surrounding ground remains stable, or
- the required depth has been reached and the surrounding ground is stabilized by the rising concrete.

8.1.5.11 If a pile can not be completed and the auger has to be removed, the auger shall be withdrawn by back-screwing and the hole shall be back-filled with soil or stabilizing fluid.

8.1.6 Unsupported excavation

8.1.6.1 Excavation without the provision of support to pile bore walls is permissible in ground conditions which remain stable during excavation and where a collapse of ground material into the bore is not likely.

8.1.6.2 The upper part of the excavation shall be protected by a lead-in tube unless

- the excavation is carried out in firm soil, and
- the diameter D is smaller than 0,6 m.

8.1.6.3 Piles raking $n \leq 15$ ($\Theta \leq 86°$) or less shall not be constructed with an unsupported excavation and a full length casing shall be provided unless it can be shown that the pile bore remains stable, as for example in firm or stiff cohesive soils or rock.

8.1.6.4 If unsupported excavations pass through unstable ground strata, this part of the pile bore shall be stabilized.

8.1.7 Enlargements

8.1.7.1 The proper formation of an enlargement requires

- a stable excavation, and
- complete filling with sound concrete.

8.1.7.2 Enlargements should be constructed using mechanical tools allowing control of their operation from the surface.

8.2 Reinforcement

8.2.1 General

8.2.1.1 Steel reinforcement shall be stored in clean conditions and shall be

- clean,
- free from loose rust, and
- loose mill scale

at the time of installation and concreting.

8.2.1.2 Reinforcement cages shall be suspended or supported so as to maintain their correct position during concreting.

8.2.1.3 Where raking piles are constructed without a casing, suitable means of support shall be employed for the installation and the position control of the reinforcement.

8.2.2 Joints

8.2.2.1 Joints in reinforcement bars

- shall be such that the full strength of each bar is effective across the joint, and
- shall be made so that there is no detrimental displacement of the reinforcement during construction of the pile.

8.2.2.2 Joints between sections of reinforcement cages can require additional fixing, (e.g. by clamps or tack welding).

8.2.2.3 Reinforcing bars shall not be welded at or near bends.

8.2.2.4 Spot welding is permissible within the requirements laid down in the particular specification for the steel used.

8.2.3 Bending of reinforcement

8.2.3.1 If reinforcement protruding from the concrete at the pile head is to be bent the internal radius of the bend shall be not less than stipulated by ENV 1992-1-1.

8.2.3.2 No reinforcement shall be bent at a temperature lower than 5 °C without prior approval.

8.2.3.3 Before bending, reinforcement may be warmed to a temperature not exceeding 100 °C.

8.2.4 Assembly of cages

8.2.4.1 The assembly of cages and the fixing together of bars shall be such that

- cages can be lifted and installed without permanent distortion, and that
- all bars remain in the correct position.

8.2.4.2 Transverse reinforcement shall

- fit closely around the main longitudinal bars, and
- be bound, or
- otherwise fixed to them.

8.2.4.3 Ties or fixing shall be carried out as necessary using

- wire,
- clips, or
- welding.

8.2.4.4 Additional support such as

- stiffening rings, and/or
- lacings, and/or
- oblique bars

can be necessary.

8.2.5 Spacers

8.2.5.1

- The concentric position of the reinforcement cage in the bore, and
- the necessary concrete cover

shall be provided by spacers unless the position and the cover are otherwise provided.

8.2.5.2 Spacers shall be designed and manufactured using durable materials which will not lead neither

- to corrosion of the reinforcement nor
- to spalling of the concrete cover.

8.2.5.3 Metal pads may be used as spacers.

8.2.5.4 Where bores are uncased, large size spacers with suitable shape shall be used, so that no collapse from the walls is caused during the installation of the reinforcement.

8.2.5.5 Spacers shall be arranged symmetrically around the cage with

- at least 3 number at each level,
- at level intervals of not more than 3,0 m, and
- sufficient tolerance to the inner wall of a casing or the wall of the pile bore to allow safe installation and avoid damage to the bore walls.

8.2.5.6 The number of spacers should be increased :

- for piles of diameter $D \geq 1{,}2$ m; and
- for raking piles.

8.2.6 Installation

8.2.6.1 The reinforcement shall be installed as soon as possible after the cleaning of the pile bore.

8.2.6.2 The installation of the reinforcement has to provide for its alignment with the pile axis and maintain the correct concrete cover over its full length.

8.2.6.3 During concrete placement, the reinforcement level shall be maintained to provide the specified projection above the final cut-off level.

8.2.6.4 The elevation of the top of the cage after concrete placement shall be equal to the nominal value with a maximum deviation of $\pm$ 0,15 m.

8.2.6.5 For piles constructed by continuous flight augers, reinforcement installation subsequent to concrete placement is permitted if the method has been proved in the same ground conditions.

8.2.6.6 This subsequent installation shall take place as soon as possible after the completion of the concreting operation.

8.2.6.7 Where reinforcement cages are inserted after concreting, it can be necessary to maintain their position by suitable supports.

8.2.6.8 The subsequent installation may be assisted by light vibration or the reinforcement may be pulled-in.

8.3 Concreting

8.3.1 General

8.3.1.1 The interval between completion of excavation and commencement of concrete placement is required to be kept as short as possible.

8.3.1.2 Prior to concrete placement the cleanliness of the bore shall be checked.

8.3.1.3 If the bore is supported by a stabilizing fluid, the properties of the fluid shall be checked before concrete placement (see 6.5).

NOTE 1 : Water inside the bore can contain in suspension a significant quantity of fine sand or silt that can settle on the pile base during the interval preceding concrete placement. Cleaning or replacement of the water may be required.

NOTE 2 : The possibility of trapped fluid or segregated concrete is increased when piles are constructed with base enlargements.

8.3.1.4 Special precautions should be taken in the cleaning of base enlargements.

8.3.1.5 The concreting of an enlarged base shall be in one continuous operation without interruption.

8.3.1.6 The bore shall be partly or wholly filled with concrete in such manner as to form a continuous sound monolithic shaft of the full required cross section and height.

8.3.1.7 No soil, liquid or other foreign material which can adversely affect the performance of the pile shall be permitted to contaminate the concrete.

8.3.1.8 The workability of the concrete shall be such as to allow the whole concreting procedure to be carried out satisfactorily.

8.3.1.9 An adequate supply of concrete shall be available throughout the whole placement process to enable a smooth operation.

8.3.1.10 Fresh concrete shall always be poured into concrete which retains its full workability.

8.3.1.11 When determining the workability time of the concrete, allowance should be made to cater for potential interruptions in the supply and the time required for the placement process.

8.3.1.12 Internal vibration is not permissible for the compaction of the concrete.

8.3.1.13 Appropriate precautions shall be taken to prevent the fines of the concrete being washed out from the shaft surface by flowing groundwater.

8.3.1.14 It can be necessary to contain the fresh concrete in soft ground ($c_u \leq 15$ kN/m²) along a part or the whole of the pile length by the installation of sacrificial linings or permanent casings.

8.3.1.15 During the concreting the volume placed and the level of concrete inside the bore shall be checked and recorded.

8.3.1.16 The method and the sequence of the checking and recording shall suit the dimensions and type of pile and shall be agreed prior the beginning of the work.

8.3.1.17 The levels shall be checked at least once

- after every pour, or
- before or after a temporary casing is lifted.

8.3.1.18 For piles with diameter less than 0,6 m it may be sufficient to record the concreting of the first 10 piles of a site and a percentage of the remaining piles.

8.3.1.19 The placement shall continue until any contaminated concrete in the upper part of the concrete column has risen above cut-off level.

8.3.1.20 The height of the casting level above the cut-off level should be increased when

- the cut-off level lies deep below the working platform,
- concreting is carried out in submerged conditions, or
- temporary casings are recovered.

8.3.1.21 At an ambient air temperature less than 3 °C and falling, the heads of newly cast piles are to be protected against frost.

8.3.1.22 When the final casting level is below the working platform, the fresh concrete should be protected against contamination from above :

- by concreting above the cut-off level ;
- by backfilling the empty bore with suitable material; or
- by maintaining a stabilizing fluid inside the empty bore until the concrete has set.

8.3.1.23 In circumstances where the casting level is below the groundwater level, a pressure on the unset concrete equal to, or greater than, the external groundwater pressure shall be maintained.

8.3.1.24 The pile trimming operation

- shall be carried out only when the concrete has obtained sufficient strength,
- shall remove all concrete which is contaminated or of lower quality than required from the top of the pile, and
- shall continue until sound concrete over the whole cross section is revealed.

8.3.1.25 Trimming and cutting off of pile heads with mechanical equipment shall be done with the greatest possible care.

8.3.1.26 The risk of extensive cracks, caused by mechanical equipment used for cutting off, can require restriction of the type and size of concrete breaker employed.

8.3.2 Concreting in dry conditions

8.3.2.1 The procedure for placing concrete in dry conditions shall not be followed if there is standing water at the base of the pile bore.

8.3.2.2 A check shall be carried out immediately before the placement.

8.3.2.3 If water is recognized concrete should be placed as for submerged conditions.

8.3.2.4 Concreting shall be carried out in such way as to avoid segregation. The concrete shall be directed vertically into the centre of the bore by means of a funnel and an attached length of pipe so that the concrete does not hit

- the reinforcement, or
- the walls of the pile bore.

8.3.2.5 The internal diameter of the concreting pipe shall not be less than 8 times the maximum size of the aggregate.

8.3.3 Concreting in submerged conditions

8.3.3.1 Where concreting is carried out under water or a stabilizing fluid, the consistency shall be in accordance with table 2 and a tremie pipe be used for the placement.

NOTE : The main purpose of the tremie pipe is the prevention of segregation of the concrete during placement or its contamination by the fluid inside the bore.

8.3.3.2 Submerged concrete shall not be compacted by internal vibration.

NOTE : Compaction is dependent on the flowability of the concrete in relation to its self weight and the surcharge of the fluid above the concrete column.

8.3.3.3 The tremie pipe, including all its joints, shall be water tight.

8.3.3.4 It shall be equipped at its upper end with a hopper to receive the fresh concrete and prevent spillage of concrete which otherwise could fall freely into the hole, segregate or become contaminated.

8.3.3.5 The tremie pipe shall be smooth to allow free flow of concrete and have a uniform internal diameter of at least

- 6 times the maximum size of the aggregate, or
- 150 mm

whichever is the greater.

8.3.3.6 The external shape and dimension of the tremie pipe, including its joints, shall allow its free movement inside the reinforcement cage.

8.3.3.7 The maximum outside diameter of the tremie pipe including its joints should be not more than :

- 0,35 times the pile diameter or the inner diameter of a casing ;
- 0,6 times the inner width of the reinforcement cage for circular piles; and
- 0,8 times the inner width of the reinforcement cage for barrettes.

8.3.3.8 The tremie pipe shall be cleaned of all encrusted concrete or mortar prior to its use.

8.3.3.9 The tremie pipe shall extend to the bottom of the pile at the commencement of the concreting.

8.3.3.10 A bung or plug of suitable material, to prevent mixing of concrete with any fluid in the tremie pipe, shall be inserted into the pipe before the commencement of concrete placement.

8.3.3.11 As the first batch, a cement enriched mix or a charge of cement mortar may be used to lubricate the tremie pipe.

8.3.3.12 To allow the first concrete to leave the tremie pipe, the pipe shall be lifted slightly, not exceeding a value equal to the inner diameter of the tremie pipe. Placement shall then proceed quickly to fill the entire base of the pile so that no concrete which may have segregated at the beginning of the discharge is trapped.

8.3.3.13 During subsequent placement the tremie pipe shall be withdrawn progressively as the concrete rises in the bore.

8.3.3.14 The pipe shall at all times remain immersed in unset and workable concrete which has previously been placed and shall not be withdrawn from the concrete until the completion of the concreting process.

8.3.3.15 The immersion of the tremie pipe into the concrete should be not less than 1,5 m, particularly when disconnecting sections of the pipe and when recovering and disconnecting sections of temporary casing.

8.3.3.16 For piles with a diameter $D \geq 1{,}2$ m the immersion should be at least 2,5 m and for barrettes at least 3,0 m, particularly when two or more tremie pipes are used.

8.3.3.17 After completion of the placement the tremie pipe should not be extracted too quickly as the resulting suction can lead to pile imperfections.

8.3.3.18 When concrete is placed under stabilizing fluid

- a sample of the fluid shall be taken from the base of the bore, and
- any major filtercake or debris shall be removed from the bottom of the bore

immediately before the start of the placement.

8.3.3.19 Concreting shall proceed only when the properties of the suspension are satisfactory. Otherwise additional recycling and cleaning or substitution of the suspension is necessary.

8.3.4 Extraction of casings

8.3.4.1 The extraction of temporary casings shall not be started unless the concrete column has reached a sufficient height inside the casing to generate an adequate excess pressure

- to protect against inflow of water or soil at the tip of the casing, and
- to prevent the reinforcement cage from being lifted.

8.3.4.2 The extraction shall be carried out while concrete is still of the required workability.

8.3.4.3 During the continued extraction a sufficient quantity and head of concrete shall be maintained inside the casing to balance the external pressure so that the annular space vacated by the removal of the casing is filled with concrete.

8.3.4.4

- The supply of concrete, and
- the speed of extraction of the casing

shall be such that no inflow of soil or water occurs into the freshly placed concrete, even if a sudden drop of concrete level should occur when a cavity outside the casing is uncovered.

NOTE : This is particularly important in loose or soft ground or close to the pile top.

8.3.4.5 In addition to the general requirements, the depths of casing and of the tremie pipe shall also be recorded.

8.3.5 Permanent casings or linings

8.3.5.1 The installation of permanent casings or linings can be necessary to confine fresh concrete in the pile bore.

NOTE : In cases where sacrificial linings are installed into temporarily cased or uncased excavations or piles are constructed with permanent casings, voids can remain in the ground outside the pile shaft.

8.3.5.2 If the presence of voids, which can cause possible ground settlements affecting adjacent structures, is known or suspected, measures shall be taken to fill them.

8.3.6 Concreting of continuous flight auger piles

8.3.6.1 Concreting of piles excavated with continuous flight augers may be carried out by placing concrete through the hollow central stem of the auger, the stem being closed at its base, to avoid entry of water or soil until concrete placing commences.

8.3.6.2 Once boring has reached the final depth, concrete shall be placed through the stem to fill the pile while the auger is withdrawn.

8.3.6.3 If concrete flow cannot be initiated, it is necessary to completely remove the auger by backscrewing it from the ground, backfilling the hole so that no voids or collapses occur.

8.3.6.4 The pile may then be rebored at the same location to at least the original depth.

8.3.6.5 During withdrawal and concrete placement, the auger

- shall not be rotated, or
- shall be rotated only at low speed in the same direction as for excavation.

8.3.6.6 During continuing placement, the concrete at the tip of the auger shall be kept under a pressure exceeding the external pressure, so that the volume vacated by the auger's extraction is concurrently and completely filled.

8.3.6.7 So as to control continuity, monitoring of pile construction shall comprise

- the control of concrete supply,
- the concreting pressure,
- the rate of extraction, and
- the record of rotation of the auger.

8.3.6.8 An adequate concrete supply shall be maintained to fill the pile section until the tip of the auger has reached the working level.

NOTE : It is generally necessary to bring concrete to working level in order to insert the reinforcement cage.

8.3.7 Prepacked piles

8.3.7.1 Before constructing prepacked piles, trials shall be carried out for the determination of

- the composition, flowability and setting time of the grout,
- the spread of the grout in the packed aggregate, and
- the necessary number and the distribution of grouting pipes.

8.3.7.2 The completed and clean pile bore shall be filled with clean coarse aggregate of 25 mm size or greater with an open structure and a sufficient void ratio to allow full penetration with grout.

8.3.7.3 Grouting shall be effected through grouting pipes which shall initially extend to the bottom into the pile.

8.3.7.4 The grouting pressure and rate shall be such as to penetrate the open pores of the aggregate completely with grout.

8.3.7.5 Where grouting pipes are to be recovered simultaneously with the grouting progress, sufficient immersion shall be maintained to provide uniform distribution of grout over the entire cross section of the pile.

8.3.8 Loss of immersion of tremie or casing

8.3.8.1 When the immersion of a tremie pipe is accidentally lost during concreting, further placement shall not proceed unless :

- concrete into which fresh concrete is to be placed has retained its workability;
- the tremie pipe is re-immersed sufficiently deep into the previously placed concrete;
- no water and no contamination is introduced into concrete which will remain below the final cut-off level.

8.3.8.2 Otherwise the placement shall be suspended, the tremie pipe removed and alternative measures taken to form a sound pile as required.

8.3.8.3 In any case where the immersion of the casing is lost and/or an inflow of foreign material into the freshly concreted section of the pile is likely to have occurred, the placement shall be suspended.

8.3.8.4 The pile may be completely replaced or reformed in the original position if reinforcement can be extracted and concrete bored out, and provided these actions can be taken in time.

8.3.8.5 Piles may be recovered by the formation of a construction joint after all concrete of insufficient quality has been removed and sound concrete over the full section of the pile has been exposed forming a faultless interface.

8.3.8.6 Where the preparation of a construction joint is not possible, the pile shall be abandoned and the empty bore above the concrete column be backfilled with suitable material.

8.3.8.7 Integrity tests should be carried out to document the quality of any pile where the tremie pipe was re-immersed or a construction joint was made (see also 9.3).

8.3.9 Piles containing precast concrete elements, reinforcement tubes or permanent casings

8.3.9.1 Precast concrete elements or reinforcement tubes shall be centred inside the bores to give symmetry of section and sufficient cover.

8.3.9.2 The annulus around the element or the tube shall be grouted upwards from the bottom unless a self hardening supporting fluid is used during excavation.

8.3.9.3 Where reinforcement tubes are to be filled with grout or concrete, this may be done after installation of the tube.

8.3.9.4 Where precast elements or reinforcement tubes are installed in fully cased excavations and the annulus is completely filled with grout, the pile may be designed as a composite structure in accordance to ENV 1994-1-1.

8.3.9.5 The bond stress between the external grout and the element or tube shall be demonstrated.

8.3.10 External grouting of cast in place piles

8.3.10.1 Shaft and/or base grouting shall be carried out to cast-in-place bored piles only after the concrete has set.

8.3.10.2 Only permanent grouting pipes are allowed and their arrangement shall be appropriate to the zones and materials to be grouted.

8.3.10.3 Base grouting can be effected :

- by means of a flexible box structure installed with the reinforcement, allowing the spread of grout over the whole base area of the pile; or
- with sleeved perforated cross pipes arranged at the pile bottom, (see figure A.10).

8.3.10.4 Shaft grouting shall be carried out through grouting pipes fixed to the reinforcement cage or tube or a precast concrete element as applicable (see figure A.11).

8.3.10.5 Grouting shall proceed at appropriate pressures and grouting rates

- to allow the spread of grout at the interface of the pile with the ground, and
- to avoid hydrofracture of the surrounding ground.

8.3.10.6 After the initial grout has set, second stage grouting may be carried out.

8.3.10.7 Where grouting of a pile base and shaft is to be carried out, the shaft grouting is to be carried out before the base grouting, unless otherwise agreed prior to commencement of the process.

8.4 Bored pile walls

8.4.1 A template of steel or concrete should be installed at the working platform for the maintenance of the pile positions where specified accuracy requires.

8.4.2 Excavations should be supported by temporary casings in the construction of secant pile walls.

8.4.3 Normally in the construction of secant pile walls, alternate piles only should be reinforced. These reinforced piles should be constructed after the initially installed unreinforced bored piles are in place.

8.4.4 Where all piles are to be reinforced, the primary piles shall be constructed so as not to impair the later alternate pile installation.

8.4.5 The construction sequence of secant and contiguous pile walls, and the concrete composition employed, shall be chosen as such that the concrete of the primary piles has achieved sufficient strength for stability but has not developed a strength that would be too high for an intersection to be achieved.

NOTE : Otherwise imperfections of the wall (e.g. deviations or leakages) might result.

8.4.6 In the construction of secant pile walls, self-hardening slurry may be used for primary piles instead of concrete.

9 Supervision and monitoring

9.1 Supervision

9.1.1 A suitably qualified and experienced person shall be in charge of the execution of the work.

9.1.2 The person in charge shall be responsible for :

- the conformity of the work with this European Standard and with any additional specification and agreed working procedure;
- the monitoring of pile construction and keeping of all necessary records; and to
- keep the client's representative and/or the designer informed of any variations or deviations from the expected situation or condition of the site or any cases of non conformity.

9.2 Monitoring of pile construction

9.2.1 The specific procedures for verification, control and acceptance shall be established before the commencement of the works.

9.2.2 The pile construction process shall be monitored and all relevant data shall be recorded, including :

- setting out, pile type, dimensions and depths;
- excavation procedure, tools and equipment;
- installation of casings;
- stratification of ground and groundwater levels;
- obstructions;
- use of a stabilizing fluid;
- levels of water or of stabilizing fluid in the pile bore;
- construction of pile sockets;
- construction and control of enlargements;
- cleaning of pile bore;
- checks of stabilizing fluid;
- reinforcements type, dimensions, assembly and length;
- reinforcement installation depth and position;
- installation of precast concrete elements or reinforcement tubes or sections;
- concreting in submerged or dry conditions;
- concreting of continuous flight auger piles;

- site mixed or ready-mixed concrete;
- concrete grade, composition and consistency;
- concrete placement, quantity, duration, rise and final elevation;
- recovery of temporary casings;
- recovery of the tremie pipe;
- shaft and/or base grouting: mix composition and properties, zone of application, time, supply rate, pressure and quantity.

9.2.3 The duration's of the respective operations should also be recorded.

9.2.4 All non conformance's shall be notified.

9.2.5 During excavation, the ground behaviour shall be observed and any unforeseen change or feature that might be important for the design shall be communicated to the supervisor and the designer.

NOTE : Examples of the details and frequencies for the monitoring are given in tables 6 to 15.

9.2.6 The records shall be submitted to the client's representative and/or to the designer and shall be signed as agreed.

NOTE : Records are dealt with in clause 10, Sample records are provided in annex B.

9.2.7 After preparation of the piles for their structural use, an "as built" record plan shall be drawn up showing positions and dimensions of piles together with pile head and founding levels.

9.2.8 The record plan, the pile monitoring records and any other piling documentation shall be kept as required by the contract and/or the statutory requirements.

Table 6 : Monitoring of setting out

	Subject	Control	Purpose	Frequency	Remarks
1	main axes	survey	setting out of piles	at commencement of works	establishment of main axes for time of execution
2	working platform	survey, visual check	elevation, levelness, size, stability	each construction area	
3	– pile position, – pile rake	survey – plumb-line – tape – spirit level	check of deviations against geometrical construction tolerances	every pile – before start of excavation – after excavation – after completition	

Table 7 : Monitoring of excavation

	Subject	Control	Purpose	Frequency	Remarks
1	lead-in tube (guide wall)	– diameter – width – depth	– stability of top of uncased excavations – conformity with the design	each pile	can be omitted for circular piles with $D < 0{,}6$ m
2	condition and dimensions of tools, casings	– visual check – measurement	adequacy	before and during use (as applicable)	
3	use of tools, (general)	– progress of excavation – efficiency – over excavation	– supervision – recognition of (changing) ground conditions – depth – times – tool changes	continuously	
4	use of tools, (submerged)	as above, plus – operation speed	avoid piston effect	continuously	
5	casing installation	measurement	advance of casing during excavation	continuously	particularly important when casing advance ahead of excavation is necessary
6	water level	measurement	stability of pile bore	continuously	
7	excavated material	visual check	recognition of – strata and – soil variations	continuously	samples to be kept as necessary
8	pile depth (completion of excavation)	measurement: – depth – slope (measurement of inclined bearing strata)	achievement of specified depth	each pile	verification can also be effected with calibrated tool
9	enlargement	measurement (by operational control of equipment) (visual inspection)	– size – slope of walls – alignment	each enlargement	measure-ment preferred through calibrated equipment
10	cleaning of base	– grab – sounding – (visual inspection)	– clean interface to bearing stratum – pile performance	each pile	
11	standing water on base	– tape – visual inspection	avoid segregation and contamination of concrete	each pile	

Table 8 : Monitoring of stabilizing fluid

	Subject	Control	Purpose	Frequency	Remarks
1	supply, storage	check	supply in line with consumption	continuously	supply/storage should cater for sudden loss
2	level in pile bore	check	stability of hole	continuously	
3	properties of suspension	– density – consistency (Marsh value) – fluid loss – alkalinity – sand content	conformity – with 6.5.2 and 6.5.3 or – national standards	each pile fresh fluid – before concreting – after desanding, before re-use	

Table 9 : Monitoring of reinforcement

	Subject	Control	Purpose	Frequency	Remarks
1	delivery of materials	– delivery documents – dimensions	conformity	each delivery	
2	dimensions	measurement	conformity	spot check	
3	fabrication of cages	– dimensions – spacing of longitudinal bars – spacing of transverse bars – fixing – rigidity	conformity	each cage	where welding is carried out: check in accordance with the specification for the reinforcing steel
4	spacers	– material – size – quantity – distribution	– conformity – deviation of installation	each cage	inner dimension of the casing (if any) to be taken into account
5	installation of cages	– survey – measurement	deviation of installation	each cage	
6	reinforcement tube/ steel section	– survey – measurement	deviation of installation	each tube or section	
7	special reinforcement	accordance to special procedure	conformity	accordance to special procedure	
8	embedment – pipes for sonic coring – monitoring devices – box-outs	– position – depth – connections with cage – protection during installation – protection during concrete placement	– conformity – reliability	each cage	

Table 10 : Monitoring of fresh concrete

	Subject	Control	Purpose	Frequency	Remarks
1	continuity of supply	check	continuity of placement	before placement	
2	concrete – grade – composition	delivery document	conformity	each truck	
3	consistence	– slump or – flow table	– conformity – workability	– each truck (truck delivery) or – every 10 m^3	
4	ambient temperature	thermometer	protection of newly cast piles	when required	
5	concrete temperature	thermometer	– conformity – workability	when required	frequency to be increased when in doubt
6	workability time	workability check on fresh concrete	check of duration of workability	– when required or – in doubt	test is carried out in parallel to concrete placement

Table 11 : Monitoring of concrete placement in dry or submerged conditions

	Subject	Control	Purpose	Frequency	Remarks
1	concreting pipe, tremie pipe – conditions	visual check	– cleanliness – watertightness – internal smoothness	each pipe before or during installation	
2	– internal diameter – external dimensions	check/ measurement	– compatibility with aggregate sizes – free movement inside reinforcement	– each set of pipes – each size of pile	
3	– composition (sectional lengths)	check/ measurement	preparation for recovery	each set of pipes	
4	– installation depth	measurement	avoid segregation at commencement of concrete placement	each pile	tremie pipe should rest on the bottom
5	– separation of concrete from water inside tremie pipe	check	avoid segregation	each pile	use e.g. of – bottom lid – ball or – plastic chips
			(continued)		

Table 11 : Monitoring of concrete placement in dry or submerged conditions
(continued and concluded)

	Subject	Control	Purpose	Frequency	Remarks
6	– immersion of tremie pipe during concreting and recovery	check depth of concrete against length of tremie pipe	– maintenance of sufficient immersion – avoid segregation – avoid contamination of the concrete	continuously	– sufficient immersion also during recovery of tremie pipes – observe any accumulating water inside the tremie pipe
7	immersion of casing during recovery	check depth of concrete against tip of casing	– maintenance of sufficient of immersion – avoid necking – avoid segregation and contamination of concrete	continuously	observe any sudden drop or rise of concrete
8	casting level	depth measurement	sufficient height above cut-off level	each pile	
9	backfilling empty bore	check	site safety	each pile	
10	concrete volume	compare consumption with theoretical excavation volume	detect excessive overbreak or necking	each pile (where possible)	detailed monitoring, including records of concrete slump during casing recovery, can be necessary
11	pile head after casting	visual check	detect excessive water flow	each pile (where possible)	some bleeding will always result from self compaction of the concrete; excessive bleeding might be an indication of possible shaft inclusions

Table 12 : Monitoring of CFA piles

	Subject	Control	Purpose	Frequency	Remarks
1	conditions and dimensions of – auger – cutting head – closure device	– visual check – measurements	adequacy	before commence-ment of boring	
2	excavation process	check – speed of rotation and of – penetration	limit over excavation	continuously	
3	excavation depth / founding layer	check – speed of rotation – penetration – torque (optional) – material – depth	conformity	each pile	some information may be relative and not conclusive
4	commencement of concreting	check concrete flow	check for blockage	each pile	
5	concreting	check – concrete pressure – concrete flow and – consumption corresponding auger withdrawal	complete filling of bore with concrete	each pile, continuously	

Table 13 : Monitoring of pre-packed piles

	Subject	Control	Purpose	Frequency	Remarks
1	cleanliness of excavation	check, measurement (tape with plumb bob)	interface of pile to bearing stratum	each pile	
2	grouting pipes	– diameter – number – installation depth	provision for the grouting process	each pile	site trials recommended for the verification of the spread of grout and the distribution of grouting pipes
3	aggregate	– size – quantity	filling complete volume	each pile	
4	grout properties	– composition – consistence – workability time (setting time) – bleeding – admixtures	– workability – strength	each batch	
			(continued)		

Table 13 : Monitoring of pre-packed piles (*continued and concluded*)

	Subject	Control	Purpose	Frequency	Remarks
5	grouting process	– pumping rate – pressure – consumption – withdrawal of grouting pipes	– proper grout distribution – provision of continuous shaft	each pile, continuously	
6	grout strength	compressive strength	conformity with specification	each pile	

Table 14 : Monitoring of external grouting and of shaft/base grouting

	Subject	Control	Purpose	Frequency	Remarks
1	grouting pipes	– diameter – number – distribution – installation depth – fixing to reinforcement cage – arrangement of valves	conformity with special method statement	each pile	
2	(flexible) box structure	– area – contact to base of excavation – sealing to concrete column above – fixing to cage – function and fixing of grouting and vent pipes	– maintenance of void after concrete placement – check apparatus before installation	each pile	
3	grouting process	– pumping rate – pressure – consumption – distribution of grout	proper distribution of grout	each pile, continuously	

Table 15 : Monitoring of cutting-off

	Subject	Control	Purpose	Frequency	Remarks
1	concrete at cut-off level	visual check – concrete quality – pile section – evenness – existence of cracks – condition of reinforcement – concrete cover	provide satisfactory conditions for connection of pile to superstructure	each pile	If concrete quality is found to be inadequate at the design cut-off level, the pile is to be cut further down and to be reconcreted after the formation of a construction joint.

9.3 Pile testing

9.3.1 General

NOTE 1 : The principal requirements for pile testing are contained in ENV 1997-1. The following notes contain general remarks, which may be supplemented by national application documents, as applicable (as long as respective European Standards are not available).

NOTE 2 : Pile tests may be used for research or investigation purposes for proof of :

- resistance/deformation characteristics in the general range of specified actions;
- the soundness and proper construction of a pile.

NOTE 3 : Pile tests can consist of (see clause 3) :

- maintained load tests;
- constant rate of penetration tests;
- dynamic pile tests for the determination of the pile capacity; and
- integrity tests which measure the acoustic or vibrator properties of the pile in order to determine the presence of possible anomalies within the pile body.

NOTE 4 : The application of various procedures is as indicated in table 16 below. Definitions of the different tests are provided in clause 3.

Table 16 : Application of some test procedures

Type of test	Application		
	Proof of ultimate pile resistance	Proof of working deformation range	Structural soundness (integrity)
Maintained load pile test	yes	yes	sometimes possible [1])
Continuous rate of penetration test	yes [1])	indicative for non-cohesive ground if slow enough	no
dynamic pile test	yes [1])	possible [1])	yes [1])
Integrity test	no [1])	no	yes [1])
[1]) Subject to interpretation			

NOTE 5 : The only test which can derive the ultimate resistance directly is the maintained load test if loads are sufficient and held constant for a long enough period. Other tests require subsequent interpretation. Similarly, dynamic testing methods cannot measure consolidation or creep under load. Any approximations made to the results for the purpose of establishing load/settlement relationships should therefore be made clear in test reports.

9.3.2 Axial loading tests

9.3.2.1 The strength of the pile shall be such that at the time of testing, its structure will not be damaged.

9.3.2.2 Additional material strength testing can be necessary for this purpose.

9.3.2.3 In maintained load tests and constant rate of penetration tests, the pile head displacements in the direction of the load shall be determined by at least two measuring devices, the accuracy of which shall be at least 0,1 mm.

9.3.2.4 The transverse displacements of the pile head should also be measured.

9.3.2.5 In maintained load tests, loads should be maintained constant at each of at least 6 stages for a specified duration. Unless otherwise agreed the displacement rate should be less than 0,1 mm/20 min at the end of each stage.

9.3.2.6 In continuous rate of penetration tests the rate of displacement shall be kept constant at approximately 1 mm / min throughout the period of the test.

9.3.2.7 Other rates of displacement may be agreed prior to testing.

9.3.2.8 During each test there should be at least two independent measuring devices for load and they should check against each other to exclude gross errors.

9.3.2.9 All force measuring devices shall be calibrated at least once annually. As long as European Standards are not available different national requirements or specifications shall be observed.

9.3.2.10 For dynamic load tests the pile shall be allowed to gain sufficient strength after installation and before testing.

9.3.2.11 Dynamic and integrity tests shall be carried out using equipment built and approved for the purpose and are required to be interpreted by persons competent in this area who shall also have a knowledge of the techniques of piling and experience of the specific ground conditions.

9.3.2.12 The apparatus shall be used in accordance with the manufacturer's instructions and the pile shall be prepared for the purpose of testing in an appropriate manner.

9.3.2.13 In tests where the load is directly applied to the pile, either using kentledge, ground anchors or anchorage piles, the loading arrangements shall be such that the equipment remains stable and does not bring about soil displacements liable to change considerably the behaviour of the pile.

9.3.2.14 The supports or anchorages of a reaction system should observe the following minimum clear distances to the test pile :

a) supports of kentledge : $a \geq 3 \times D$;

b) bond lengths of vertical anchorages : $a \geq 3 \times D$ and $a \geq 3{,}0$ m;

c) bond lengths of inclined anchorages : $a \geq 5 \times D$ and $a \geq 5{,}0$ m.

9.3.2.15 On completion of tests the results, together with full details of the pile tested, its location and a summary of ground conditions, shall be presented without undue delay in a report to the employer, using graphical and numerical form where appropriate.

9.3.2.16 Where rapid loading has been applied, full correlation data with maintained load tests in similar ground shall be provided.

10 Records

10.1 The site records shall consist of two parts; the first making reference to the site and the general information including :

- the pile (type, dimensions ...);
- the construction method; and
- the reinforcement and concrete specification.

The second part shall contain particular information related to the construction procedure.

10.2 The general information part shall be similar for the different types of piles and methods and shall contain the details listed in table 17 and table 18.

10.3 The particular information part shall be specific to the type of pile and the construction method and shall contain the details listed in table 19.

10.4 As appropriate, the information can be provided in the form of

- individual records compiled for each pile, or
- summary records for groups of piles of the same type, constructed with the same method.

10.5 Details of recording and the format of the site records shall be agreed before the commencement of the piling.

NOTE : Sample construction records are provided in Annex B.

Table 17 : General information of the site

	Subject	necessity
1	site location	X
2	contract identification	X
3	structure	X
4	main contractor	(X)
5	foundation (piling) contractor	X
6	client/employer	(X)
7	engineer/designer	(X)
X necessary information		
(X) information as applicable		

Table 18 : General information of the procedure

	Subject	necessity
1	pile diameter/size/enlargements	X
2	excavation method	X
3	details of stabilizing fluid	X
4	cleaning method	X
5	reinforcement details	X
6	concrete specification	X
7	concrete placement details	X
	X necessary information	

10.6 Records of any integrity testing shall provide

- the reason for the testing,
- the testing method and procedure,
- the test results, and
- the conclusions on the pile integrity.

NOTE : Recording requirements for static or dynamic load testing and the format of the load test report are provided in ENV 1997-1.

10.7 All records shall be signed by the contractor's representative and by the client's representative unless otherwise agreed.

Table 19 : Schedule of as-built information to be provided

Nr	Subject	cased/ uncased excavation	excavation supported by fluids	continuous flight auger piles
1	pile reference number	X	X	X
2	excavation times	X	X	X
3	interruptions of excavation	X	X	X
4	removal of obstructions	X	X	—
5	temporary/permanent casing	X	—	—
6	depth of casing	X	—	—
7	lead in tube/guide wall	—	X	(X)
8	depth of lead in tube	—	X	(X)
9	depth of pile	X	X	X
10	stratification log	X	X	(X)
11	ground water table	X	X	(X)
12	cleaning	X	X	—
13	stabilizing fluid – properties	—	X	—
14	– recovery	—	X	—
		(continued)		

Table 19 : Schedule of as-built information to be provided (*continued and concluded*)

	reinforcement			
15	– length	X	X	X
16	– suspension	X	X	X
17	– installation time	X	X	X
	concrete placement			
18	– dry/submerged conditions	X	X	—
19	– duration	X	X	X
20	– interruptions	X	X	X
21	– volume	X	X	X
22	– pressure	—	—	X
23	– site tests	X	X	X
24	recovery of casing	X	—	—
25	recovery of lead in tube	—	X	(X)
26	backfilling empty bore	X	X	X
	precast concrete elements			
27	– type and details	X	X	—
28	– installation	X	X	—
29	– external grouting process	X	X	—
30	– properties of self hardening slurry	X	X	—
31	– suspension	X	X	—
32	– cover	X	X	—
	external grouting			
33	– details of grouting pipes/box structure	X	X	(X)
34	– grout properties	X	X	(X)
35	– grouting process	X	X	(X)
	prepacked piles			
36	– details of aggregate	X	—	—
37	– details of grouting system		—	—
38	– grout properties	X	—	—
39	– grouting process of bore	X	—	—
	shaft and base grouting			
40	– grouted area	X	X	X
41	– details of grouting system	X	X	X
42	– grout properties	X	X	X
43	– grouting process	X	X	X
	construction deviations			
44	– position	X	X	X
45	– rake	X	X	X

X necessary information
(X) information as applicable
— not applicable

11 Specific Requirements

11.1 Regarding :

- safety on the site;
- safety of the working practices;
- legality of manual works and inspections inside excavations; and
- operational safety of piling and auxiliary equipment and tools;

the respective national standards, specifications or statutory requirements regarding execution of bored piling works shall be observed, as long as respective European Standards are not available.

11.2 Equipment shall be in accordance with EN 791.

11.3 Particular attention shall be drawn to

- all processes requiring men operating alongside heavy equipment and heavy tools,
- the danger of open holes,
- manual working procedures and inspections carried out inside excavations.

11.4 Excavation by hand should be kept to a minimum.

11.5 Excavation by hand shall be restricted to dry conditions where the ground is naturally stable or where support of the excavation walls is continuously be maintained.

11.6 Employment of personnel inside a bore is permitted only if the available space for the work is at least 0,75 m in diameter.

11.7 Nuisance and/or environmental damage that can be caused by the piling work shall be kept to a minimum.

11.8 Such nuisance and/or environmental damage can be caused by :

- noise;
- ground vibration;
- ground pollution;
- surface water pollution;
- groundwater pollution; and
- air pollution.

NOTE : The kind and extent of possible nuisance or environmental impact depends on :

- the location;
- the working method;

- the actual processes.

11.9 Regarding nuisance and environmental protection, for each particular situation

- the national requirements (as long as respective European Standards are not available), and
- the local requirements

shall be observed.

Annex A (informative)

Glossery

A.1 **Mini (or micro) pile :** Bored pile with diameter $D < 0{,}3$ m. Usually constructed by special methods (not covered by this European Standard).

A.2 **Cast-in-place bored pile :** A pile cast either within a bored hole in the ground or within a driven casing.

A.3 **Plain bored pile :** Bored pile constructed in soils which are sufficiently stable not to require support to bore hole walls.

A.4 **Raking pile :** Pile installed at an inclination related to the horizontal.

A.5 **Displacement pile :** Pile formed in the ground without excavation or removal of material from the ground (e.g. a driven or a screw pile, not covered by this European Standard).

A.6 **Driven pile :** Pile which is driven into the soil by hammering, vibration or static pressure, the soil being displaced (not covered by this European Standard).

A.7 **Driven cast-in-place pile :** Pile installed by driving a closed ended permanent or temporary casing, and filling the hole so formed with plain or reinforced concrete (not covered by this European Standard).

A.8 **Precast pile :** Totally preformed pile of reinforced or prestressed concrete cast in one length or a series of joined lengths and usually installed by driving (not covered by this European Standard).

A.9 **Screw pile :** Displacement pile in which the pile or the pile tube comprises a limited number of helices at its base and is installed under the combined action of a torque and a vertical thrust. By the screwing-in and/or by the screwing-out, the ground is essentially laterally displaced and virtually no soil is excavated (not covered by this European Standard).

A.10 **Cast-in-place screw pile :** Screw pile formed by screwing into the ground a closed ended permanent or temporary casing, comprising at its base a displacement head in the form of a screw. The hole so formed is filled with plain or reinforced concrete (not covered by this European Standard).

A.11 **Precast screw pile :** Screw pile formed by screwing into the ground a cylindrical preformed pile of reinforced or prestressed concrete, comprising at its base a limited number of concrete flanges (not covered by this European Standard).

A.12 **Pile head :** Upper part of a pile.

A.13 **Pile base :** (1) Bottom area of a pile.

A.14 **Pile base :** (2) Bottom part of a pile.

A.15 **Pile shaft :** The body of the pile between the head and the base.

A.16 **Skin friction :** Frictional and/or adhesive resistance on the pile surface.

A.17 **Negative skin friction :** Frictional and/or adhesive force by which surrounding soil or fill transfers downward load to a pile when the soil or fill settles relative to the pile shaft.

A.18 **Socket :** Bottom part of a pile in hard ground (usually rock).

A.19 **Excavation :** (1) Digging, lifting and removing soil, rock or fill for the formation of a borehole,
(2) the borehole constructed for a bored pile.

A.20 **Obstruction :** Natural (or man made) hard strata, blocks or similar ground requiring special tools or methods for the excavation.

A.21 **Reinforcement cage :** Reinforcement for piles comprising longitudinal steel bars arranged to form the generatrices of a cylinder or a rectangular prism around which links, hoops or helices are wound and fixed.

A.22 **Spacer, spacer pad :** Appliance of plastic or steel material or concrete (pad) fixed to the steel reinforcement to hold the reinforcement cage laterally and maintain the concrete cover to reinforcement.

A.23 **Centralizer :** Device to locate reinforcement centrally in a bore hole.

A.24 **Plan deviation of pile :** Horizontal distance between the as built and the design pile axis at the working level. (Pile eccentricity refers to the deviation at the cut-off level).

A.25 **Suspension rods :** Steel appliances to prevent a reinforcement cage for the upper part of a pile from dropping to the bottom of the hole (hangers).

A.26 **Starter bars :** Steel bars inserted into the fresh concrete at the pile head so that they partially project to provide connection with the superstructure.

A.27 **Casting level :** Final level to which concrete is cast in a pile excavation. It is above the cut-off level by a margin depending on the execution procedure.

A.28 **Empty bore :** Length of excavation from the working level to the casting level or the prescribed pile head.

A.29 **Cut-off level (trimming) :** Prescribed level to which a pile is cut or trimmed back before connecting it to the superstructure.

A.30 **Cutting-off :** (1) Removal of contaminated or substandard concrete from the pile head. (2) Removal of surplus concrete above the designed cut-off level.

A.31 **Preboring :** Preliminary excavation process mainly for the penetration of top layers or the removal of obstructions.

A.32 **(Hammer) grab :** Excavation tool with two or more jaws or shovels, to remove soil or debris from an excavation by an intermittent operation.

A.33 **Chisel :** Tool for breaking up obstructions in a pile excavation or for socketing a pile into hard soil or rock.

A.34 **Bucket :** Boring tool in the form of a cylindrical container, at the bottom of a kelly bar, used for intermittent excavation and incorporating cutting blades or teeth and corresponding openings in its hinged base plate for the intake of material.

A.35 **Auger :** Tool consisting of a stem, helical flights and a cutting edge or edges for intermittent excavation (when operated by a kelly bar, Figure A.4) or continuous excavation (continuous flight auger, Figure A.9).

A.36 **Kelly bar :** Sliding shaft on a boring rig that transmits the torque necessary for the boring operation from a powered rotary table to the boring tool.

A.37 **Casing :** Steel tube used to maintain stability of a pile excavation (e.g. in unstable ground).

A.38 **Permanent casing :** Permanent continuous surround to a cast-in place pile designed to support bore walls and/or to act as a protective or load bearing unit.

A.39 **Cutting ring :** Bottom part of a casing, usually reinforced and with teeth to facilitate penetration into the ground.

A.40 **Liner, lining :** Tube, generally of thin steel plate, forming part of the pile shaft (e.g. used for the protection of pile shafts in soft grounds or to reduce negative skin friction).

A.41 **Stabilizing fluid :** Water mixed with clay, bentonite or other material for the support of the excavation walls and the base in unstable ground.

A.42 **Drilling fluid/mud :** Suspension composed of water and bentonite, polymers or clay, and with or without cement and other additions, for stabilization of bore hole walls and for flushing.

A.43 **Bentonite :** A naturally-occurring or manufactured sodium or calcium montmorillonite clay. When wetted the minerals swell to form a suspension that is fluid when stirred, but thixotropic action causes the fluid to gel when the suspension is at rest.

A.44 **Bentonite suspension :** Stabilizing fluid that comprises bentonite and water.

A.45 **Mudding-in :** Technique of stirring bentonite or clay powder and water by an auger into granular soil to facilitate the installation of a temporary casing.

A.46 **Boring (drill) string :** Tool assembly used for continuous excavation consisting of a head (e.g. drilling head, bit, auger, bucket) and an operating string (e.g. drilling pipes, kellybars, stabilizers, counter weights).

A.47 **Air lifting :** Pumping technique in which air is pumped into the base of a suction pipe to cause reduced density of material in the pipe and induce upward flow to evacuate solids and fluids (flushing).

A.48 **Direct circulation boring :** Continuous excavation method in which fluid is passed down the central pipe of the boring string for the purpose of displacing spoil upward in the pile bore.

A.49 **Reverse circulation boring :** Continuous excavation method in which fluid contained in the bore is pumped up a central pipe to transport spoil (e.g. by air lifting).

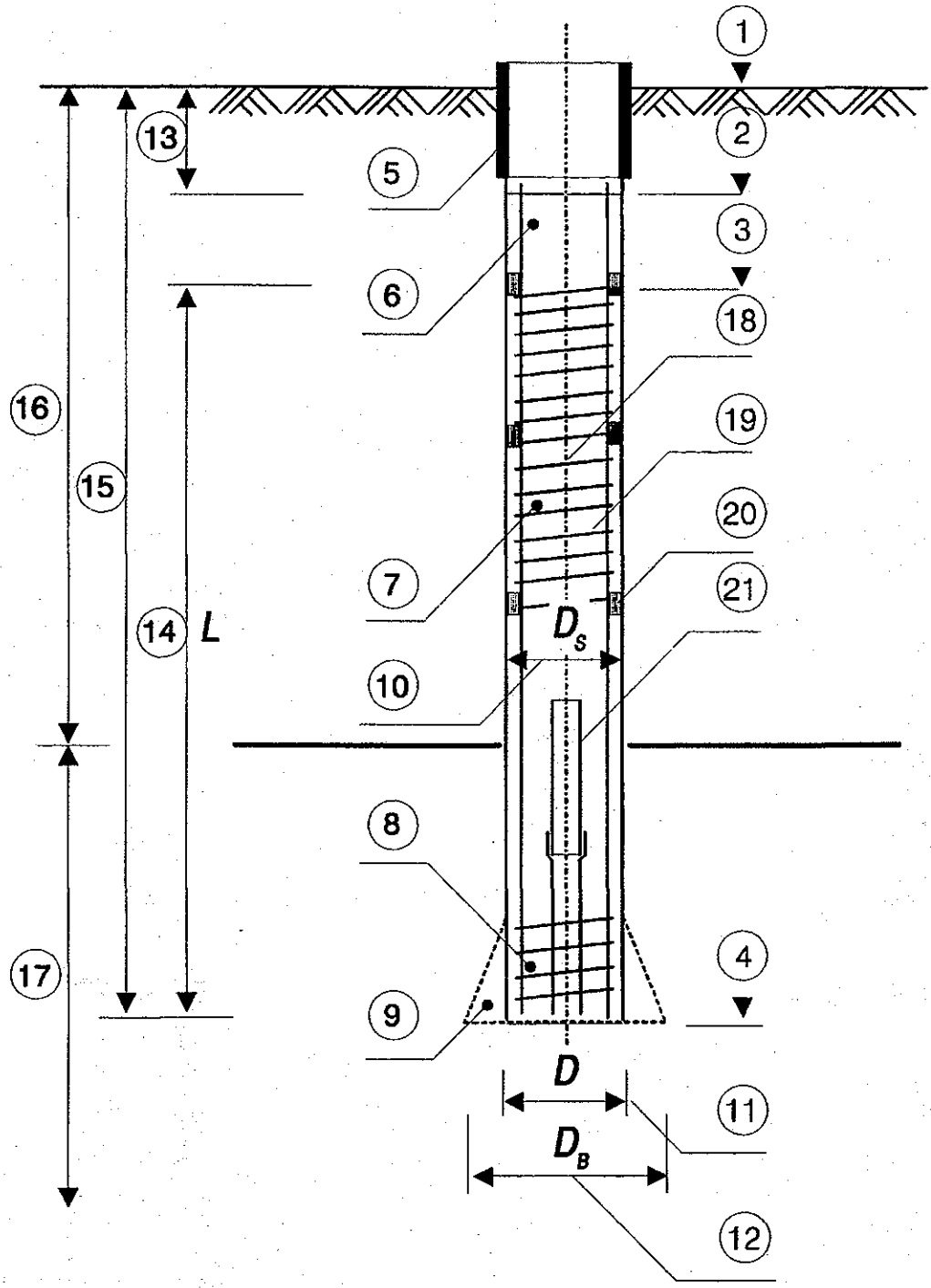
A.50 **Concreting pipe :** Metal pipe comprising several joined lengths, surmounted by a hopper or chute for concrete placement.

A.51 **Tremie pipe :** Concreting pipe, with watertight joints for submerged concrete placement. During placement the lower end of the pipe remains immersed into the concrete.

A.52 **Grout :** Fluid mixture of a setting agent (usually cement), fine aggregate and water that generally hardens after being placed in position.

A.53 **Pile base grouting :** Injection of grout under pressure below the base of an installed pile base in order to enhance performance under load. Grouting pipes or a preformed void at the pile base are installed for this purpose.

A.54 **Pile shaft grouting :** Injection of grout carried out after pile concrete has set for the enhancement of skin friction by the use of grouting pipes which are installed together with the pile reinforcement.

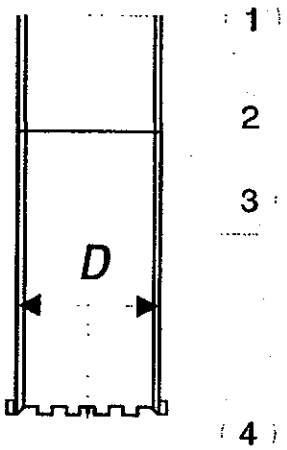


1 working level
2 casting level
3 cut-off-level (C.O.L.)
4 base level

5 lead in tube
6 pile head
7 pile shaft
8 pile base
9 base enlargement
10 shaft diameter
11 pile diameter
12 base diameter

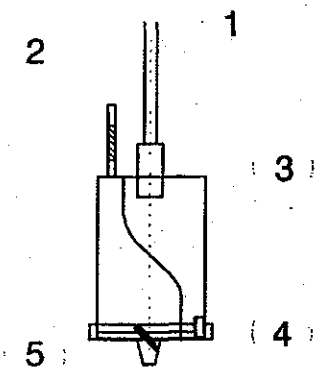
13 empty bore
14 length *L*
15 excavation depth
16 overburden soil
17 bearing layer
18 pile axis
19 reinforcement cage
20 spacer
21 concreting pipe

Figure A.1 : Bored pile : Designations



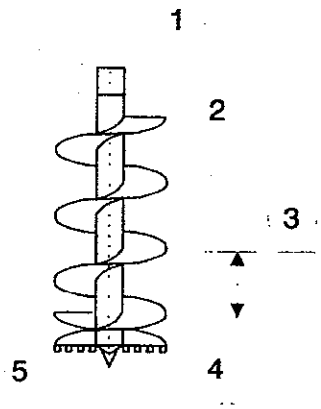
1 joint
2 (temporary / permanent) casing
3 pile shaft diameter
4 cutting ring

Figure A.2 : Casing



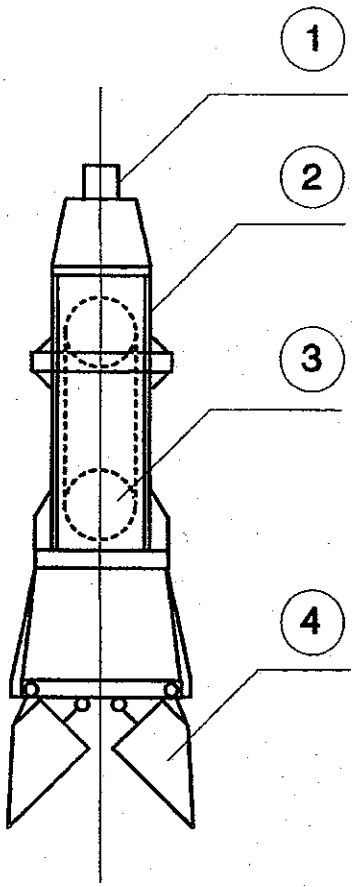
kelly 1
release lever 2
bucket 3
base plate 4
stinger 5

Figure A.3 : Drilling bucket



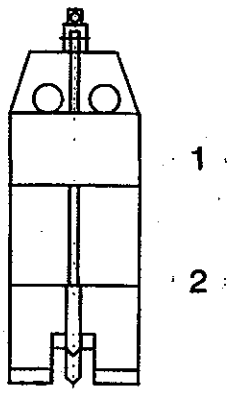
1 stem
2 flight
3 pitch
4 cutting edge
5 stinger

Figure A.4 : Auger



suspension 1
body 2
pulleys 3
jaws 4

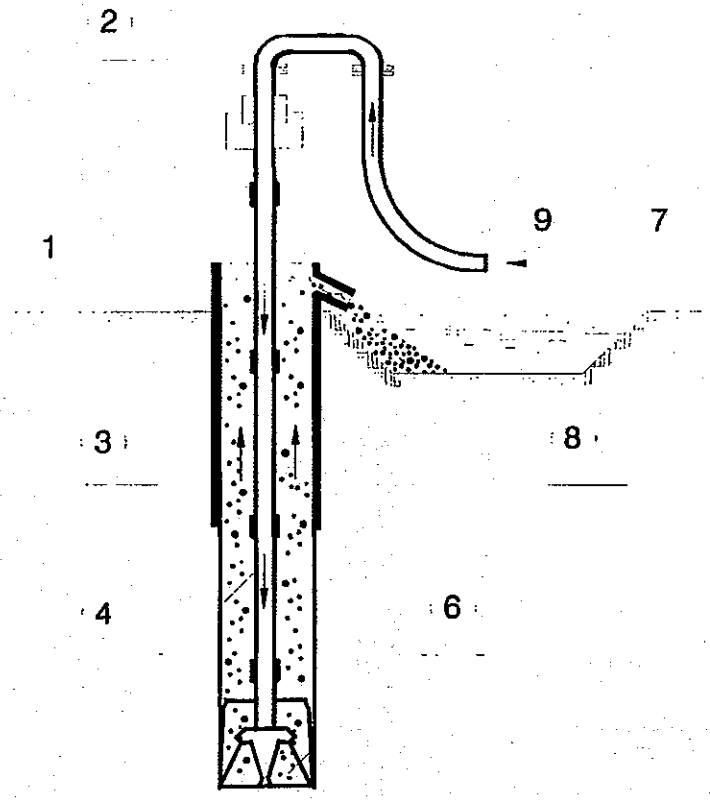
Figure A.5 : Grab



1 chisel body
2 tip

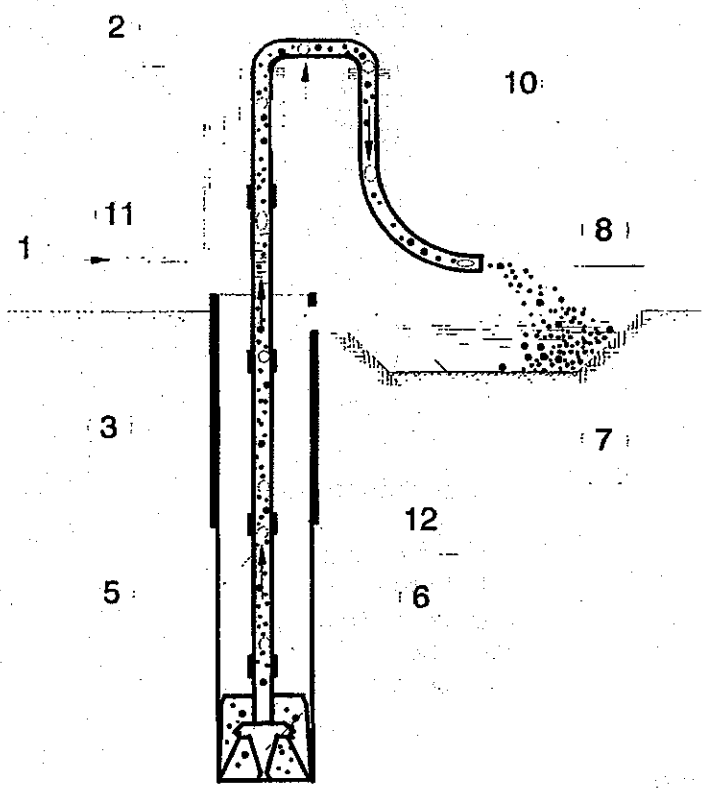
Figure A.6 : Drop

Figures A.2 - A.6 : Tools for discontinuous excavation



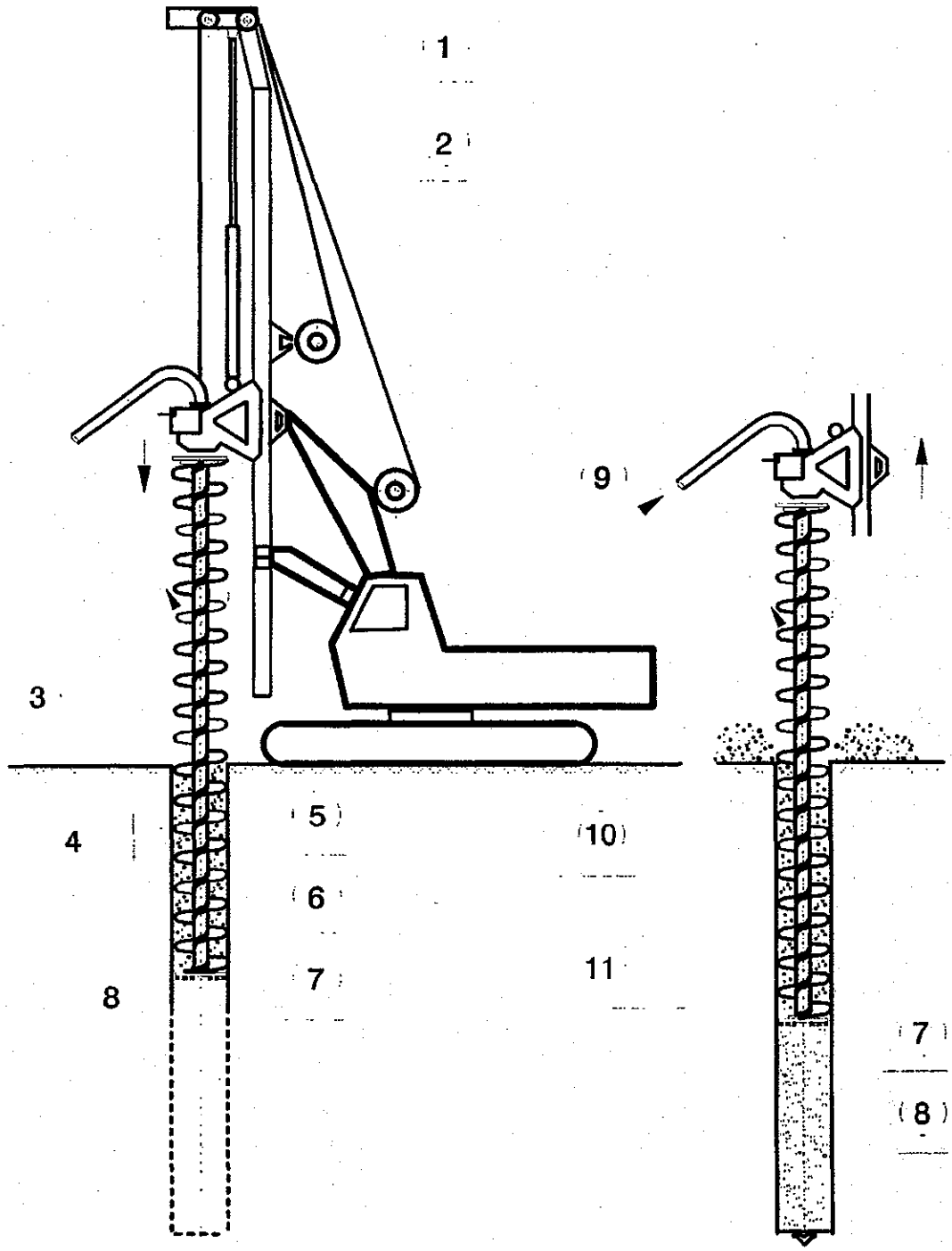
1 working level
2 power swivel
3 casing / lead in tube
4 drill string
5
6 drilling bit
7 mud pit
8 cuttings
9 from the pump

Figure A.7 : Direct circulation boring system



1 working level
2 power swivel
3 casing / lead in tube
4
5 air lift drill pipes
6 drilling bit
7 mud pit
8 cuttings
9
10 discharge hose
11 air hose
12 air inlet valve

Figure A.8 : Reverse circulation boring system



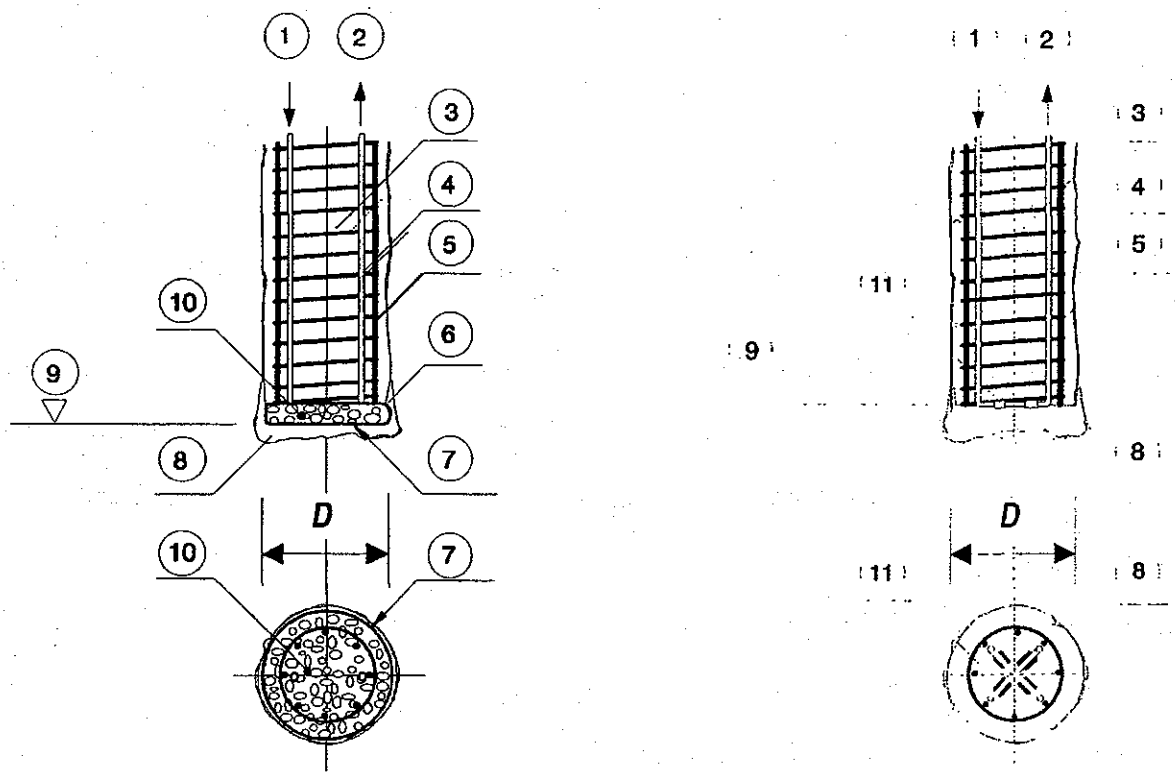
a) Boring

1 thrust cylinder
2 boom
3 working level
4 pitch
5 spoil
6 continuous flight auger

b) Concreting

7 hollow stem
8 bonde
9 concrete supply
10 spoil
11 concrete

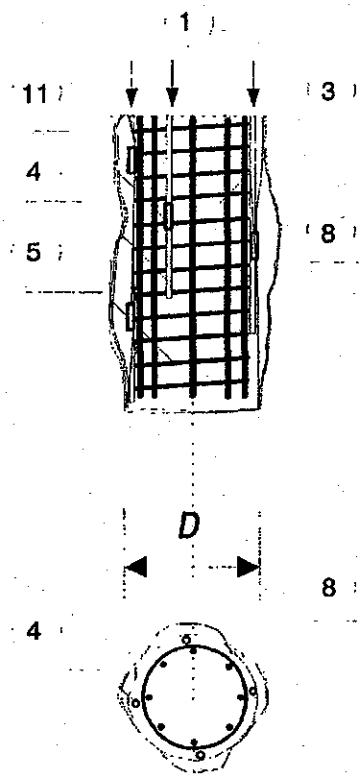
Figure A.9 : Continuous flight auger drilling



a) with flexible box structure

b) with grouting pipes

Figure A.10 : Pile base grouting (examples)



1 grouting
2 grouting control
3 concrete
4 groutig pipe
5 reinforcement cage
6 seal
7 box
8 grout
9 base level
10 filling (gravel)
11 valves

Figure A.11 : Shaft grouted pile (example)

Annex B (informative)

Sample records

1 This Annex contains sample construction records for :

2 The records B.1 to B.6 can be supplemented by additional forms as applicable, such as:

- survey records;
- stabilizing fluid control records;
- concrete mixing records (in cases of site mixing only);
- delivery documents for concrete and/or grout;
- consistency, temperature and workability tests on site for concrete and for grout;
- concrete placement records;
- grouting records;
- cut-off inspection forms.

B.1 Construction of Bored Piles with Cased or Unsupported Excavation: General Data

Contractor _____ Pile type and method _____

Site _____

Working drawing no. _____ cased excavation _____ ☐

unsupported excavation ☐

1 Pile data

a) Diameter _____ m
b) External casing diameter _____ m
c) Cutting shoe diameter _____ m
d) Boring tool diameter _____ m
e) Excavation under water _____ ☐

2 Reinforcement

Drawing no. _____
a) Placement of the reinforcement cage
- before concrete placement _____ ☐
- subsequent to concrete placement _____ ☐

b) Spacers _____ ☐
- type _____
- qty./longitudinal intervals _____ / _____ m

3 Concrete

a) Nominal strength: C _____
Consistency: S/F/superplasticized _____
b) Ready-mixed concrete _____ ☐
Site mixed concrete _____ ☐
c) Cement type (Supplier) _____
d) Cement content _____ kg/m³

e) Aggregate (maximum size) _____
f) Water cement ratio W/C = _____
W = weight of water C = weight of cement
g) Concrete admixtures _____
% of cement weight _____
h) Retarding admixtures _____
Workability time _____

4 Concrete placement

a) Submerged conditions _____ ☐
Dry conditions _____ ☐
b) Method of placement
- tremie pipe ∅ _____ m ☐
- pumping hose ∅ _____ m ☐
- different placing method _____ ☐
- description _____

c) Cleaning of pile base _____
d) Measures for separating concrete from water at commencement of placement

5 Comments/ observations _____

☐ Mark as appropriate

B.2 Construction of Bored Piles with Cased or Unsupported Excavations : Particular Data

Bored pile no. _____ Compression pile _____ ☐

_____ Tension pile _____ ☐

_____ Rake _____

☐ Mark as appropriate

1 Ground strata

m below working level	m above principal datum	Ground description	Groundwater	Boring tool casing from ..... to ..... m
	± 0	working level ▽		

Scale 1 :

2 Times of execution

1	2	3	4	5
Process	Ambient temperature °C	Times from	to	Date
Excavation				
Chiselling				
Interruption				
Base formation				
Concrete placement				

3 Pile data

a) Depth measurement after excavation

_____ m below working level

b) chiselling: from

_____ m to _____ m

below working level

c) Deviation of position at working level

Axis: ___ : _____ cm Axis: ___ : _____ cm

4 Reinforcement

Deviations from drawing no. _____

Deviations along length _____

Modifications _____

_____

_____

5 Concrete

Special events _____

_____

_____

6 Concrete placement

Water level inside the bore at start of placement below working level _____ m

Concrete consumption

Theoretical _____ m^3 Actual _____ m^3

7 Comments/observations

Deviations from general data

_____

_____

_____

8 Signatures/date

Foreman/superintendent _____

Contractor's representative _____

Client's representative _____

B.3 Construction of Bored Piles with Supporting Fluids: General Data

Contractor _____ Pile type and method _____

Site _____

Working drawing no. _____

1 Pile data

a) Diameter of pile/barrette _____ m

b) Dimension of guide wall or lead-in tube _____ m

c) Excavation tool _____

_____

d) External dimensions

– of the excavation tool _____ m

– of the cutting shoe _____ m

2 Reinforcement

Drawing no. _____

a) Placement of the reinforcement cage

– before concrete placement ☐

– subsequent to concrete placement _____ ☐

b) Spacers _____ ☐

– type _____

– qty./longitudinal intervals _____ / _____ m

3 Concrete

a) Nominal strength: C _____

Consistency: S/F/superplasticized _____

b) Ready-mixed concrete _____ ☐

Site mixed concrete ☐

c) Cement type (Supplier) _____

_____

d) Cement content _____ kg/m³

e) Aggregate (maximum size) _____

f) Water cement ratio W/C = _____

W = weight of water C = weight of cement

g) Concrete admixtures _____

% of cement weight _____

h) Retarding admixtures _____

Workability time _____

4 Concrete placement

a) Submerged conditions ☐

Dry conditions _____ ☐

b) Method of placement

– tremie pipe Ø _____ m ☐

– pumping hose Ø _____ m ☐

– different placing method _____ ☐

– description _____

_____

c) Cleaning of pile base _____

_____

_____

d) Measures for separating concrete from water at commencement of placement

_____

_____

5 Comments/ observations _____

_____

☐ Mark as appropriate

B.4 Construction of Bored Piles with Supporting Fluids: Particular Data

Bored pile no. _____ Compression pile _____ ☐

_____ Tension pile _____ ☐

_____ Rake _____

☐ Mark as appropriate

1 Ground strata

m below working level	m above principal datum	Ground description	Groundwater	Boring tool casing from ..... to ..... m
	± 0	working level ▽		
Scale 1 :				

2 Times of execution

1	2	3	4	5
Process	Ambient temperature °C	Times from	Times to	Date
Excavation				
Chiselling				
Interruption				
Base formation				
Concrete placement				

3 Pile data

a) Depth measurement after excavation

_____ m below working level

b) Chiselling: from

_____ m to _____ m

c) Deviation of position at working level

Axis: __ : _____ cm Axis: __ : _____ cm

4 Stabilizing fluid actual values

	Unit	Before concreting	After
Density	g/cm³		
Marsh val.	sec		
Fluid loss	cm³		
Sand cont.	%		
Alkalinity	pH		

Fluid level above bottom level of

guide wall/lead-in tube _____ m

above Groundwater _____ m

5 Reinforcement

Deviations from drawing no. _____

Deviations along length _____

Modifications _____

6 Concrete

Special events _____

7 Concrete placement

Fluid level inside the bore at start of placement above bottom level of guide wall/lead-in tube

_____ m

Concrete consumption

Theoretical _____ m³ actual _____ m³

8 Comments/observations

Deviations from general data _____

9 Signatures/date

Foreman/superintendent _____

Contractor's representative _____

Client's representative _____

B.5 Construction of Continuous Flight Auger Piles: General Data

Contractor _____ Pile type and method _____

Site _____ Plant and equipment _____

Working drawing no. _____

1 Pile data

a) Length of the auger _____ m
b) Auger diameter (external) D_a _____ m
c) Stem diameter D_i _____ m
d) Pitch of the helix _____ m
e) Ratio D_i / D_a _____
f) Bottom closed ☐ Bottom open ☐

2 Reinforcement

Drawing no. _____

a) Placement of the reinforcement cage
- before concrete placement ☐
- subsequent to concrete placement ☐
- use of vibrator ☐

b) Spacers ☐
- type _____
- qty./longitudinal intervals _____ / _____ m

3 Concrete

a) Nominal strength: C _____
Consistency: S/F/superplasticized _____
b) Ready-mixed concrete ☐
Site mixed concrete ☐
c) Cement type (Supplier) _____
d) Cement content _____ kg/m³

e) Aggregate (maximum size) _____
f) Water cement ratio W/C = _____
W = weight of water C = weight of cement
g) Concrete admixtures _____
% of cement weight _____
h) Retarding admixtures _____
Workability time _____

4 Concrete placement

a) Submerged conditions ☐
Dry conditions _____ ☐
b) Method of placement
- tremie pipe ∅ _____ m ☐
- pumping hose ∅ _____ m ☐
- different placing method _____ ☐
- description _____

c) Cleaning of pile base _____
d) Measures for separating concrete from water at commencement of placement _____

5 Comments/ observations

_____

☐ Mark as appropriate

B.6 Construction of Continuous Flight Auger Piles: Particular Data

Bored pile no. _____ Compression pile _____ ☐
_____ Tension pile _____ ☐
_____ Rake _____

1 Ground strata

m below working level	m → Penetration per revolution	bar → Concrete pressure
	working level ±0 ▽	

Scale 1 :

2 Times of execution

1	2	3	4	5
Process	Ambient temperature °C	Times from	Times to	Date
Excavation				
Concrete placement				
Installation of reinforce-ment				

☐ Mark as appropriate

3 Pile data

Deviation of position at working level
Axis: _____ : _____ cm Axis: : _____ cm

4 Boring procedure

Penetration per revolution as a function of depth, derived from plotted records, see graph

5 Reinforcement

Deviations from drawing no. _____
Deviations along length _____
Modifications _____

6 Concrete

Special events _____

Monitoring of concrete pressure see graph.

7 Concrete placement

Concrete consumption
Theoretical _____ m³ Actual _____ m³

8 Comments/observations

Deviations from general data _____

9 Signatures/date

Foreman/superintendent _____
Contractor's representative _____
Client's representative _____

Annex C (informative) Obligation of the provisions

The provisions are marked corresponding to their obligation:

- *(RQ)* : Requirement;
- *(RC)* : Recommendation;
- *(PE)* : Permission;
- *(PO)* : Possibility and eventuality.

1 Scope

1.1 - 1.11
Provisions

2 Normative references

NOTE 1
NOTE 2
2.1 *(RQ)*
2.2 List

3 Definitions

NOTE
3.1 - 3.22

4 Needs for the construction of bored piles

4.1 *(RC)*
4.2 *(RQ)*
4.3 *(RQ)*
4.4 *(RQ)*
EXAMPLES

5 Site investigation

5.1 General

NOTE
5.1.1 *(RQ)*
5.1.2 *(RQ)*
5.1.3 *(RQ)*
5.1.4 *(RC)*
5.1.5 *(RC)*
5.1.6 *(PE)*
5.1.7 *(RQ)*
5.1.8 *(RQ)*

5.2 Specific requirements

5.2.1 *(RQ)*
5.2.2 *(RQ)*

6 Materials and products

6.1 General

6.1.1 *(RQ)*
6.1.2 *(RQ)*
6.1.3 *(RQ)*

6.2 Materials for concrete and grout

6.2.1 Cement

6.2.1.1 *(RQ)*
6.2.1.2 *(PE)*
6.2.1.3 *(RQ)*
6.2.1.4 *(RC)*

6.2.2 Aggregates

6.2.2.1 *(RQ)*
6.2.2.2 *(RQ)*
6.2.2.3 *(RC)*
6.2.2.4 *(RQ)*
6.2.2.5 *(RQ)*

6.2.3 Water

6.2.3.1 *(RQ)*
6.2.3.2 *(PE)*

6.2.4 Additions and admixtures

6.2.4.1 *(RQ)*
6.2.4.2 *(RQ)*
6.2.4.3 *(RQ)*
6.2.4.4 *(PE)*
6.2.4.5 *(RQ)*
6.2.4.6 *(PE)*
NOTE
6.2.4.7 *(RQ)*
6.2.4.8 *(PE)*

6.3 Concrete in situ

6.3.1 General

6.3.1.1 *(RQ)*
6.3.1.2 *(RQ)*
6.3.1.3 *(PE)*
6.3.1.4 *(PE)*
6.3.1.5 *(RQ)*
6.3.1.6 *(PE)*
6.3.1.7 *(RQ)*
NOTE
6.3.1.8 *(PO)*

6.3.2 Mixing

6.3.2.1 *(RQ)*
6.3.2.2 *(PE)*
6.3.2.3 *(RQ)*
6.3.2.4 *(RQ)*
6.3.2.5 *(RQ)*

6.3.3 Sampling and testing

6.3.3.1 *(RQ)*
6.3.3.2 *(RQ)*
6.3.3.3 *(RQ)*
6.3.3.4 *(RQ)*
6.3.3.5 *(PE)*
6.3.3.6 *(PO)*
EXAMPLES
6.3.3.7 *(RQ)*
6.3.3.8 *(RQ)*

6.4 Grout

6.4.1 *(RQ)*
6.4.2 *(RQ)*
6.4.3 *(RQ)*
6.4.4 *(RC)*
NOTE
6.4.5 *(PE)*

6.5 Stabilizing fluids

6.5.1 General

6.5.1.1 *(RQ)*
6.5.1.2 *(RQ)*

6.5.2 Bentonite suspensions

6.5.2.1 *(RQ)*
6.5.2.2 *(RQ)*
6.5.2.3 *(RQ)*
6.5.2.4 *(PE)*
6.5.2.5 *(PE)*
6.5.2.6 *(PE)*

6.5.3 Polymers and other suspensions

6.5.3.1 *(PE)*
6.5.3.2 *(RQ)*

6.6 Steel

6.6.1 *(RQ)*
6.6.2 *(RQ)*
6.6.3 *(RQ)*
6.6.4 *(RQ)*

7 Design related considerations

7.1 General

7.1.1 *(RQ)*
NOTE
7.1.2 *(PO)*
7.1.3 *(RQ)*
7.1.4 *(PE)*
7.1.5 *(RC)*
7.1.6 *(RC)*
7.1.7 *(RQ)*
7.1.8 *(RQ)*
7.1.9 *(RC)*
NOTE
7.1.10 *(PO)*

7.2 Geometrical construction tolerances

7.2.1 *(RQ)*
NOTE
7.2.2 *(RQ)*

7.3 Piles forming a wall

7.3.1 *(PO)*
7.3.2 *(PO)*
7.3.3 *(RQ)*
7.3.4 *(RQ)*

7.4 Excavation

7.4.1 *(RQ)*
7.4.2 *(RQ)*
7.4.3 *(RQ)*
7.4.4 *(RQ)*
NOTE
7.4.5 *(RQ)*
7.4.6 *(RQ)*
7.4.7 *(RQ)*

7.5 Precast concrete elements

7.5.1 *(RQ)*
7.5.2 *(RQ)*
7.5.3 *(RQ)*

7.6 Reinforcement

7.6.1 General

7.6.1.1 *(RQ)*
7.6.1.2 *(RQ)*
7.6.1.3 *(RQ)*
7.6.1.4 *(RC)*

7.6.2 Longitudinal reinforcement

7.6.2.1 *(RQ)*
7.6.2.2 *(RQ)*
7.6.2.3 *(RQ)*
7.6.2.4 *(RC)*
7.6.2.5 *(RQ)*
7.6.2.6 *(PE)*
7.6.2.7 *(RC)*
7.6.2.8 *(RQ)*
7.6.2.9 *(PE)*
7.6.2.10 *(RQ)*

7.6.3 Transverse reinforcement

7.6.3.1 *(RQ)*
7.6.3.2 *(RC)*
7.6.3.3 *(RQ)*
7.6.3.4 *(RC)*
7.6.3.5 *(RC)*
7.6.3.6 *(RQ)*

7.6.4 Concrete cover

7.6.4.1 *(RQ)*
7.6.4.2 *(RC)*
7.6.4.3 *(PE)*

7.5 Reinforcement tubes and sections

7.6.5.1 *(RQ)*
7.6.5.2 *(RQ)*
7.6.5.3 *(PO)*
7.6.5.4 *(RQ)*

8 Execution

8.1 Excavation

8.1.1 General

8.1.1.1 *(RQ)*
NOTE 1
NOTE 2
8.1.1.2 *(RQ)*
EXAMPLE
8.1.1.3 *(RQ)*
8.1.1.4 *(RQ)*
8.1.1.5 *(RC)*
NOTE 1
NOTE 2
8.1.1.6 *(RQ)*
8.1.1.7 *(RQ)*
8.1.1.8 *(RQ)*
8.1.1.9 *(RQ)*
8.1.1.10 *(RQ)*
8.1.1.11 *(RQ)*
8.1.1.12 *(RQ)*

8.1.2 Methods and tools

NOTE
8.1.2.1 *(PO)*
8.1.2.2 *(RQ)*
8.1.2.3 *(PO)*
8.1.2.4 *(PE)*
8.1.2.5 *(RQ)*
NOTE

8.1.3 Excavations supported by casings

8.1.3.1 *(RQ)*
8.1.3.2 *(PE)*
8.1.3.3 *(RQ)*
8.1.3.4 *(RQ)*
8.1.3.5 *(RC)*
8.1.3.6 *(RQ)*
8.1.3.7 *(PE)*
8.1.3.8 *(RQ)*
8.1.3.9 *(RQ)*
NOTE
8.1.3.10 *(RQ)*
8.1.3.11 *(RQ)*
NOTE

8.1.4 Excavation supported by fluids

8.1.4.1 *(RQ)*
8.1.4.2 *(RQ)*
8.1.4.3 *(PE)*
8.1.4.4 *(RQ)*
8.1.4.5 *(RQ)*
8.1.4.6 *(RQ)*
8.1.4.7 *(PE)*
8.1.4.8 *(RQ)*
NOTE
8.1.4.9 *(RQ)*
8.1.4.10 *(RC)*

8.1.5 Boring with continuous flight augers

8.1.5.1 *(PE)*
8.1.5.2 *(RQ)*
8.1.5.3 *(RQ)*
8.1.5.4 *(RQ)*
8.1.5.5 *(RQ)*
8.1.5.6 *(RQ)*
8.1.5.7 *(RQ)*
8.1.5.8 *(RQ)*
8.1.5.9 *(RQ)*
8.1.5.10 *(RQ)*
8.1.5.11 *(RQ)*

8.1.6 Unsupported excavation

8.1.6.1 *(PE)*
8.1.6.2 *(RQ)*
8.1.6.3 *(RQ)*
8.1.6.4 *(RQ)*

8.1.7 Enlargements

8.1.7.1 *(RQ)*
8.1.7.2 *(RC)*

8.2 Reinforcement

8.2.1 General

8.2.1.1 *(RQ)*
8.2.1.2 *(RQ)*
8.2.1.3 *(RQ)*

8.2.2 Joints

8.2.2.1 *(RQ)*
8.2.2.2 *(PO)*
8.2.2.3 *(RQ)*
8.2.2.4 *(PE)*

8.2.3 Bending of reinforcement

8.2.3.1 *(RQ)*
8.2.3.2 *(RQ)*
8.2.3.3 *(PE)*

8.2.4 Assembly of cages

8.2.4.1 *(RQ)*
8.2.4.2 *(RQ)*
8.2.4.3 *(RQ)*
8.2.4.4 *(PO)*

8.2.5 Spacers

8.2.5.1 *(RQ)*
8.2.5.2 *(RQ)*
8.2.5.3 *(PE)*
8.2.5.4 *(RQ)*
8.2.5.5 *(RQ)*
8.2.5.6 *(RC)*

8.2.6 Installation

8.2.6.1 *(RQ)*
8.2.6.2 *(RQ)*
8.2.6.3 *(RQ)*
8.2.6.4 *(RQ)*
8.2.6.5 *(PE)*
8.2.6.6 *(RQ)*
8.2.6.7 *(PO)*
8.2.6.8 *(PE)*

8.3 Concreting

8.3.1 General

8.3.1.1 *(RQ)*
8.3.1.2 *(RQ)*
8.3.1.3 *(RQ)*
NOTE 1
NOTE 2
8.3.1.4 *(RC)*
8.3.1.5 *(RQ)*
8.3.1.6 *(RQ)*
8.3.1.7 *(RQ)*
8.3.1.8 *(RQ)*
8.3.1.9 *(RQ)*
8.3.1.10 *(RQ)*
8.3.1.11 *(RC)*
8.3.1.12 *(RQ)*
8.3.1.13 *(RQ)*
8.3.1.14 *(PO)*
8.3.1.15 *(RQ)*
8.3.1.16 *(RQ)*
8.3.1.17 *(RQ)*
8.3.1.18 *(PO)*
8.3.1.19 *(RQ)*
8.3.1.20 *(RC)*
8.3.1.21 *(RQ)*
8.3.1.22 *(RC)*
8.3.1.23 *(RQ)*
8.3.1.24 *(RQ)*
8.3.1.25 *(RQ)*
8.3.1.26 *(PO)*

8.3.2 Concreting in dry conditions

8.3.2.1 *(RQ)*
8.3.2.2 *(RQ)*
8.3.2.3 *(RC)*
8.3.2.4 *(RQ)*
8.3.2.5 *(RQ)*

8.3.3 Concreting in submerged conditions

8.3.3.1 *(RQ)*
NOTE
8.3.3.2 *(RQ)*
NOTE
8.3.3.3 *(RQ)*
8.3.3.4 *(RQ)*
8.3.3.5 *(RQ)*
8.3.3.6 *(RQ)*
8.3.3.7 *(RC)*
8.3.3.8 *(RQ)*
8.3.3.9 *(RQ)*
8.3.3.10 *(RQ)*
8.3.3.11 *(PE)*
8.3.3.12 *(RQ)*
8.3.3.13 *(RQ)*
8.3.3.14 *(RQ)*
8.3.3.15 *(RC)*
8.3.3.16 *(RC)*
8.3.3.17 *(RC)*
8.3.3.18 *(RQ)*
8.3.3.19 *(RQ)*

8.3.4 Extraction of casings

8.3.4.1 *(RQ)*
8.3.4.2 *(RQ)*
8.3.4.3 *(RQ)*
8.3.4.4 *(RQ)*
NOTE
8.3.4.5 *(RQ)*

8.3.5 Permanent casings or linings

8.3.5.1 *(PO)*
NOTE
8.3.5.2 *(RQ)*

8.3.6 Concreting of continuous flight auger piles

8.3.6.1 *(PE)*
8.3.6.2 *(RQ)*
8.3.6.3 *(RQ)*
8.3.6.4 *(PE)*
8.3.6.5 *(RQ)*
8.3.6.6 *(RQ)*
8.3.6.7 *(RQ)*
8.3.6.8 *(RQ)*
NOTE

8.3.7 Prepacked piles

8.3.7.1 *(RQ)*
8.3.7.2 *(RQ)*
8.3.7.3 *(RQ)*
8.3.7.4 *(RQ)*
8.3.7.5 *(RQ)*

8.3.8 Loss of immersion of tremie or casing

8.3.8.1 *(PE)*
8.3.8.2 *(RQ)*
8.3.8.3 *(RQ)*
8.3.8.4 *(PE)*
8.3.8.5 *(PE)*
8.3.8.6 *(RQ)*
8.3.8.7 *(RC)*

8.3.9 Piles containing precast concrete elements, reinforcement tubes or permanent casings

8.3.9.1 *(RQ)*
8.3.9.2 *(RQ)*
8.3.9.3 *(PE)*
8.3.9.4 *(PE)*
8.3.9.5 *(RQ)*

8.3.10 External grouting of cast in place piles

8.3.10.1 *(RQ)*
8.3.10.2 *(RQ)*
8.3.10.3 *(PO)*
8.3.10.4 *(RQ)*
8.3.10.5 *(RQ)*
8.3.10.6 *(PE)*
8.3.10.7 *(RQ)*

8.4 Bored pile walls

8.4.1 *(RC)*
8.4.2 *(RC)*
8.4.3 *(RC)*
8.4.4 *(RQ)*
8.4.5 *(RQ)*
NOTE
8.4.6 *(PE)*

9 Supervision and monitoring

9.1 Supervision

9.1.1 *(RQ)*
9.1.2 *(RQ)*

9.2 Monitoring of pile construction

9.2.1 *(RQ)*
9.2.2 *(RQ)*
9.2.3 *(RC)*
9.2.4 *(RQ)*
9.2.5 *(RQ)*
NOTE
9.2.6 *(RQ)*
NOTE
9.2.7 *(RQ)*
9.2.8 *(RQ)*

9.3 Pile testing

9.3.1 General

NOTE 1
NOTE 2
NOTE 3
NOTE 4
NOTE 5

9.3.2 Axial loading tests

9.3.2.1 *(RQ)*
9.3.2.2 *(PO)*
9.3.2.3 *(RQ)*
9.3.2.4 *(RC)*
9.3.2.5 *(RC)*
9.3.2.6 *(RQ)*
9.3.2.7 *(PE)*
9.3.2.8 *(RC)*
9.3.2.9 *(RQ)*
9.3.2.10 *(RQ)*
9.3.2.11 *(RQ)*
9.3.2.12 *(RQ)*
9.3.2.13 *(RQ)*
9.3.2.14 *(RC)*
9.3.2.15 *(RQ)*
9.3.2.16 *(RQ)*

10 Records

10.1 *(RQ)*
10.2 *(RQ)*
10.3 *(RQ)*
10.4 *(PE)*
10.5 *(RQ)*
NOTE
10.6 *(RQ)*
NOTE
10.7 *(RQ)*

11 Specific Requirements

11.1 *(RQ)*
11.2 *(RQ)*
11.3 *(RQ)*
11.4 *(RC)*
11.5 *(RQ)*
11.6 *(RQ)*
11.7 *(RQ)*
11.8 *(PO)*
NOTE
11.9 *(RQ)*