

Execution of special geotechnical work — Bored piles

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National foreword

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The UK participation in its preparation was entrusted by Technical Committee B/526, Geotechnics, to Subcommittee B/526/5, Construction of piles, pile shafts and boreholes, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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Summary of pages

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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

Contents

Foreword	4
1 Scope	5
2 Normative references	9
3 Definitions	10
4 Needs for the construction of bored piles	13
5 Site investigation	14
5.1 General	14
5.2 Specific requirements	15
6 Materials and products	16
6.1 General	16
6.2 Materials for concrete and grout	16
6.2.1 Cement	16
6.2.2 Aggregates	16
6.2.3 Water	17
6.2.4 Additions and admixtures	17
6.3 Concrete in situ	18
6.3.1 General	18
6.3.2 Mixing	19
6.3.3 Sampling and testing	20
6.4 Grout	21
6.5 Stabilizing fluids	21
6.5.1 General	21
6.5.2 Bentonite suspensions	21
6.5.3 Polymers and other suspensions	22
6.6 Steel	22
7 Design related considerations	23
7.1 General	23
7.2 Geometrical construction tolerances	24
7.3 Piles forming a wall	26
7.4 Excavation	26
7.5 Precast concrete elements	27
7.6 Reinforcement	27
7.6.1 General	27
7.6.2 Longitudinal reinforcement	27
7.6.3 Transverse reinforcement	28
7.6.4 Concrete cover	29
7.6.5 Reinforcement tubes and sections	29

8	Execution	29
8.1	Excavation	29
8.1.1	General	29
8.1.2	Methods and tools	31
8.1.3	Excavations supported by casings	32
8.1.4	Excavation supported by fluids	34
8.1.5	Boring with continuous flight augers	34
8.1.6	Unsupported excavation	35
8.1.7	Enlargements	36
8.2	Reinforcement	36
8.2.1	General	36
8.2.2	Joints	36
8.2.3	Bending of reinforcement	37
8.2.4	Assembly of cages	37
8.2.5	Spacers	38
8.2.6	Installation	38
8.3	Concreting	39
8.3.1	General	39
8.3.2	Concreting in dry conditions	41
8.3.3	Concreting in submerged conditions	41
8.3.4	Extraction of casings	43
8.3.5	Permanent casings or linings	43
8.3.6	Concreting of continuous flight auger piles	43
8.3.7	Prepacked piles	44
8.3.8	Loss of immersion of tremie or casing	45
8.3.9	Piles containing precast concrete elements, reinforcement tubes or permanent casings	45
8.3.10	External grouting of cast in place piles	46
8.4	Bored pile walls	46
9	Supervision and monitoring	47
9.1	Supervision	47
9.2	Monitoring of pile construction	47
9.3	Pile testing	56
9.3.1	General	56
9.3.2	Axial loading tests	57
10	Records	58
11	Specific Requirements	62
Annex A (informative)	Glossary	64
Annex B (informative)	Sample records	74
Annex C (informative)	Obligation of the provisions	83

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 bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

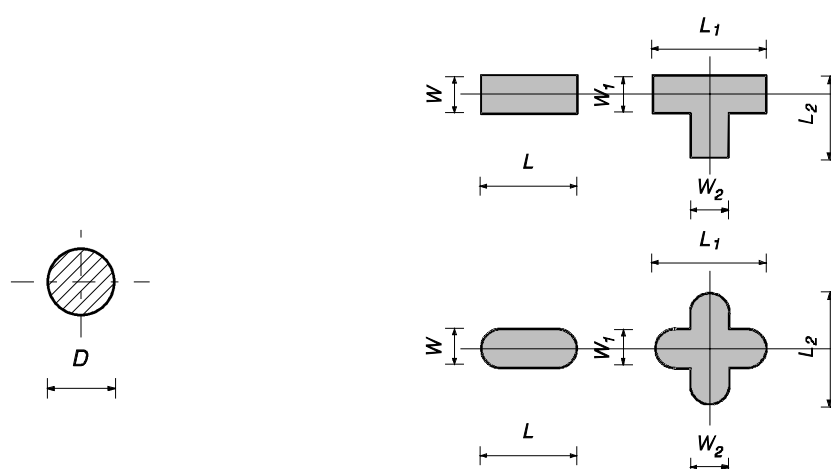
1 Scope

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

L : Barrette length

W : Barrette thickness

A : Cross-sectional area of the shaft

Figure 1 — Circular bored pile 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.

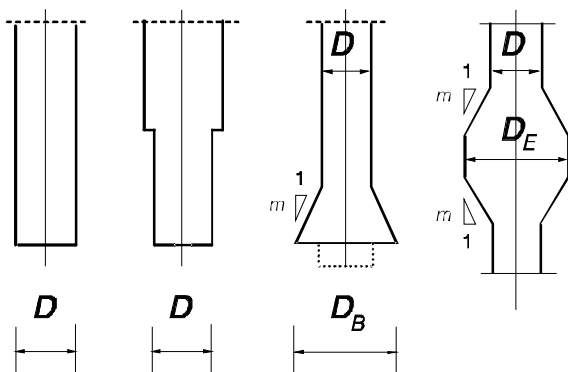


Figure 3 — Examples for straight shaft piles and piles with shaft and base enlargement

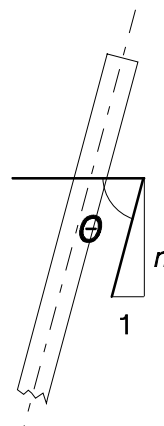


Figure 4 — Definition of the rake

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 $\geq 0,3$ 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: $n \geq 4$ ($\theta \geq 76^\circ$) (see Figure 4) ;
- rake for permanently cased piles: $n \geq 3$ ($\theta \geq 72^\circ$);
- base enlargements or cross-sectional area of barrette piles: $A \leq 10 \text{ m}^2$;

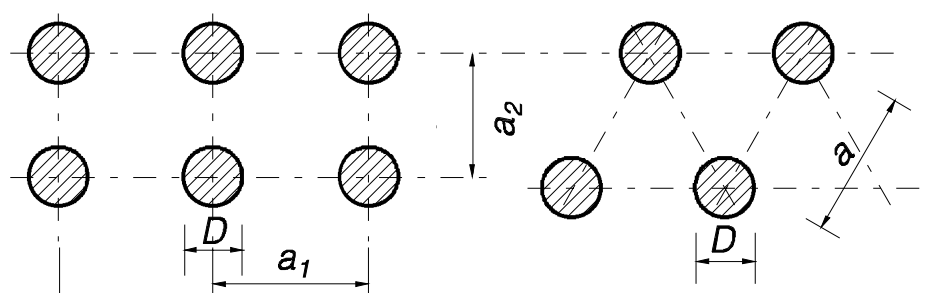
1.6 Shaft or base enlargements covered by this European Standard are:

- 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).

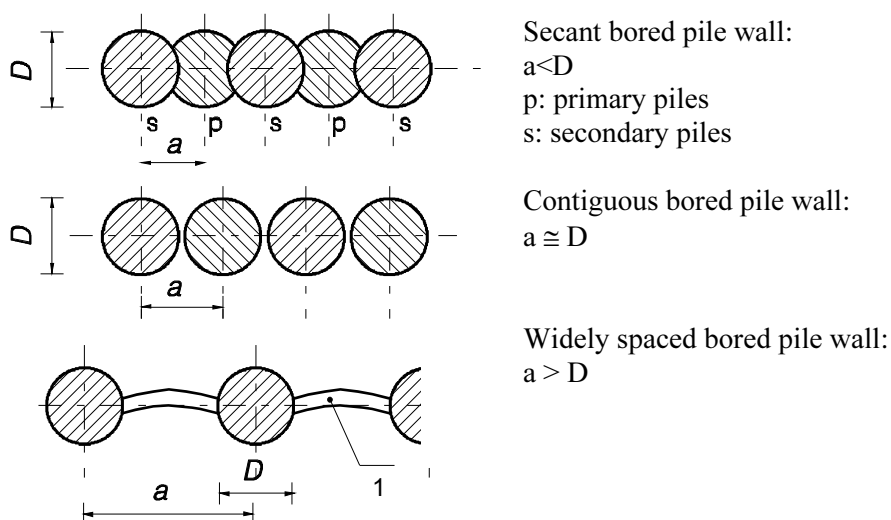
1.7 The provisions of this European Standard apply to:

- 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



a : Distance of piles
1: Lagging

Figure 6 — Example of bored pile walls

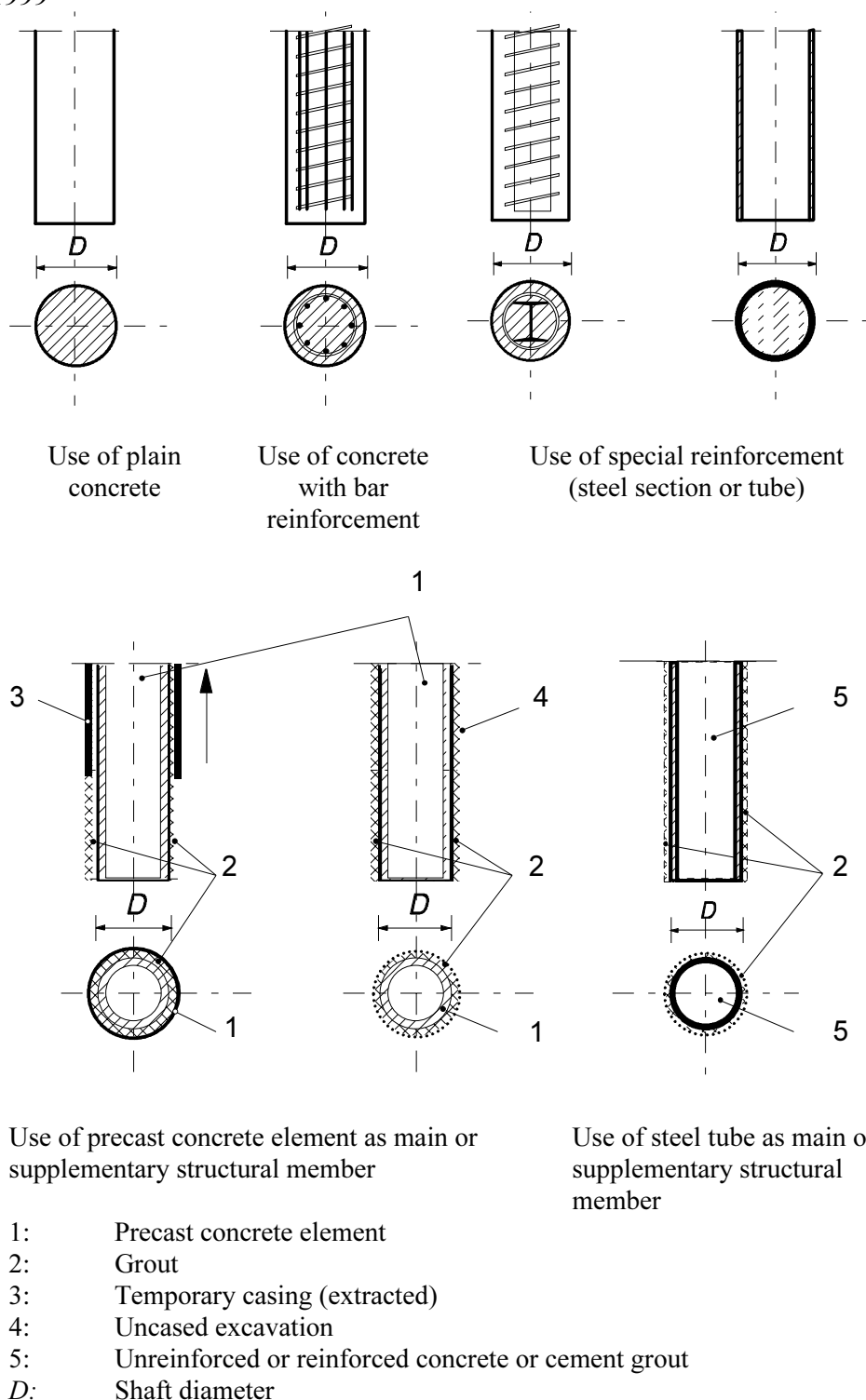


Figure 7 — Examples of circular piles

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

fr: pieu
de: Pfahl

3.2
bored pile
pile formed with or without a pile casing by excavating or boring a hole in the ground and filling with plain or reinforced concrete.

fr: pieu foré
de: Bohrpfahl

- 3.3**
barrette
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.
- fr: barrette**
de: Schlitzwandelement
- 3.4**
compression pile
pile to resist compressive forces.
- fr: pieu en compression**
de: Druckpfahl
- 3.5**
continuous flight auger pile (CFA-pile)
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).
- fr: pieu à la tarière continue creuse (CFA)**
de: Schneckenbohrpfahl
- 3.6**
end bearing pile
pile transmitting forces to the ground mainly by compression on its base.
- fr: pieu travaillant en pointe**
de: Spitzendruckpfahl
- 3.7**
enlarged base
base of a pile formed to have an area greater than that of its shaft. For bored piles, normally constructed by the use of special underreaming or bellong-out tools (see Figure 3).
- fr: base élargie**
de: Fußaufweitung
- 3.8**
friction pile
pile transmitting actions to the ground mainly by friction and adhesion between the lateral surface of the pile and the adjacent ground.
- fr: pieu flottant**
de: Reibungspfahl
- 3.9**
prepacked pile
pile where the completed excavation is filled with coarse aggregate which is subsequently injected with cement mortar from the bottom up.
- fr: pieu ballasté injecté**
de: Prepacked-Pfahl
- 3.10**
shaft diameter
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.
- fr: diamètre du fût**
de: Pfahldurchmesser
- 3.11**
tension pile
pile designed to resist tensile forces.
- fr: pieu en traction**
de: Zugpfahl
- 3.12**
preliminary pile
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.
- fr: pieu préliminaire**
de: Probepfahl (1)
- 3.13**
trial pile
pile installed to assess the practicability and suitability of the construction method for a particular application.
- fr: pieu de faisabilité**
de: Probepfahl (2)

3.14

test pile

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

fr: pieu d'essai

de: Probepfahl (3)

3.15

working pile

pile for the foundation of a structure.

fr: pieu de fondation

de: Bauwerkspfahl

3.16

static pile test

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

fr: essai de chargement statique de pieu

de: statische Probelastung

3.17

maintained load pile test

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).

fr: essai de chargement par palier

de: lastgesteuerte Probelastung

3.18

constant rate of penetration test

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

fr: essai de chargement à vitesse d'enfoncement constante

de: weggesteuerte Probelastung

3.19

dynamic pile test

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

fr: essai de chargement dynamique de pieu

de: dynamischer Pfahlversuch

3.20

integrity test

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

fr: essai d'intégrité

de: Integritätsprüfung

3.21

sonic test

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.

fr: essai d'auscultation sonique par réflexion

de: Ultraschallversuch

3.22

sonic coring

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

fr: essai d'auscultation sonique par transparence

de: Ultraschallversuch im Pfahl

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 Boreholes 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 $\frac{1}{4}$ 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	$\geq 325 \text{ kg/m}^3$
— placement in submerged conditions	$\geq 375 \text{ kg/m}^3$
Water-cement ratio (W/C)	$< 0,6$
Fines content $d < 0,125 \text{ mm}$ (inclusive of cement)	
— coarse aggregate $d > 8 \text{ mm}$	$\geq 400 \text{ kg/m}^3$
— coarse aggregate $d \leq 8 \text{ mm}$	$\geq 450 \text{ kg/m}^3$

Table 2 — Consistency ranges for fresh concrete in different conditions

Flow diameter range mm	Slump range mm	Typical conditions of use (examples)
$460 \leq \emptyset \leq 530$	$130 \leq H \leq 180$	— concrete placed in dry conditions
$530 \leq \emptyset \leq 600$	$H \geq 160$	— placed by pumping or — concrete placed in submerged conditions under water by tremie
$570 \leq \emptyset \leq 630$	$H \geq 180$	— concrete placed by tremie in submerged conditions under a stabilizing fluid.
NOTE: The measured slump (H) or flow diameter ($\emptyset$) 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 m³ or less) ;
- c) two additional samples after interruptions of the works longer than 7 days;
- d) one sample for every 75 m³ 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/cm³ 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;
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- 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:

$$e \leq e_{max} = 0,10 \text{ m for piles with: } D \leq 1,0 \text{ m;}$$

$$e \leq e_{max} = 0,1 \times D \text{ for piles with: } 1,0 \text{ m} < D \leq 1,5 \text{ m;}$$

$$e \leq e_{max} = 0,15 \text{ m for piles with: } D > 1,5 \text{ m;}$$

b) deviation of inclination of vertical piles or piles with an inclination of $n \geq 15$ ($\theta \geq 86^\circ$):

$$i \leq i_{max} = 0,02 (\triangleq 0,02 \text{ m/m}) ;$$

c) deviation of inclination of piles raking $4 \leq n < 15$ ($76^\circ \leq \theta < 86^\circ$):

$$i \leq i_{max} = 0,04 (\triangleq 0,04 \text{ m/m});$$

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.

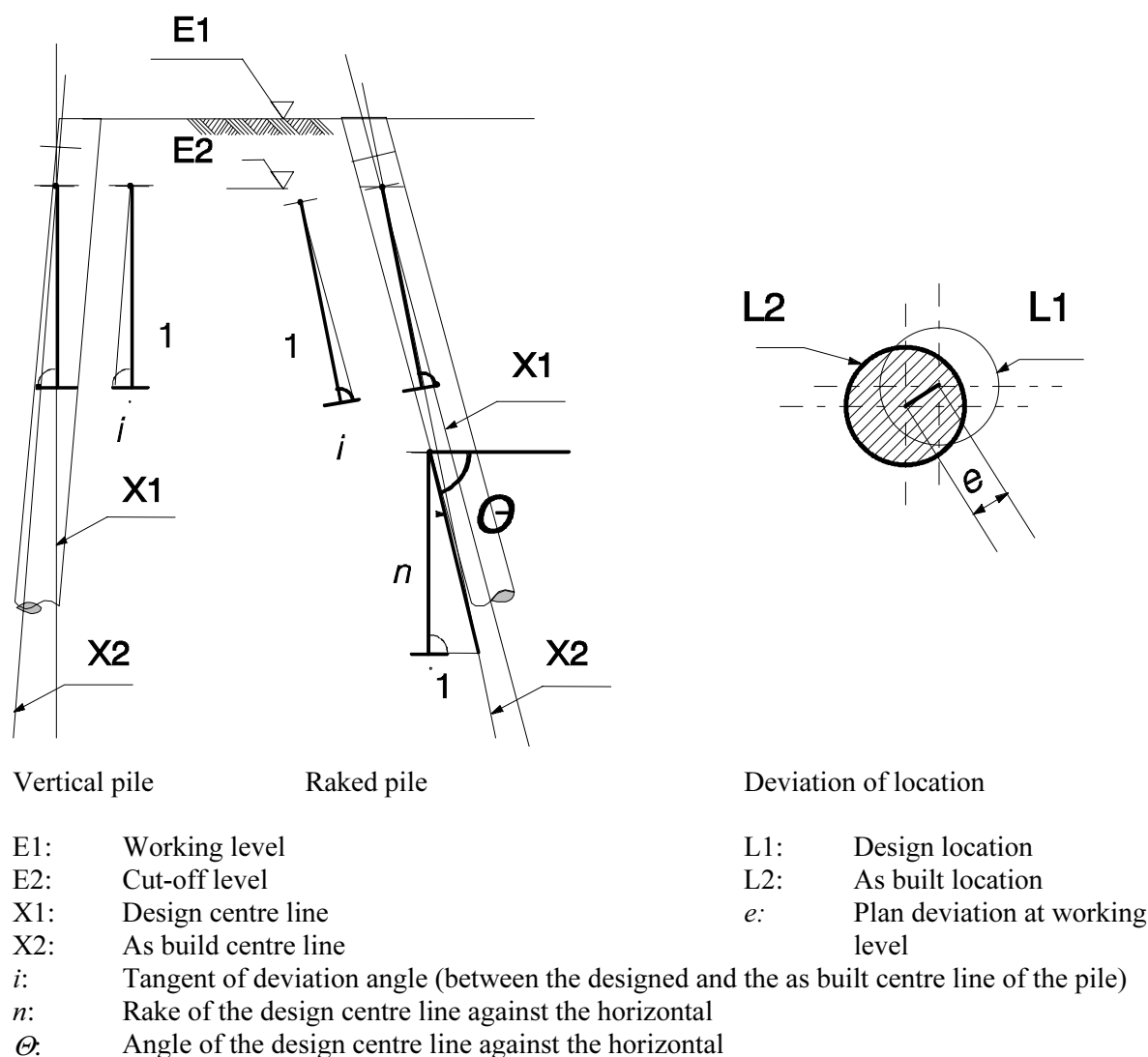


Figure 8 — Definition of geometrical construction deviations

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.