BS EN 12699:2015

BSI Standards Publication

Execution of special geotechnical work — Displacement piles

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National foreword

This British Standard is the UK implementation of EN 12699:2015. It supersedes BS EN 12699:2001 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/526, Geotechnics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

Execution of special geotechnical works - Displacement piles

Exécution des travaux géotechniques spéciaux - Pieux avec refoulement du sol

Ausführung von Arbeiten im Spezialtiefbau - Verdrängungspfähle

This European Standard was approved by CEN on 12 March 2015.

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Foreword

This document (EN 12699:2015) 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of an identical text or by endorsement, at the latest by October 2015, and conflicting national standards shall be withdrawn at the latest by October 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 12699:2000.

The technical changes in comparison to EN 12699:2000 are:

— driven piles independent of dimension are included;

— sections describing concrete and testing have been minimised.

The document has been prepared to stand alongside EN 1997 (all parts), *Eurocode 7: Geotechnical design*. Clause 7 covers design aspects of piles.

Annex A and Annex B are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

1.1 This European Standard establishes general principles for the execution of displacement piles, that means piles which are installed in the ground without excavation or removal of material from the ground except for limiting heave and/or limiting vibration as well as removal of obstructions or to assist penetration.

Piles are driven into the ground using impact, vibration, pressing, screwing or a combination of these methods.

1.2 The material of displacement piles covered by this European Standard can be:

— steel;

— cast iron;

— concrete, mortar;

— timber;

— grout;

— combination of above.

1.3 This European Standard covers prefabricated, cast *in situ*, or a combination of these methods to form displacement piles of regular shape.

Examples are given in Figure A.2 and Figure A.3.

1.4 Displacement piles may be installed in soils enhanced by ground improvement techniques. The ground improvement can be executed before, at the same time or after installation of the piles.

1.5 Other than practical considerations there are for the purpose of this European Standard no limitations regarding cross section dimensions, shaft or base enlargements, length or rake.

1.6 The provisions of this European Standard apply to:

— single piles;

— pile groups;

— concrete sheet piles.

1.7 Columns constructed by ground improvement techniques (such as mixed *in situ* columns, jet grouting, compaction grouting, vibro flotation, stone columns) are not covered by this European Standard. Bored piles are covered in EN 1536. Steel and timber sheet pile walls are covered in EN 12063. Micropiles are covered in EN 14199.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 206:2013, *Concrete - Specification, performance, production and conformity*

EN 1090-2, *Execution of steel structures and aluminium structures — Part 2: Technical requirements for steel structures*

EN 1990, *Eurocode - Basis of structural design*

EN 1991 (all parts), *Eurocode 1: Actions on structures*

EN 1992 (all parts), *Eurocode 2: Design of concrete structures*

EN 1993 (all parts), *Eurocode 3: Design of steel structures*

EN 1994 (all parts), *Eurocode 4: Design of composite steel and concrete structures*

EN 1995 (all parts), *Eurocode 5: Design of timber structures*

EN 1996 (all parts), *Eurocode 6 — Design of masonry structures*

EN 1997-1, *Eurocode 7: Geotechnical design - Part 1: General rules*

EN 1997-2, *Eurocode 7 - Geotechnical design - Part 2: Ground investigation and testing*

EN 1998 (all parts), *Eurocode 8 — Design of structures for earthquake resistance*

EN 1999 (all parts), *Eurocode 9 — Design of aluminium structures*

EN 10025 (all parts), *Hot-rolled products of non-alloy structural steels*

EN 10080, *Steel for the reinforcement of concrete - Weldable reinforcing steel - General*

EN 10083-1, *Steels for quenching and tempering - Part 1: General technical delivery conditions*

EN 10083-2, *Steels for quenching and tempering - Part 2: Technical delivery conditions for non alloy steels*

EN 10083-3, *Steels for quenching and tempering - Part 3: Technical delivery conditions for alloy steels*

EN 10210 (all parts), *Hot finished structural hollow sections of non-alloy and fine grain structural steels*

EN 10219 (all parts), *Cold formed welded structural hollow sections of non-alloy and fine grain steels*

EN 10248 (all parts), *Hot rolled sheet piling of non alloy steels*

EN 10249 (all parts) *Cold formed sheet piling of non alloy steels*

EN 12794, *Precast concrete products — Foundation piles*

EN 13670, *Execution of concrete structures*

EN 16228 (all parts), *Drilling and foundation equipment — Safety*

EN ISO 2560, *Welding consumables - Covered electrodes for manual metal arc welding of non-alloy and fine grain steels - Classification (ISO 2560)*

EN ISO 4063, *Welding and allied processes - Nomenclature of processes and reference numbers (ISO 4063)*

EN ISO 5817, *Welding - Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) - Quality levels for imperfections (ISO 5817)*

EN ISO 9606-1, *Qualification testing of welders - Fusion welding - Part 1: Steels (ISO 9606-1)*

EN ISO 9692-1, *Welding and allied processes - Types of joint preparation - Part 1: Manual metal arc welding, gas-shielded metal arc welding, gas welding, TIG welding and beam welding of steels (ISO 9692-1)*

EN ISO 9692-2, *Welding and allied processes - Joint preparation - Part 2: Submerged arc welding of steels (ISO 9692-2)*

EN ISO 11960, *Petroleum and natural gas industries - Steel pipes for use as casing or tubing for wells (ISO 11960)*

EN ISO 14341, *Welding consumables - Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels - Classification (ISO 14341)*

EN ISO 17660-1, *Welding - Welding of reinforcing steel - Part 1: Load-bearing welded joints (ISO 17660-1)*

EN ISO 18276, *Welding consumables - Tubular cored electrodes for gas-shielded and non-gas-shielded metal arc welding of high-strength steels - Classification (ISO 18276)*

prEN ISO 22477-1:2006, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 1: Pile load test by static axially loaded compression (ISO/DIS 22477-1:2005)*

prEN ISO 22477-10:2014, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 10: Testing of piles: rapid load testing (ISO/DIS 22477-10:2014)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
displacement pile
fr: pieu avec refoulement du sol
de: Verdrängungspfahl
pile which is installed in the ground without excavation or removal of material from the ground except for limiting heave and/or limiting vibration as well as removal of obstructions or to assist penetration

3.2
prefabricated pile
fr: pieu préfabriqué
de: Fertigpfahl
pile or pile element which is manufactured in a single unit or in pile segments before installation

3.3
cast in situ displacement pile
fr: pieu exécuté en place
de: Ortbetonverdrängungspfahl
pile installed by driving a closed ended concrete shell or permanent or temporary casing, and filling the hole so formed with plain or reinforced concrete, grout or mortar

3.4
combined pile
fr: pieu mixte
de: zusammengesetzter Pfahl
pile made up of two or more types or sizes of piles joined together

Note 1 to entry: The connection between the components is designed to transmit axial load and bending and to prevent separation during and after construction. See Figure A.8.

3.5
screw pile
fr: pieu vissé
de: Schraubpfahl
pile in which the pile or pile tube comprises a limited number of helices at its base and which is installed under the combined action of a torque and a vertical thrust

Note 1 to entry: By the screwing-in and/or by the screwing-out, the ground is essentially laterally displaced and virtually no soil is removed. See Figure A.10.

3.6
jacked pile
fr: pieu vériné
de: eingepresster Pfahl
pile pressed into soil by means of static force

3.7
grouted pile
fr: pieu injecté
de: verpresster Pfahl
pile fitted with an enlarged shoe to create along a part or the full length of the pile a space which is filled or grouted during driving with grout, mortar or a mixture of grout and soil

Note 1 to entry: See Figure A.11.

3.8
post grouted pile
fr : pieu post-injecté
de: nachverpresster Pfahl
pile where shaft and/or base grouting is performed after installation through pipes fixed along or incorporated in the pile

Note 1 to entry: See Figure A.12.

3.9
casing
fr: tubage
de: Verrohrung
steel tube used temporarily or permanently

Note 1 to entry: The temporary casing supports the soil surrounding the wall of the pile shaft during construction and is withdrawn on completion of concreting or grouting. In permanent situation the casing can act as a protective or load bearing unit.

3.10
drive tube
fr: tube de fonçage
de: Vortreibrohr
closed ended steel tube used to displace the ground during the formation of a driven cast in situ pile

Note 1 to entry: Drive tube is withdrawn during or after casting.

3.11
liner, lining
fr: gaine, chemise
de: Hülse
tube, generally of thin steel plate, forming part of the shaft of a pile

Note 1 to entry: For example, they can be used for the protection of pile shafts in soft or aggressive grounds or to reduce negative skin friction.

3.12
pile joint
fr: raccord
de: Pfahlkupplung
means of joining lengths of pile elements either by welding or by mechanical or other jointing systems

Note 1 to entry: For examples, see Figure A.7, Figure A.8 and Figure A.9.

3.13
pile shoe
fr: sabot
de: Pfahlschuh
shoe or point fitted to the base of a pile or drive tube to form the toe

Note 1 to entry: For examples, see Figure A.4.

3.14
wings
fr: ailes
de: Flügel
shaft enlargements to steel piles formed by welding steel sections to the pile

Note 1 to entry: See example in Figure A.2j.

3.15
leader
fr: mât
de: Mäkler
steel sections used for guiding driving equipment and/or pile during driving

Note 1 to entry: See Figure A.6.

3.16
impact hammer
fr: mouton, marteau
de: Rammbär
tool of construction equipment for driving or extracting piles or drive tubes by impact (striking or falling mass)

3.17
vibrator (vibrating hammer)
fr: vibrateur
de: Vibrationsbär
tool of construction equipment for driving or extracting piles, drive tubes or casing by the application of vibratory forces

3.18
helmet
fr: casque
de: Schlaghaube
device, usually steel, placed between the base of the impact hammer and the pile or drive tube so as to uniformly distribute the hammer impact to the top of the pile

Note 1 to entry: See Figure A.6.

3.19
hammer cushion
fr: martyr du marteau
de: Haubenfutter
device or material placed between the impact hammer and the helmet to protect the hammer and the pile head from destructive direct impact

Note 1 to entry: The hammer cushion material shall have enough stiffness to transmit hammer energy efficiently into the pile. See Figure A.6.

3.20
pile cushion
fr: martyr du casque
de: Pfahlfutter
material, commonly softwood, placed between the helmet and the top of a precast concrete pile

Note 1 to entry: See Figure A.6.

3.21
follower
fr: faux-pieu
de: Rammjungfer
temporary extension, used during driving, that permits the driving of the pile top below ground surface, water surface, or below the lowest point to which the driving equipment can reach without disengagement from the leaders

3.22
mandrel
fr: mandrin
de: Dorn
steel core for driving that is inserted into a closed-end tubular pile

Note 1 to entry: After installation the mandrel is withdrawn.

3.23
driving
fr: fonçage
de: Einbringen
method used to install the piles or drive tubes or casings into the ground, such as hammering, vibrating, pressing, screwing or by a combination of these methods

3.24
driven pile
fr: pieu foncé
de: Rammpfahl
pile which is forced into the soil by driving, the soil being displaced by the pile or drive tube

3.25
driving assistance
fr: aide au fonçage
de: Einbringhilfe
method used to assist a pile to penetrate the ground

3.26
coring
fr: carottage
de: Kernbohren
removal of soil by core sampler (e.g. to mitigate the effects of heave by pile driving)

Note 1 to entry: Removal can also be done by preboring, see 3.28.

3.27
jetting
fr: lançage
de: Spülen
use of pressurized water to facilitate the driving of a pile by means of hydraulic displacement of parts of the soil

3.28
preboring (pre-augering, pre-drilling)
fr: préforage
de: Vorbohren
boring through obstructions or materials too dense to penetrate with the planned pile type and driving equipment to avoid deviation and/or facilitate driving

Note 1 to entry: Removal can also be done by coring, see 3.26.

3.29
grouting
fr: injection
de: Verpressen
pumping of grout or mortar with a pressure which is higher than the hydrostatic pressure

3.30
restrike
fr: surbattage
de: Nachrammen
additional series of hammer blows used to drive the prefabricated pile or casing to verify the driving criteria and/or bearing capacity

3.31
redrive
fr: refonçage
de: Ausrammen
method used to form an enlarged shaft or base on a temporarily cased driven cast in situ pile

3.32
probe pile
fr: pieu initial
de: Anfangspfahl
first working pile on construction site

3.33
test pile
fr: pieu d'essai
de: Probepfahl (zur Ermittlung der Tragfähigkeit)
pile to which a load is applied to determine the resistance deformation characteristics of the pile and surrounding ground

3.34
trial pile
fr: pieu de faisabilité
de: Probepfahl (zum Herstellungsversuch)
pile installed to assess the practicability and suitability of the construction method for a particular application

Note 1 to entry: A trial pile can also be used as a test pile.

3.35
preliminary pile
fr: pieu préliminaire
de: Vorversuchspfahl
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, driving equipment and/or for confirming the design, dimensions and bearing capacity

3.36
driving criteria
fr: critères de fonçage
de: Einbringkriterien
driving parameters used to be fulfilled when driving a pile

3.37
set
fr: refus
de: Eindringung
mean permanent penetration of a pile in the ground per blow measured by a series of blows

3.38
monitoring
fr: contrôle, monitoring
de: Überwachung
passive role of checking and observing the technical quality of the piling process

3.39
supervision
fr: surveillance
de: Bauaufsicht
active role of overseeing or directing the piling operations

3.40
recording
fr: enregistrement
de: Dokumentation, Aufzeichnung
making of a permanent record of the facts relating to the piling operations and aspects monitored

3.41
static pile load test
fr: essai de chargement statique
de: statische Pfahlprobebelastung
loading test where a pile is subjected to chosen static axial and/or lateral actions at the pile head for the analysis of its capacity

3.42
maintained load pile test
fr: essai de chargement par palier
de: lastgesteuerte Pfahlprobebelastung
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)

3.43
constant rate of penetration pile load test
fr: essai de chargement à vitesse d'enfoncement constante
de: weggesteuerte Pfahlprobebelastung
static loading test in which a test pile is forced into the ground at a constant rate and the force is measured (CRP - test)

3.44
dynamic pile load test
fr: essai de chargement dynamique
de: dynamische Pfahlprobebelastung
loading test where a pile is subjected at the pile head to a dynamic force and measurements of strain and acceleration are made for analysis of its load bearing capacity

3.45
rapid pile load test
fr: essai de chargement dynamique
de: schnelle Pfahlprobebelastung
loading test where a pile is subjected to a particular axial rapid load at the pile head for the analysis of the bearing capacity

Note 1 to entry: See prEN ISO 22477-10:2014, Testing of piles: rapid load testing.

3.46
integrity test
fr: essai d'intégrité
de: Integritätsprüfung
test carried out on an installed pile for the verification of soundness of materials and/or of the pile geometry

EXAMPLE low strain integrity test, sonic test and coring test

3.47
grout
fr: coulis
de: Verpressmörtel
homogenous mixture of cement and water to which admixtures, additions, filler or sand can be added

3.48
mortar
fr: mortier
de: Zementmörtel/Feinkornbeton
concrete with an aggregate size of 4 mm or less

3.49
filling
fr: remplissage
de: Verfüllen
placing under no applied fluid pressure other than the height of grout, mortar or concrete

3.50
piling platform level
fr: niveau de la plate-forme de fonçage
de: Arbeitsebene
level of the piling platform on which the piling rig works

Note 1 to entry: See Figure A.13.

3.51
casting level
fr: niveau de bétonnage
de: Betonierhöhe
final level to which the concrete is cast

Note 1 to entry: It is above the cut off level by a margin depending on the execution procedure. See Figure A.13.

3.52
cut off level
fr: niveau de recépage
de: Kapphöhe
prescribed level to which a pile is cut or trimmed back to before connecting it to the superstructure

Note 1 to entry: See Figure A.13.

3.53
toe level
fr: fond, pointe (du pieu)
de: Pfahlfußebene
lowest level of pile

Note 1 to entry: See Figure A.13.

3.54
pile top
fr: sommet (du pieu)
de: Pfahlkopffläche
upper area of pile

Note 1 to entry: See Figure A.13.

3.55
pile head
fr: tête (du pieu)
de: Pfahlkopf
upper part of pile

Note 1 to entry: See Figure A.13.

3.56
pile shaft
fr: fût (du pieu)
de: Pfahlschaft
body of the pile between the head and the base

Note 1 to entry: See Figure A.13.

3.57
pile bottom
fr: pied (du pieu)
de: Pfahlfuß
lower part of a pile

Note 1 to entry: See Figure A.13.

3.58
pile toe
fr: pointe (du pieu)
de: Pfahlspitze
lowest part of a pile

Note 1 to entry: See Figure A.13.

3.59
pile base
fr: fond, base (du pieu)
de: Pfahlsohle
bottom area of pile

Note 1 to entry: See Figure A.13.

3.60
cathodic protection
fr: protection cathodique
de: kathodischer Korrosionsschutz
means of protecting steel piles from corrosion by providing a consumable anode or by applying an external electrical potential

3.61
stray current
fr: courant vagabond
de: Streustrom
direct current that is induced in the soil which can cause corrosion of a pile

3.62
initial set
fr: début de prise
de: Abbindebeginn
stage after mixing concrete when it turns from liquid to solid

3.63
heave
fr: soulèvement
de: Hebung
upward movement of ground or pile

3.64
brooming
fr: effilochage
de: Besenwirkung
separation of fibres at the toe or head of a timber pile

3.65
execution specification
fr: spécifications d'exécution
de: bautechnische Unterlagen
set of documents covering all drawings, technical data and requirements necessary for the execution of a particular project

3.66
project specification
fr: spécifications du projet
de: Projektspezifikation
project specific document describing the requirements applicable for the particular project

3.67
top driving
fr: fonçage en tête
de: Kopframmung
method used to install the pile or the drive tube into the ground by driving at the top of pile or the drive tube

3.68
bottom hammering
fr: battage en pied
de: Innenrohrrammung
method used to install the pile or the drive tube into the ground by hammering with a hammer inside the drive tube on a plug at the bottom of the drive tube

4 Information needed for the execution of the work

4.1 General

4.1.1 Prior to the execution of the work, all necessary information shall be provided.

4.1.2 This information should include:

— any legal or statutory restrictions;

— the location of main grid lines for setting out;

— the conditions of structures, roads, services, etc. adjacent to the work, including any necessary surveys;

— a suitable quality management system, including supervision, monitoring and testing.

4.1.3 The information regarding the conditions, both within and immediately surrounding the site, shall cover, where relevant:

— the geometry of the site (boundary conditions, topography, access, slopes, etc.);

— the existing underground structures, services and known contaminations;

— the environmental restrictions, including noise, vibration, pollution;

— the future or ongoing activities such as dewatering, tunnelling, deep excavations.

4.2 Special features

4.2.1 The special features shall cover, where relevant:

— execution specifications (see 3.65);

— previous use of the site;

— adjacent foundations (types, loads and geometry);

— geotechnical information and data as specified in Clause 5;

— presence of obstructions in the ground (old masonry, anchors, etc.);

— presence of headroom restrictions;

— presence of archaeological remains;

— presence of natural and/or man made cavities (mines, etc.);

— presence of polluted ground;

— any specific requirements for the piling works, in particular those pertaining to tolerances, quality of materials;

— where available, previous experience with displacement piles or other foundations or underground works on or adjacent to the site;

— proposed or ongoing adjacent activities such as underpinning, pre-treatment of soil, dewatering.

4.2.2 Necessity, extent, procedure and content for any survey of the conditions of structures, roads, services, etc. within and adjacent to the works area shall be established.

4.2.3 The survey shall be carried out and be available prior to the commencement of the works and its conclusions shall be used to define the threshold values for any movement which may affect adjacent structures by the works area constructions.

4.2.4 Any additional or deviating requirements falling within the permission clauses given in this standard shall be established and agreed before the commencement of the works and the quality control system shall be suitably amended.

NOTE Such additional or deviating requirements can be:

— reduced or increased geometrical construction deviations;

— application of different or varying construction materials;

— special anchorage or doweling of displacement piles to underlying rock;

— special reinforcement such as the use of steel tubes or steel cores or sections or fibres (steel or manmade);

— grouting of pile shafts or bases;

— use of rock shoes;

— use of driving assistance (preboring, waterjetting,...);

— use of friction reducing coatings.

5 Geotechnical investigation

5.1 General

5.1.1 The geotechnical investigation shall fulfil the requirements of EN 1997-1 and EN 1997-2.

5.1.2 The depth and the extent of the geotechnical investigation should be sufficient to identify all ground formations and layers affecting the construction, to determine the relevant properties of the ground and to recognize the ground conditions (e.g. where end bearing is to be relied on, it should demonstrate that any possible founding stratum is not immediately underlain by a weaker stratum where there is a possibility of a punching failure or excessive movements).

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

NOTE 1 Guidance is given in EN 1997–2 on the depth and the contents of investigations.

5.1.4 The report shall be available in time, to allow for reliable design and execution of the displacement piles.

5.1.5 The sufficiency of the geotechnical investigation shall be checked for the design and execution of the displacement piles.

5.1.6 If the geotechnical investigations are not sufficient, a supplementary investigation shall be conducted.

5.2 Specific requirements

5.2.1 Particular attention shall be paid to the following aspects, which are relevant to the execution of displacement piles:

a) ground level at any point of investigation or testing relative to the recognized national datum or to a fixed reference chart datum;

b) piezometric levels of all water-tables and permeability of the soils;

c) presence of coarse, highly permeable soils or cavities (natural or artificial), which can cause a sudden drop of concrete during the placement, and thus can require special measures;

d) presence, strength and deformation characteristics of soft soils, such as very soft clay or peat, which can cause difficulties during concreting (deformation or instability);

e) presence of boulders or obstructions which can cause difficulties during driving and, an assessment of their size and frequency, when applicable;

f) presence, position, strength of hard rock or other hard materials which can cause difficulties during driving and may require driving assistance;

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) presence and characteristics of the near surface ground that will form the piling platform sub-grade, in order to assess the requirements for a safe and effective piling platform in accordance with 8.3;

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

j) unfavourable chemistry of groundwater, soil and rock, and water temperatures if required;

NOTE Degradation of concrete can be detrimental to long term performance as it can reduce the skin friction with time.

k) detrimental chemistry of waste materials;

l) presence of pretreated soil, which can have an adverse effect during driving;

m) mining beneath the site;

n) site stability problems (slope stability for instance);

o) thickness and characteristics of bearing strata.

5.2.2 The piezometric levels of the various water-tables existing on the site shall be monitored separately and over a sufficient period of time to estimate the highest piezometric levels which can occur during construction of the piles.

5.2.3 Particular attention shall be paid to artesian conditions.

5.2.4 The strength of the soils and rocks shall be determined by laboratory tests and/or *in situ* tests over the full depth of the piles and to a certain depth below their base.

NOTE The investigation depth depends on the nature of the ground and the function of the piles (foundation or retaining structure).

5.2.5 When displacement piles are required to reach rock, the level of the rock surface shall be determined.

NOTE The area to investigate depends on the function of the piles (foundation or retaining structure).

6 Materials and products

6.1 General

6.1.1 All material and products shall meet the requirements set in the respective European Standards, the provisions valid in the place of use and the provisions given in the project specification.

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

6.2 Prefabricated displacement piles

6.2.1 Concrete piles

The materials and fabrication of prefabricated concrete piles, including joints, shall comply with EN 12794.

6.2.2 Steel piles

6.2.2.1 The materials, and fabrication of steel piles shall as a minimum comply with:

— EN 1993-1;

— EN 1993-5;

— EN 10210 or EN 10219 or EN ISO 11960 when hollow sections (e.g. tubes) are used;

— EN 10025, when hot rolled products (e.g. H-sections) are used.

NOTE 1 Requirements on inspection documents can be found in EN 10204.

NOTE 2 For reused material see EN 1993–5:2007, 3.1.

6.2.2.2 Concrete which is subsequently cast in a steel pile shall comply with EN 206:2013, Annex D if the concrete is used for structural purpose in design.

6.2.3 Cast iron piles

Cast iron piles shall comply with the specification of the manufacturer and the design.

6.2.4 Timber piles

6.2.4.1 The materials, fabrication and handling of timber piles shall comply with EN 1995-1-1 and project and execution specification.

6.2.4.2 The section dimensions should not change more than 0,015 meter by meter.

6.2.4.3 The straightness of the pile shall not deviate from the straight line more than 1 % of the length.

6.2.4.4 Piles shall be provided in one piece unless otherwise approved.

6.2.4.5 Preservation methods shall comply with the specification.

6.3 Cast *in situ* displacement piles

6.3.1 Mortar and concrete

6.3.1.1 General

6.3.1.1.1 Mortar and concrete used in cast *in situ* displacement piles shall comply with EN 206:2013, Annex D.

6.3.1.1.2 Cast *in situ* mortar and concrete shall be composed to minimize segregation during placing, to flow easily around the reinforcement, and when set, to provide a dense (and watertight) material.

6.3.1.1.3 The mortar and concrete shall comply with the requirements related to strength and durability in the hardened state as well as with the requirements related to consistency in the fresh state.

NOTE 1 Compressive strength classes for hardened concrete are given in EN 206:2013. The range usually used for cast *in situ* displacement piles is between C20/25 and C45/55.

NOTE 2 Higher compressive strength concrete can be used.

6.3.1.1.4 Semi dry concrete may be used if tamped during installation. The cement content for semi dry concrete shall be of at least 350 kg/m^3. The strength class shall be at least C25/30 and workability as specified.

6.3.1.2 Aggregates

6.3.1.2.1 Aggregates shall comply with EN 206:2013, Annex D.

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

6.3.1.3 Cement contents

6.3.1.3.1 The cement contents of concrete shall conform with EN 206:2013, Table D.1.

6.3.1.3.2 When aggregates size is smaller than 4 mm, cement and fine contents content should be increased.

6.3.1.4 Water

Mixing water shall comply with EN 206:2013.

NOTE Potable water is acceptable for the preparation of grout, mortar or concrete.

6.3.1.5 Water/cement ratio

The water/cement ratio shall comply with EN 206:2013.

6.3.1.6 Admixtures

Admixtures used shall comply with EN 206:2013.

NOTE 1 The admixtures commonly used for concreting are:

— water reducing/plasticizing;

— high range water reducing/super-plasticizing; and

— set retarding.

NOTE 2 Admixtures are used:

— to give a mix of high plasticity;

— to improve concrete flow;

— to minimize bleeding and avoid 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 3 Inappropriate application of admixtures can result into damages.

6.3.1.7 Fresh concrete

Concrete for cast *in situ* piles shall comply with EN 206:2013, Annex D.

6.3.1.8 Production of concrete

The production of concrete as well as the conformity and production control shall be in accordance with EN 206:2013.

6.3.1.9 Sampling and testing on site

6.3.1.9.1 All sampling and testing of fresh concrete on site shall comply with EN 13670 and the execution specification.

NOTE Conformity testing to confirm that the properties of the concrete comply with the specification is part of producers obligations (see EN 206:2013).

6.3.1.9.2 The minimum number of cylinder or cube specimens in a sample is three.

6.3.1.9.3 When the concrete is not produced in a certified quality assurance system, the following sampling shall be carried out:

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

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

— two additional samples after interruptions of the works longer than seven days;

— at least one sample for every 75 m^3 of concrete cast on the same day;

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

6.3.1.9.4 When the concrete is not produced in a certified quality assurance system, the characteristic compressive strength shall be determined for each sample at least on one specimen tested at seven days and one specimen tested at 28 days.

6.3.1.9.5 For each sample, at least one specimen should be kept until conformity of concrete compressive strength is assessed on specimens tested at 28 days.

6.3.1.9.6 Where the concrete is produced in a continuous and certified quality assurance system, deviating requirements from those of non-certified quality assurance system for concrete sampling on site may be specified.

6.3.1.9.7 The frequency of testing of consistence, concrete temperature and workability time shall comply with the execution specification.

6.3.1.9.8 A full record of all tests carried out on the concrete shall be kept and results shall be noted in the concrete placement record.

6.3.2 Grout

6.3.2.1 Where relevant European Standards are not available, grout shall be prepared, maintained and controlled in accordance with the respective national standards and/or regulations in the place of use.

NOTE There is a European Standard for grout for prestressing systems, EN 446. The requirements EN 446 are not applicable to this standard.

6.3.2.2 Grout composition shall take account of the application and the ground conditions and be documented.

6.3.2.3 Admixtures may be used.

6.3.3 Reinforcement

6.3.3.1 Reinforcement material used in cast *in situ* displacement piles shall comply with the relevant European Standards, this standard and the execution specification.

6.3.3.2 The reinforcement steel cages or single bar used in cast *in situ* displacement piles shall comply with EN 10080.

6.3.3.3 The steel elements used in cast *in situ* displacement piles shall comply with EN 10025-2, EN 10210 (all parts), EN 10219 (all parts), EN ISO 11960, EN 10248 (all parts), EN 10249 (all parts), EN 10083 and EN 13670 where relevant.

NOTE Different types of steel element can be used such as cold formed or hot rolled sheet pile products or structural hollow products, etc.

6.3.3.4 Materials other than steel to be used as reinforcement such as glass fibre shall have an established suitability and be in accordance with the requirements given in the execution specification.

6.4 Coatings and corrosion protection compounds

Coatings and compounds for corrosion protection shall comply with the design specifications. The continuity of the protection, close to the connection elements shall comply with the specifications and the design.

7 Considerations related to design

7.1 General

7.1.1 The design shall be based on relevant parts of EN 1990, EN 1991, EN 1992, EN 1993, EN 1994, EN 1995, EN 1996, EN 1997, EN 1998 and EN 1999 (Eurocode 0 – 9), see Clause 2.

7.1.2 This European Standard gives design rules related to execution which are not covered by the above standards and which can affect the design or the detailing of displacement piles.

7.1.3 The design of displacement piles shall establish the type and size of pile and that its installation is appropriate for the particular ground conditions and environmental constrains.

NOTE This can often be established on the basis of previous comparable experience.

7.1.4 If no comparable experience exists regarding the driveability, one or more driving tests should be carried out at chosen locations before the main work commences.

NOTE 1 A driving test offers the possibility of investigating driving procedures, equipment, techniques to assist driving and to assess the effect of pile construction on soil behaviour and the environment. In addition driving tests can be used to establish installation criteria and give an indication of the pile length and bearing capacity.

NOTE 2 Driveability studies using wave equation analysis or similar can help to define suitable driving procedures, driving equipment and driving stresses.

7.1.5 When the driveability of the piles is investigated, account shall be taken of any requirements in the design or specification regarding techniques to assist driving in 8.10.1.

7.2 Geometrical construction tolerances

7.2.1 Geometrical construction tolerances given in 8.2 shall be taken into account in the design.

7.2.2 If the specified tolerances are exceeded, the extent of a possible overloading of any structural part shall be investigated and suitable remedial measures taken if necessary.

NOTE For example the determination of eccentricity of the forces applied on pile head to horizontal and vertical tolerances in between the piling platform level and the cut-off level.

7.2.3 For the recording of construction deviations the centre of a cast *in situ* pile is considered as the centre of the largest circle which can be drawn within the section of the pile head.

7.2.4 Tolerances of reinforcement shall be taken into account in design.

7.3 Sequence of installation

7.3.1 The sequence of installation in 8.4 shall be taken into account in the pile design.

7.4 Protection of piles

7.4.1 Piles shall be protected against attack by organisms, aggressive substances, ice abrasion, corrosion and stray current where such risks exist.

7.4.2 Measures to be taken shall be considered and specified in the design. Possible measures include:

— the use of an adequate chemical steel composition;

— the use of an adequate concrete or mortar composition;

— cathodic protection;

— organic or inorganic coatings or treatment;

— concrete or grout coating;

— durability and concrete cover according to EN 1992-1-1:2004, Clause 4 and EN 206:2013, Annex D;

— durability according to EN 1993-5:2007, Clause 4;

— use of sacrificial material thickness;

— use of permanent casings or liners.

7.4.3 Piles shall not be surface treated in such a way that the shaft-resistance is reduced unless allowed or required by the design.

NOTE Negative friction can be reduced by the application of a suitable coating.

7.4.4 Timber piles for permanent structures shall only be used below the lowest anticipated ground water table or free water level during the life time of the structure unless adequate protection is provided.

7.4.5 For cast *in situ* piles where the soil has a characteristic undrained shear strength c_u less than 15 kPa a permanent casing or liner or other stabilizing measures should be considered.

NOTE Other indirect measurements of undrained shear strength c_u can be used.

7.5 Needs for driving assistance

7.5.1 The influence of driving assistance methods on the performance of the piles and safety of existing structures or potentially unstable slopes shall be considered in the design.

7.5.2 Any driving assistance such as predriving, preboring, water jetting, chiselling or preblasting shall be planned and be approved prior to start of work.

7.5.3 Driving aids should be carried out in such a manner that the bearing capacity of piles already in place or the safety of existing structures is not detrimentally affected.

7.6 Design for impact driving of prefabricated piles

7.6.1 General

7.6.1.1 Installation procedures, pile driving hammers, pile and hammer cushioning, soil conditions, pile size and length, and other factors affecting the driving stresses imparted to the pile shaft should be evaluated and taken into account when determining the driving criteria.

7.6.1.2 If there is the risk of overstressing the pile shaft a driveability study using wave equation analysis should be carried out in advance. Under these circumstances stress wave measurements while driving should be made to verify the prediction.

7.6.1.3 Stresses during driving should not exceed, at any point along the pile shaft, the values shown below in 7.6.2, 7.6.3 and 7.6.4.

7.6.1.4 The negative impact on the pile caused by the installation shall be taken into account in the design.

NOTE Pile driving can decrease the structural capacity of the pile.

7.6.1.5 When driving precast concrete piles in free water or in highly permeable soils the risk of hydraulic fatigue should be considered.

NOTE Hydraulic fatigue or "water bursting" is caused by alternate major compressive and tensile stresses in the pile during driving, leading to fatigue of the concrete. The fatigue mechanisms in the concrete are enhanced by great water pressures in the cracks occurring in the process alternate suction and expulsion of water.

7.6.2 Prefabricated concrete piles

7.6.2.1 The driving system should be chosen to limit the transferred energy so that:

— in compression:

  — the maximum stress (including the prestress) during driving does not exceed 0,8 × characteristic concrete strength in compression at the time of driving;

— in tension:

  — the force should not exceed 0,9 x f_{yk} x A minus prestress force, where:

  f_{yk}: the characteristic yield strength of the reinforcement;

  A: area of the reinforcement.

7.6.2.2 Where stresses are actually monitored during impact driving, these may be 10 % higher than the values stated in 7.6.2.1.

7.6.2.3 When assessing the driving stresses, attention should be paid when driving from a hard layer into a soft layer as high tensile stresses can occur in the pile.

NOTE Also when driving piles to bedrock high tensile or compressive stresses can occur.

7.6.3 Steel piles

7.6.3.1 The driving system should be chosen to limit the transferred energy so that the maximum stress in steel piles during driving does not exceed 0,9 × the characteristic yield strength of the steel.

7.6.3.2 Where stresses are actually monitored during impact driving, these may be up to 20 % higher than the values stated in 7.6.3.1.

NOTE The yield strength increases for dynamic impact loads.

7.6.4 Timber piles

7.6.4.1 The transferred energy of the driving system should be chosen so that the maximum calculated stress generated during driving should not exceed 0,8 times the characteristic compressive strength.

7.6.4.2 Allowance should be made for reduction in section caused by drilling and notching details.

7.7 Specific design related considerations

7.7.1 General

Where the following matters are of importance to the quality or performance of the displacement piles they should be specified in an early stage of the design, prior to or during the execution stage. Items include:

— method of joining;

— quality of the weld for splices;

— method, minimum length and tolerances of cutting back pile elements;

— initial curvature of pile element;

— curvature of pile after installation/driving;

— shape and structure of shoe or other precautions if necessary to protect and secure the toe of the pile in the bedrock;

— effects of time on pile capacity;

— effect of ground heave on previously installed piles;

— restrike testing of prefabricated piles;

— adjustment of the driving criteria when a follower is used.

7.7.2 Reinforcement of cast *in situ* piles

7.7.2.1 The standard covers a large range of diameters. For small diameter piles less than 150 mm, the general specification can be adapted to cater for the lack of space (e.g. minimum bars number and spacing).

7.7.2.2 The reinforcement cage for cast *in situ* piles shall be designed not only to have adequate strength in the final pile, but also adequate strength and stiffness during handling of the cage and construction of the pile. It shall also allow the fresh concrete to flow easily around each of its components.

7.7.2.3 Unless otherwise agreed in the design, cast *in situ* concrete piles shall be reinforced over their full length.

7.7.2.4 A cast *in situ* displacement pile may be designed as an unreinforced concrete element if:

— pile head reinforcement is provided in accordance with 7.7.2.5 and

— the design actions and/or actions caused by the construction and/or actions resulting from the ground produce only compressive stresses in the pile.

7.7.2.5 Pile heads for unreinforced piles shall be reinforced to cater for accidental loads (e.g. resulting from all construction works on the site).

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

7.7.2.6 Piles should also be reinforced over any length through soft or loose soil.

7.7.2.7 Tension piles shall in any case be reinforced over their whole length.

7.7.2.8 Unless otherwise specified by design the minimum amount of longitudinal reinforcement shall be as indicated in Table 1 where reinforcement is required:

Table 1

Cross section area of concrete	Minimum amount of reinforcement
$A_c < 0{,}5\ m^2$	$A_s \geq 0{,}5\ \%\ A_c$
$0{,}5\ m^2 < A_c < 1{,}0 m^2$	$A_s \geq 0{,}0025\ m^2$
$A_c > 1{,}0\ m^2$	$A_s \geq 0{,}25\ \%\ A_c$

7.7.2.9 For reinforced concrete piles the minimum longitudinal reinforcement shall be four bars of 12 mm diameter or an equivalent central bar, a permanent casing or a steel profile.

7.7.2.10 For reinforced grout piles the minimum size of bars may be reduced to 8 mm.

7.7.2.11 For dry conditions the minimum clear distance between the longitudinal reinforcement bars shall be at least three times the maximum diameter of the aggregates, but not less than 50 mm for reinforced concrete.

7.7.2.12 For under water concreting the clear distance between the longitudinal reinforcement cage bars shall be at minimum:

— 100 mm;

— 80 mm when using $d \leq 20$ mm aggregate.

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

7.7.2.13 The transversal reinforcement shall fulfil the following values:

— minimum diameter of the bars: 5 mm;

— minimum distance between the bars: as for the longitudinal bars.

7.7.2.14 The nominal cover c_{nom} to all reinforcement in cast *in situ* piles shall be not less than:

— 50 mm to the internal face of the casing for piles with temporary casing;

— 75 mm when the reinforcement is installed after concreting;

— 25 mm to the internal face of a permanent casing or lining.

The nominal distance between the inside of the casing and the reinforcement for displacement piles with a temporary casing is not to be less than 1,5 times the largest grain size in the used concrete.

NOTE Guidance on the minimum cover of appropriate grout or mortar to load bearing elements is given in Annex B.

7.7.2.15 The minimum cover for grout to an internal face of a permanent casing or lining in cast *in situ* piles can be reduced to 10 mm.

7.7.2.16 The corrosion protection of high strength steel and pre-stressing steel shall take into account the tensile stresses and corresponding crack widths.

NOTE 1 The corrosion protection of a tension element embedded in concrete does not depend on, whether this element is identified as an anchor or a pile, but solely on the magnitude of the tension stresses in the tension element, i.e. utilization of high strength steel can imply the need for special corrosion protection depending on the induced crack widths in the concrete.

NOTE 2 The steel can be classified as high-strength steel if it has f_y > 500 MPa (limit as recommended in EN 1993–5).

7.7.3 Pile shoe

7.7.3.1 Pile shoe shall be manufactured from durable material capable of withstanding the stresses caused by the installation method and ground conditions without damage.

7.7.3.2 The pile shoe for cast *in situ* piles shall be designed to prevent water from entering into the drive tube during construction.

7.7.3.3 When driving prefabricated concrete piles or steel piles into hard rock, onto a sloping rock surface, suspected hard rock or when driving in soil with suspected contents of boulders, the pile toe shall be designed for this.

NOTE 1 In weak rock or soils the pile toe can be protected with other methods e.g. bands, extra reinforcement, plates.

NOTE 2 Typical examples of pile and rock shoes are shown in Figure A.4.

7.7.3.4 When driving timber piles the toe should have protection unless comparable experience shows otherwise.

7.7.3.5 The shoe of grouted steel piles shall be enlarged to achieve sufficient grout cover.

7.7.4 Pile joint

Joints between load bearing elements shall satisfy the required capacity in compression, tension and bending.

NOTE 1 Typical examples of pile joints are shown in Figure A.7, Figure A.8 and Figure A.9.

NOTE 2 For requirements on joints for precast concrete piles see EN 12794.

7.7.5 Pile enlargement

7.7.5.1 Where pile enlargements are considered, the method of forming the enlargement and the nominal value of shaft and base perimeter to be used in the design shall be established and agreed in the Execution Specification.

NOTE Examples of enlargements are shown in Figure A.2.

7.7.5.2 When redrives are used to form enlarged bases or enlarged shafts on cast *in situ* piles the method used to form the pile and the nominal value of base and shaft perimeter to be used in the design shall be agreed before commencement of the work.

NOTE 1 If the enlarged base is installed by hammering inside the tube (bottom hammering) using semi dry concrete instead of the basic perimeter the base volume can be specified.

NOTE 2 If the enlarged base is installed by top driving with wet concrete instead of the basic perimeter the base volume can be specified.

7.7.6 Spacing of piles

7.7.6.1 The spacing of piles shall be considered in relation to pile type, length of pile and the ground conditions and their behaviour in groups.

7.7.6.2 The possible interference of one pile with another during installation should be considered when determining pile type, pile spacing, orientation and installation sequence.

7.7.7 Combined piles

Careful consideration shall be given to the joining of elements and to the method of construction of combined piles to ensure adequate bearing capacity, structural strength and durability.

NOTE An example of joint can be seen in Figure A.8.

7.7.8 Screw piles

For pile systems which comprises more than one helix at the base, removal of material from the ground can be relevant which shall be considered in the design.

8 Execution

8.1 General

8.1.1 All works shall be planned, carried out and documented in a manner appropriate to the application.

8.1.2 All reasonable precautions should be taken during piling operations which include pile, equipment and material handling so as to ensure safety on and around the site and to minimize risk of damage and influence of vibrations and noise on people and adjacent properties.

8.1.3 Before starting piling works a plan of execution describing piling equipment, the installation method and a global sequence of installation of the piles should be available and approved.

8.1.4 Where possible trial drives or the probe piles should be installed close to positions of soil investigation.

8.1.5 Effect of ground heave on previously installed piles shall be checked, see 9.2.10 and 9.2.11.

8.2 Construction tolerances

8.2.1 Unless specified otherwise, piles on land shall be installed within the following geometrical deviations:

- plan location of vertical and raking piles (measured at the working level):
  - $e \leq 0{,}1$m;
- inclination of vertical piles:
  - $i \leq i_{max} = 0{,}04$ (0,04 m/m);
- inclination of raking piles:
  - $i \leq i_{max} = 0{,}04$ (0,04 m/m);
  - i is the tangent to the angle between the designed and as built centre line of the pile;
- direction of raking piles:
  - deviation ≤ 2°.

8.2.2 When over water other construction tolerances may apply.

8.2.3 Where geometrical construction deviations other than those stated in 8.2.1 are required or allowed they shall be agreed before the commencement of the work.

NOTE This might be the case in regard to constructional demands (small diameter piles, walls), ground conditions, available piling equipment or low cut-off level.

8.3 Site preparation

The piling platform shall be designed, installed and maintained in such a way that operations can be carried out safely and effectively.

8.4 Sequence of installation

8.4.1 The global sequence of driving piles shall be planned.

8.4.2 When planning the sequence, account should be taken of:

— the effects of any lateral or vertical movement of a pile or a group of piles;

— the bearing capacity of previously installed piles is not reduced;

— compaction of the soil surrounding the previously installed pile;

— the vibrations caused by driving cast *in situ* piles do not affect adjacent fresh concreted piles or concrete which has taken initial set;

— the effects on local and global stability of the surrounding soil.

8.4.3 For piles which have displaced more than specified the overall pile performance shall be reassessed.

8.4.4 Local or comparable experience can influence the proposed sequence of installation.

8.5 Equipment and Methods

8.5.1 General

The piling equipment shall comply with EN 16228.

8.5.2 Impact hammer

8.5.2.1 Piles, casings or drive tubes shall be driven with a suitable hammer, which allows penetration to the prescribed depth or attains the required resistance without damage and limiting environmental disturbance.

8.5.2.2 For top driven piles the driving system shall be coaxial and sit squarely on the pile or drive tube.

8.5.2.3 The configuration of the driving system shall be chosen to suit the pile and soil conditions (see 7.6).

8.5.3 Vibrating hammer

8.5.3.1 Piles, casings or drive tubes shall be driven with a suitable vibrating hammer which allows penetration to the prescribed depth or attains the required resistance without damage and limiting environmental disturbance.

8.5.3.2 The vibrating hammer should be placed centrally on the pile head or drive tube.

8.5.3.3 The centrifugal force, the vibration frequency and the displacement amplitude of the vibrating hammer shall be chosen to fit the pile and soil conditions.

8.5.3.4 A combination of vibratory and impact driving can also be considered where a vibrating hammer is usually used for pitching and initial installation and an impact hammer is used for driving piles to required resistance or depth.

8.5.3.5 If damage to structures or services in the vicinity is likely to occur, piles or tubes should be driven with vibrating hammers regulated independently in eccentric moment and frequency.

8.5.4 Equipment for screw piles

The torque, rotational speed and pressure shall be selected so that piles or drive tubes can penetrate to prescribed depth or attain the required resistance without damage and avoiding unacceptable soil disturbance.

8.5.5 Equipment for jacked piles

8.5.5.1 The pressure and reaction system shall be selected so that the pile can penetrate to the prescribed depth or attain the required resistance without damage to the pile or the reaction structure.

8.5.5.2 A calibrated load measuring device shall be incorporated in the jacking system.

8.5.6 Auxiliary equipment

8.5.6.1 When pile cut off level is below ground or water level a follower can be placed coaxially between helmet and pile top.

8.5.6.2 To minimize energy loss the follower should have approximately the same dynamic stiffness as the pile (see 7.6).

8.5.7 Drive tube

The drive tube shall be free from significant external or internal variation of the diameter which might prevent the proper formation of the pile.

8.6 Prefabricated piles

8.6.1 General

8.6.1.1 The specific directives given for handling, pitching and storing the piles shall be followed. Where no specific directives are given the pile elements shall be handled and stored so that they are not overstressed.

8.6.1.2 Where specified, one or more piles shall be restruck after a specified period to determine the effects of time on pile bearing resistance (see 7.7.1).

8.6.1.3 If the driving criteria is not fulfilled on restriking, the bearing resistance of the pile shall be reassessed (see EN 1997-1).

8.6.2 Prefabricated concrete piles

8.6.2.1 The head of a prefabricated concrete pile which is being impact driven should be protected with a pile cushion to ensure that the impact stresses are reduced and spread evenly on the pile top.

8.6.2.2 The specific instructions given for joining the pile elements shall be followed.

8.6.3 Steel piles

8.6.3.1 The head of a top impact driven steel pile or cast iron pile should be covered with a close fitting steel helmet to prevent damage to the pile top.

8.6.3.2 The base of a bottom driven steel pile or cast iron pile shall be strong enough to resist the impact forces of the hammer and to contain the force of the plug material (see 8.7.2.3).

8.6.3.3 Welding and cutting of steel elements.

8.6.3.3.1 For structural steel the welding process, the joint preparation, the welding procedure, the testing and inspection shall comply with EN 1090-2 and the execution specification.

NOTE For guidance on minimum criteria see Table 2.

Table 2 — Guidance on welding, testing and inspection, minimum criteria for piles and pile details in structural steels

Welding						Testing and inspection of welds		
Type of joint	**Type of weld**	**Joint preparation**	**Welding consumables**	**Welding process according to** EN ISO 4063*	**Description of welding procedure**	**Acceptance class for defects** EN ISO 5817	**Type of testing**	**Extend of testing**
butt joint / lap joint [a]	EN ISO 9692-1, EN ISO 9692-2	EN ISO 9692-1, EN ISO 9692-2	EN ISO 2560 EN ISO 18275 EN ISO 14341 EN ISO 17362 EN ISO 18276	111 114 12 131 135 136	EN ISO 15609-1	C	Visual	100 %
							NDT	See EN 1090–2***
butt joint / lap joint [b]	EN ISO 9692-1, EN ISO 9692-2	EN ISO 9692-1, EN ISO 9692-2			EN ISO 15609-1	D	Visual	100 %

[a] for structural welds**

[b] for non - structural welds**

* When welding is executed in a workshop, all welding procedures suitable for carbon steels are acceptable.

** Structural weld is a weld when a steel member is a bearing element e.g. a steel pipe, beam; non-structural weld is a weld for non-bearing element as a temporary or permanent casing or lining or a driving tube.

*** Extend of NDT in accordance with execution specification and EN 1090–2.

8.6.3.3.2 The top of a steel pile or cast iron pile shall be cut square to the pile axis before top driving.

8.6.3.3.3 If edge preparation or cutting of the steel elements is necessary this shall be done in accordance with EN ISO 9692-1.

8.6.3.3.4 When lengths of pile are to be butt-jointed on site, adequate facilities shall be provided for supporting and aligning them prior to welding. The lengths shall be secured in such a manner that eccentricity or angle between the axes of the two segments shall be in accordance with the design and the relevant standards.

8.6.3.3.5 Welding operations shall not be performed where affected detrimentally by vibration.

8.6.3.3.6 Welding shall be carried out by a qualified welder according to EN ISO 9606-1.

8.6.4 Timber piles

8.6.4.1 Before driving, precautions to prevent brooming shall be taken.

8.6.4.2 When it is necessary to employ piles formed by two or more lengths the joint should be secured by means of a proven method. See examples in Figure A.8 and Figure A.9.

8.6.4.3 Any joints shall satisfy the required capacity in compression, tension and bending.

8.6.4.4 After driving, the heads of piles should be cut off square to sound wood and treated with preservative before capping.

8.6.5 Combined piles

When driving, care should be taken not to overstress, either in compression or tension, pile segments formed from different materials or the joint connecting them.

8.7 Cast *in situ* piles

8.7.1 General

8.7.1.1 All plant, materials and operations employed in the formation of a pile shall be such as to ensure that the completed pile satisfies the minimum required cross section.

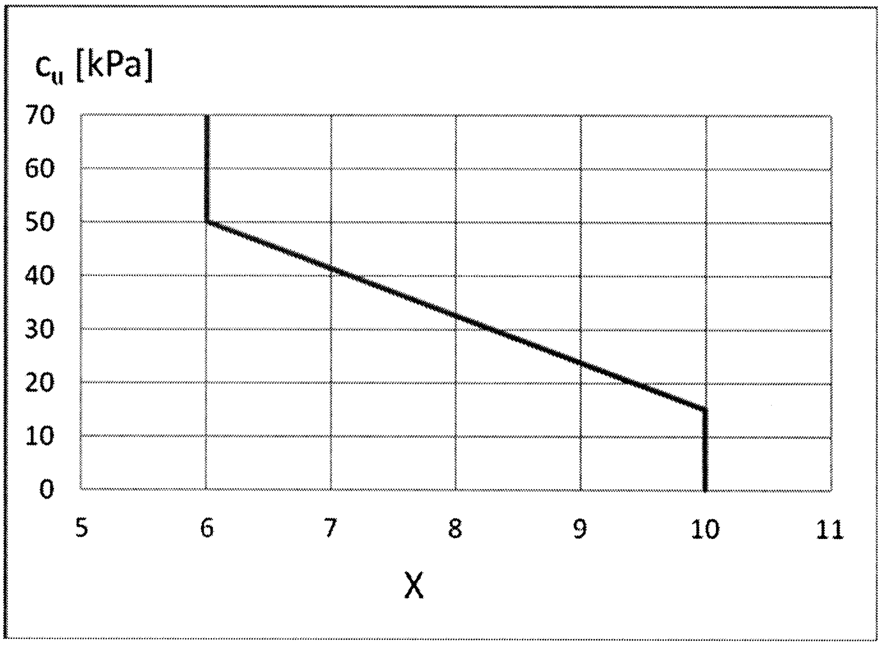
8.7.1.2 The driving of the drive tube shall be in accordance 8.5.

8.7.1.3 The sequence for driving of temporary cased piles shall be such as to prevent damage to any recently completed piles before the concrete in these piles has reached sufficient strength, see 8.4.

8.7.1.4 Unless otherwise specified or determined from site experience, no piles without permanent casing should be installed within 6 diameters centre to centre of adjacent piles until the concrete in these piles has reached sufficient strength.

8.7.1.5 If the soil has an undrained shear strength of less than 50 kPa the distance centre to centre between temporary cased fresh cast *in situ* piles should be increased in accordance with Figure 1 if the concrete has not reached sufficient strength.

NOTE Other indirect measurements of undrained shear strength c_u can be used



Key

X number of diameters (Centre to centre)

Figure 1 — Minimum distance between fresh piles (centre to centre) without permanent casing in soft soil

8.7.1.6 When semi-dry compacted concrete is used for pile shafts, the recommended distances may be reduced to half the distances given in Figure 1.

8.7.2 Temporary cased piles

8.7.2.1 For a top driven drive tube, the base shall be covered with a shoe or other closure devise to prevent water and soil entering the tube.

8.7.2.2 If the pile shoe is displaced or damaged so that soil or water enters the drive tube the pile shall not be concreted before one or more of the following operations have been completed:

— the tube shall be filled with free flowing material if necessary, withdrawn and driven again; or

— the pile shall be repositioned; or

— if an obstruction is present and can be practically and safely removed the pile shall subsequently be formed in its original location.

8.7.2.3 When the drive tube is impact driven from the bottom concrete, gravel or sand may be used as a plug at the bottom of the drive tube provided it is not damaged during driving.

8.7.2.4 Handling and installation of reinforcement.

8.7.2.4.1 The reinforcement cage shall be constructed to enable it to be handled and lowered into the drive tube without damage or distortion.

8.7.2.4.2 Where reinforcement cages are formed or extended on site by welding, the area and quality of the welds shall be adequate for the forces applied during handling and under working conditions after the pile has been concreted, and shall be carried out in accordance with EN 1992-1-1.

8.7.2.4.3 Welding of reinforcing steel shall be in accordance with EN ISO 17660-1.

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

8.7.2.4.5 The installation procedure of the reinforcement shall provide for its alignment with the pile axis and maintain the correct concrete cover over its full length.

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

8.7.2.4.7 Reinforcement installation subsequent to concrete placement is permitted if the method has been proved in comparable ground conditions.

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

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

8.7.2.4.10 The installation process may be assisted by light vibration or the reinforcement may be pulled-in e.g. with a mandrel.

8.7.2.5 Concreting

8.7.2.5.1 The concreting of cast *in situ* piles shall be done in dry conditions by one of the following three methods:

1) by using high workability concrete that is discharged in sufficient quantity into the drive tube before and during extraction of the tube;

2) by pumping concrete of high workability into the drive tube;

3) by using semi-dry concrete that is added in small charges in the drive tube, each charge being expulsed and compacted by internal tamping during the incremental withdrawal of the tube.

The first and third methods may be combined e.g. fabrication of the pile base (eventual enlarged) with semi-dry concrete, and of the pile shaft with high workability concrete.

8.7.2.5.2 The presence of soil and/or water in the tube shall be checked immediately before concreting.

8.7.2.5.3 In case water and soil is present in the tube the installation has to be interrupted and the tube is to be backfilled and to be extracted. Subsequently, the tube may be driven again at the same location at least to the same depth and the pile concreted in dry conditions.

NOTE Where there is no soil in the tube, concreting under submerged conditions can be authorized.

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

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

8.7.2.5.6 The concrete shall be placed in sufficient quantity and with sufficient workability and coherence in order:

— to ensure that no significant quantities of air are entrapped;

— to avoid lifting of the concrete during withdrawal of the tube;

— to prevent segregation of the concrete;

— to prevent inflow of soil or water.

8.7.2.5.7 External vibrating or light tamping of the drive tube may be used during tube extraction to improve the concrete outflow and the concrete compaction.

8.7.2.5.8 An adequate head of concrete shall be maintained above the toe of the drive tube during extraction.

8.7.2.5.9 The level of concrete within the drive tube should be maintained at or above working level during the tube extraction operation.

8.7.2.5.10 The pile should be cast to the piling platform level unless relevant experience has proven that this is not necessary to ensure integrity and geometry.

8.7.2.5.11 If a semi-dry concrete mix is used, the method of casing extraction shall ensure that the semi-dry concrete is not lifted up with the casing and is adequately compacted and tamped.

8.7.2.5.12 During concreting the volume placed and the level of concrete inside the tube should be checked.

8.7.2.5.13 The method and the sequence of checking the concrete level should suit dimensions, type of pile and soil conditions and should be agreed prior to the commencement of the work.

8.7.2.5.14 In cold weather with ambient air temperature less than 3 °C and falling, the heads of newly cast piles shall be protected against frost.

8.7.3 Permanently cased piles

8.7.3.1 Permanent casing or linings can be used for cast *in situ* piles e.g. to avoid pile necking, excessive pile enlargements or as protection in aggressive soils or groundwater.

8.7.3.2 Handling and installation of reinforcement and concreting shall comply with 8.7.2.4 and 8.7.2.5.

8.8 Grouted piles

8.8.1 Grouting during driving

8.8.1.1 An enlarged shoe can be used to create a space along a part or the full perimeter of the pile which is filled with grout, mortar or concrete during driving, see Figure A11.

8.8.1.2 The grouting can be carried out at the shoe level through a pipe fixed temporarily or permanently along the pile or through the drive tube, so that the grout or mortar remains observable at the working platform.

8.8.1.3 The rate of flow from the pump shall take into account the speed of driving and the size of space around the pile.

8.8.2 Grouting after driving

8.8.2.1 For concrete piles, shaft grouting shall be carried out through permanent grouting pipes fixed to or incorporated in the pile.

8.8.2.2 For steel piles, shaft and base grouting shall be carried out through grouting pipes attached permanently or temporarily to the pile or through drive tube with non-return valves.

8.8.2.3 For cast *in situ* piles with permanent steel core or tube inserted into closed driven tube grouting under pressure shall be carried out during extraction of temporary casing.

8.8.2.4 Grouting shall proceed at appropriate pressures and grouting rates:

— to allow the spread of grout at the interface of the pile with the ground;

— to avoid fracturing of the surrounding ground.

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

8.8.2.6 Shaft and/or base grouting shall be carried out to cast *in situ* piles only after the concrete has set and/or cured as specified.

8.9 Trimming of concrete piles

8.9.1 Cutting off and stripping of the pile head shall be done carefully to avoid damage to the rest of the pile.

8.9.2 Particular attention shall be paid to the quality of the concrete in the top of the pile. Any defective concrete in the head of the completed pile shall be cut down to sound concrete and made good with new concrete well bonded onto the old.

8.10 Driving assistance methods

8.10.1 Driving assistance can be used to facilitate the driving of piles. Methods include:

— water jetting during driving;

— predriving;

— preboring;

— preblasting;

— chiselling;

— coring;

— enlargements on the drive tube or pile base;

— grouting at the pile toe.

8.10.2 These methods shall not impair:

— the performance of previously installed piles;

— the stability of surrounding soil (sliding, liquefaction, heave, lateral movements);

— the stability of adjacent structures.

8.10.3 The water jetting shall be stopped immediately if the pile or drive tube tends to deviate from its position, inclination or penetration stops.

8.11 Ground movement limiting methods

When driving piles in a group and when the piles will cause unacceptable soil movement preboring or coring can be used to mitigate the effects.

8.12 Cast *in situ* base enlargements

8.12.1 Methods of base enlargement shall be agreed before commencement of the work. See 7.7.5.

8.12.2 Cast *in situ* base enlargements may be formed by ramming concrete into the ground below the bottom of the drive tube.

8.12.3 The concrete consumption shall be measured and recorded as required.

8.12.4 For piles which are subject to tensile forces (e.g. by tensile actions from the superstructure or when heave is likely to occur), particular care shall be taken to provide sufficient anchoring of the reinforcement cage in the enlarged base.

9 Supervision, monitoring and testing

9.1 Supervision

9.1.1 The execution of any type of displacement pile shall require careful supervision and monitoring of the work.

NOTE 1 This includes the supervision and the specified monitoring for the surrounding constructions.

NOTE 2 Clause 9 gives the additional provisions to take into account for the establishment of the execution specification for the supervision, control and testing of piles.

9.1.2 Control of the execution shall be in accordance with the project specifications and comply with EN 1997-1, EN 13670, EN 1090-2 and this standard.

9.1.3 The following items shall be supervised and controlled during the various phases of construction:

a) preliminary work prior to the construction phase:

   1) location of piles;

   2) materials;

   3) bearing elements and reinforcement cages (dimensions, assembly and length) and other elements to be inserted;

b) piles construction:

   1) installation method (tools and equipment), dimensions and depth;

   2) Installation execution (where applicable: installation of casings, construction of pile sockets and of enlargements, etc.);

3) placing (depth, position) the reinforcement cage or other elements (e.g. precast concrete or steel elements);

4) concreting (concrete characteristics, concrete placement: quantity, duration, rise and final level, recovery of the tremie pipe, etc.);

5) post concreting phase (recovery of temporary casings, shaft and/or base grouting including the grout characteristics, etc.).

NOTE Not all items are applicable to each type of displacement pile.

9.1.4 Material testing shall comply with the execution specification, EN 206:2013 and this standard (see e.g. 6.3.1 and 9.1.3).

9.1.5 All non conformance shall be notified as specified in project specification.

9.1.6 During execution, the ground behaviour shall be observed and any unforeseen change or feature relevant to the performance of the pile shall be notified as specified in the project specification.

9.2 Monitoring of pile construction

9.2.1 The monitoring of all works connected with the execution of the various stages of construction shall be in accordance with the execution specification and piling plan.

9.2.2 The pile construction process shall be monitored including behaviour of previously installed piles and all relevant data indicated in Clause 10 and when required those indicated in 10.3 shall be recorded.

9.2.3 The effects of piling close to sensitive structures or potentially unstable slopes shall be monitored. The measurement shall be compared to criteria for acceptable performance.

NOTE Possible methods are measurements of vibration, pore pressure, deformation and inclination.

9.2.4 Frequency of monitoring shall be specified and agreed before commencement of piling work.

9.2.5 Records of monitoring shall be provided within an agreed period and kept on site until the completion of the piling works.

9.2.6 All instruments that are used for monitoring the pile installation and/or the effects of installation shall be suitable for the purpose and calibrated.

9.2.7 All non conformance shall be notified.

9.2.8 The full driving record of a proportion of the piles should be recorded in order to establish whether the soil conditions correlate with those used in the design.

This should also include:

— for impact hammers the hammer drop height and weight or hammer energy together with number of blows per unit of penetration;

— for screw piles the torque and pressure applied;

— for vibrated piles the power rating, amplitude and frequency and rate of penetration;

— for jacked piles force applied to the pile.

9.2.9 Where driven bearing piles are driven to a final set, energy and set should be measured.

Where hammer energy is not measured in real time by rig instrumentation, regular checks on hammer efficiency should be made using dynamic measurements of strain and acceleration in the pile head.

9.2.10 Where heave or lateral displacements are likely to be detrimental to pile integrity and performance, pile top level and plan location readings with respect to a stable reference level mark should be taken before and after driving of neighbouring piles and/or after possible excavations.

9.2.11 End bearing piles, which have risen more than the acceptable limits, shall be driven back to their original design criteria.

NOTE Integrity testing can be carried out after redriving of concrete piles

9.3 Pile testing

9.3.1 General

Testing shall be in accordance with prEN ISO 22477-1:2006 and prEN ISO 22477-10:2014.

As long as a European Standard concerning static axially loaded tension test on pile is not available, the national standards can be used as reference for the requirements on this test.

The use of pile load tests (see 3.41 to 3.45) and pile integrity tests (see 3.46) shall comply with EN 1997-1 and this standard.

NOTE 1 Usually pile load tests are used to determine the response of a representative pile and the surrounding ground to actions, both in terms of settlement and limit load, and they consist of:

— static load tests (maintained or constant rate of penetration tests); or

— dynamic load tests.

NOTE 2 Usually pile integrity tests are used to prove the soundness and proper construction of a pile. They determine the propagation of mechanical waves in the pile concrete in order to determine the presence of possible anomalies within the pile body.

NOTE 3 The application of various pile tests is as indicated in Table 3.

NOTE 4 The only test which can derive the ultimate resistance directly is the maintained pile load test if loads are sufficient and held constant for a long enough period. Other tests require subsequent interpretation. Dynamic testing methods cannot measure consolidation or creep under load. Any approximations made to the results for the purpose of establishing load/settlement relationships is therefore to be made clear in test reports.

Table 3 — Application of some test procedures

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

9.3.2 Pile load tests

9.3.2.1 Static and dynamic loading tests should be carried out after sufficient time, taking account of any gain in strength of pile material, and with regard to changes in soil resistance due to pore pressure effects.

9.3.2.2 Pile load tests by static axially loaded compression shall comply with EN 1997-1, prEN ISO 22477-1:2006 and the provisions valid in the place of use.

NOTE prEN ISO 22477-1:2006 on the pile load test by static axially loaded compression is in preparation. As long as this International Standard is not available, the national standards can be used.

9.3.2.3 Dynamic pile loading tests shall comply with EN 1997-1 and the provisions valid in the place of use.

NOTE EN 1997–1 provides requirements for the use of any type of dynamic pile load tests and the content of their test reports. While no European Standard on test procedures is available, national standards can be used.

9.3.2.4 Pile loading test reports shall comply with EN 1997-1.

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

9.3.3 Integrity tests

9.3.3.1 As long as a specific European Standard is not available on integrity tests, such tests shall comply with this standard (see 9.3.3.2), the national standards and/or the provisions valid in the place of use.

NOTE EN 1997–1 does not provide requirements on these tests.

9.3.3.2 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.

10 Records

10.1 Site records shall consist of two parts; the first making references and general information regarding:

— the pile (type, dimensions; etc.);

— the construction method (including machine type); and

— the material specification (reinforcement and concrete specification, steel quality, timber quality).

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 construction methods and shall contain the details listed below.

site location	X
contract identification	X
structure	X
main contractor	(X)
foundation (piling) contractor	X
client/employer	(X)
engineer/designer (foundation and pile)	(X)
pile type/size / quality	X
execution method	X
reinforcement details	(X)
concrete specification	(X)
concrete placement details	(X)
prefabricated pile manufacturer	(X)
material quality	(X)

X necessary information

(X) information as applicable

10.3 The particular information part shall be specific to the type of pile and the construction method and should contain the details listed in Table 4 below.

Table 4

Data	**Prefabricated displacement piles**	**Cast *in situ* displacement piles**
Pile reference number (location)	X	X
Pile type	X	X
Nominal dimensions	X	X
Length of prefabricated pile	X	(X)
Date and time of driving, redriving	X	X
Date of concreting (manufacturing)	(X)	X
Plan location of installed pile	X	X
Inclination of installed pile	X	X
Depth from ground level at pile position to pile toe	X	X
Toe level	X	X
Pile head level as constructed	X	X
Pile cut-off level	X	X
Type, weight, drop and mechanical condition of hammer, torque and equivalent information for other equipment	X	X

Data	Prefabricated displacement piles	Cast *in situ* displacement piles
Number and type of cushion used and type and condition of follower used during driving of the pile	X	X
Length, level and details of reinforcement (grade etc.)	(X)	X
Final set of pile or pile tube in millimetres per 10 blows or number of blows per metre or part of metre penetration	X	(X)
Rotation torque for screw piles	(X)	X
Concrete/mortar/grout mix or grade	X	X
Volume of concrete/mortar/grout supplied to pile	–	X
Injection pressure of grout	(X)	(X)
All information regarding obstructions delays and other interruptions to the sequence of work	X	X
Number and location of joints	(X)	(X)
Length of permanent casing or liner	–	(X)
X necessary information (X) information as applicable		

10.4 The additional particular information details listed in Table 5 below should be recorded.

Table 5

Data	Prefabricated displacement piles	Cast *in situ* displacement piles
Standing groundwater level from direct observation or given site investigation data	(X)	(X)
Ground level at pile position at commencement of installation of pile (commencing surface)	(X)	(X)
Piling platform level	(X)	(X)
The sets taken at intervals during the last 3 m of driving	(X)	(X)
Temporary compression (elastic deformation) of ground and pile from time of a marked increase in driving resistance until pile reached its final level	(X)	(X)
Diameter and length of prebore/precore	(X)	(X)
Depth and type of driving assistance	(X)	(X)
Details of any surface coatings	(X)	(X)
Pore pressure readings	(X)	(X)
Inclination readings	(X)	(X)
Lateral movements	(X)	(X)
X necessary information (X) information as applicable		

10.5 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, executed with the same method.

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

11 Special 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,

where European Standards are not available, respective national standards, specifications or statutory requirements regarding execution of piling works shall be observed

11.2 Equipment shall be in accordance with EN 16228.

11.3 Particular attention shall be drawn to:

— all processes requiring personnel operating with or alongside heavy equipment and heavy tools;

— manual working procedures and inspections carried out inside excavations.

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

11.5 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 type and extent of possible nuisance or environmental impact depends on:

— the location;

— the working method;

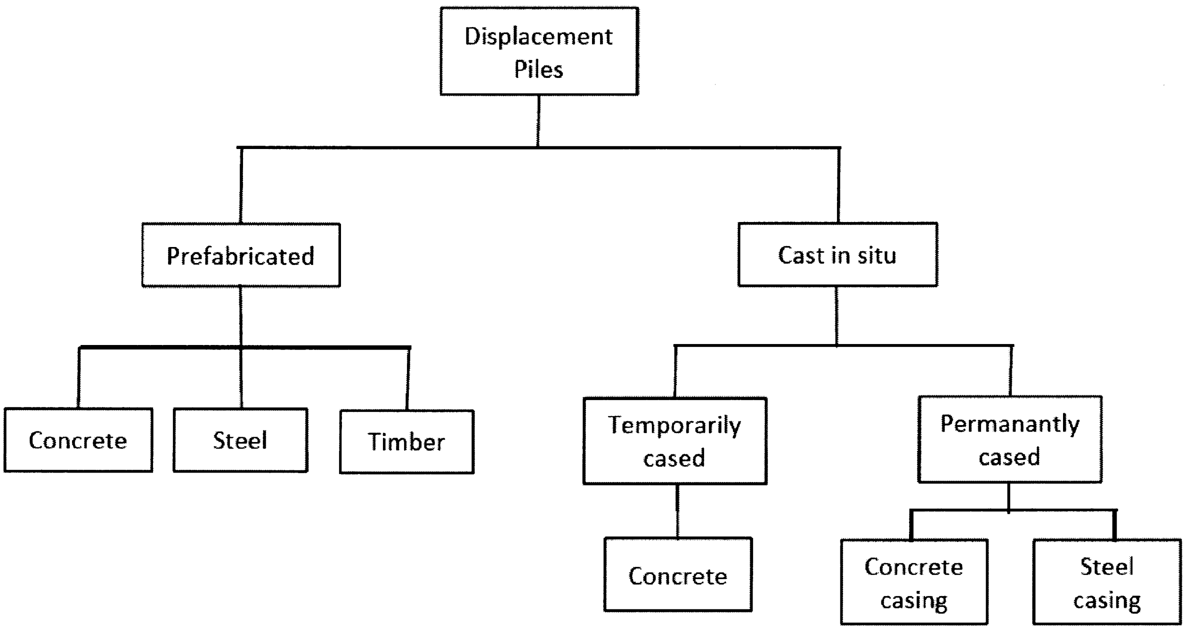
— the actual processes.

11.6 Where respective European Standards are not available regarding nuisance and environmental protection, national and local requirements shall be observed.

11.7 Where sensitive structures, installations or unstable slopes are present in the vicinity of the site or possible sphere of influence of the piling works, their condition should be carefully observed and documented prior to and during the execution of the piling works.

Annex A
(informative)

Classification and examples



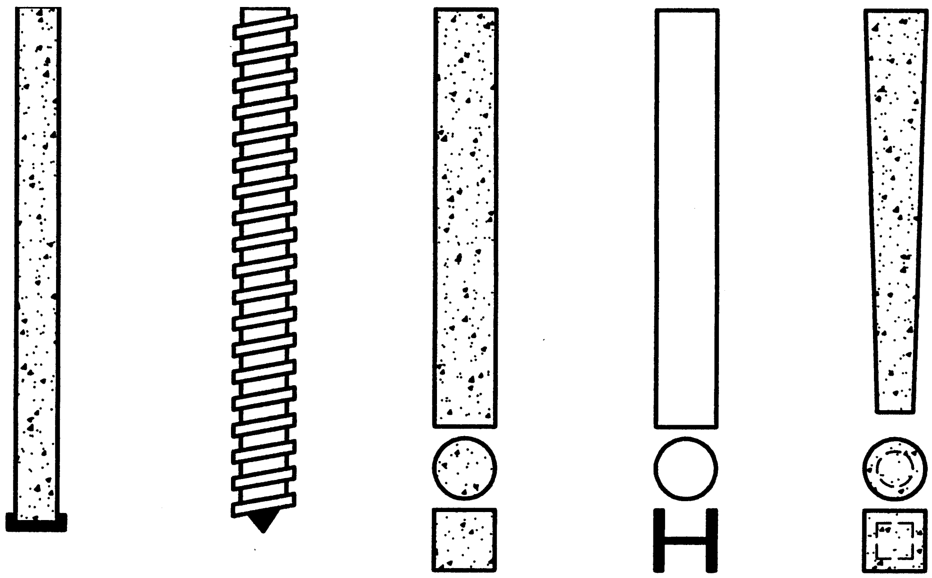
NOTE 1 Prefabricated piles can be solid or hollow and can be extended by welding, splicing or jointing.

NOTE 2 Methods of driving piles apply to several types and requirements are noted in 8.5.

NOTE 3 Additional methods to improve pile capacity and assist installation are noted in 8.10 and 8.12.

NOTE 4 Both prefabricated and cast *in situ* piles can be grouted. Requirements and possibilities are noted in 8.8.

Figure A.1 — Family tree chart for displacement piles



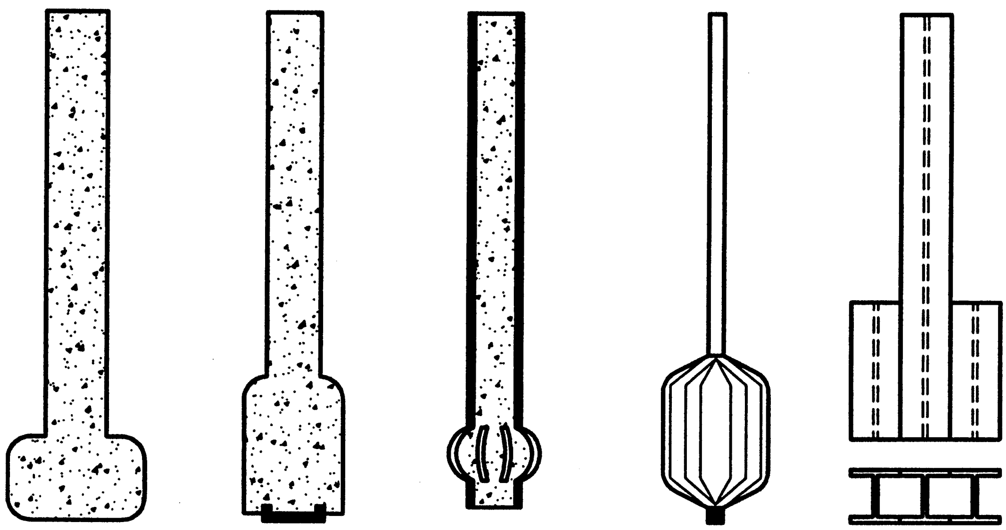
a) Example of driven cast in place pile

b) Example of screwed cast in place pile

c) Example of prefabricated concrete pile (round or square)

d) Example of steel pile (round or H)

e) Example of prefabricated concrete conical pile (round or square)



f) Example of cast in place pile with enlarged base

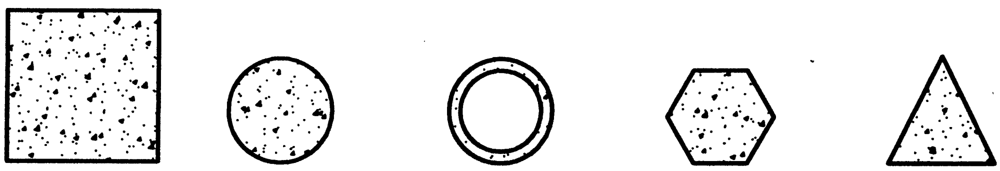
g) Example of cast in place pile with enlarged base

h) Example of cast in place cased pile with enlarged base

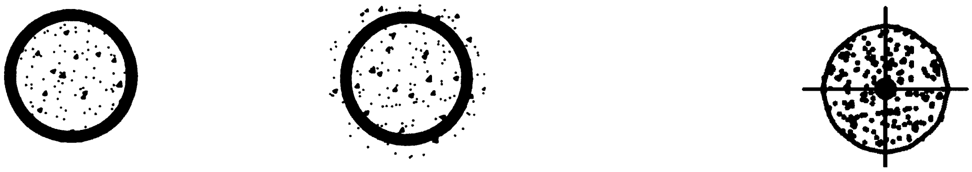
i) Example of pile with base of expanded body

j) Example of enlarged base on steel H-pile

Figure A.2 — Examples of shafts and bases of displacement piles



a) Examples of cross sections of prefabricated concrete piles

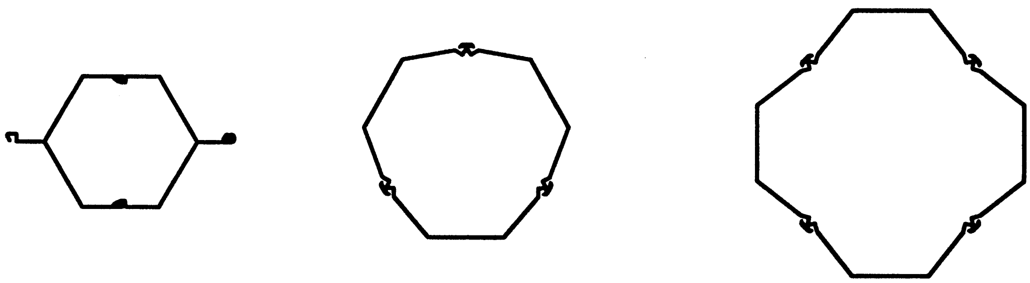


b) Example of cross section for cast *in situ* pile with permanent casing

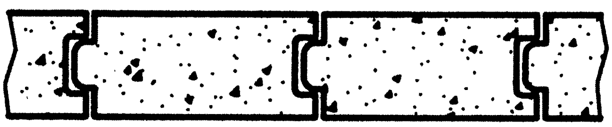
c) Example of cross section for grouted pile

d) Example of cross section for grouted pile with temporary casing and central bar or pipe

e) Examples of cross sections for steel piles

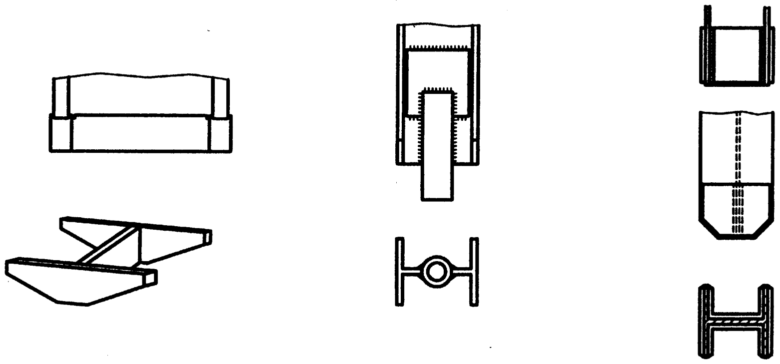


f) Examples of cross sections of steel piles formed from steel sheet piles

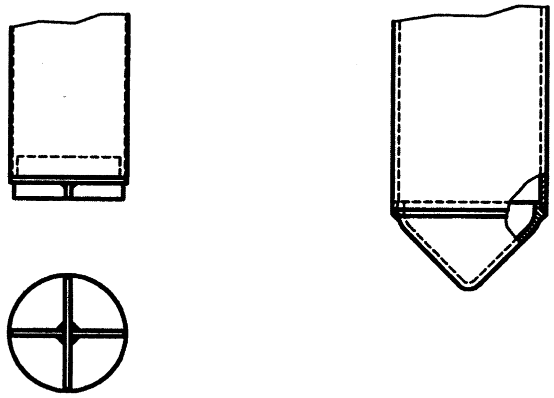


g) Example of concrete sheet piles forming a wall

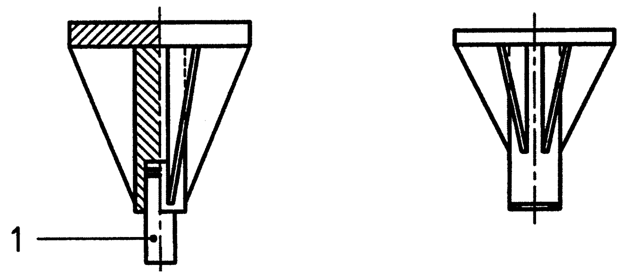
Figure A.3 — Examples of cross sections for displacement piles

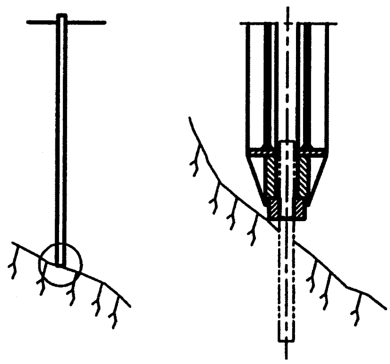


a) Examples for H-pile



b) Examples for tubular pile





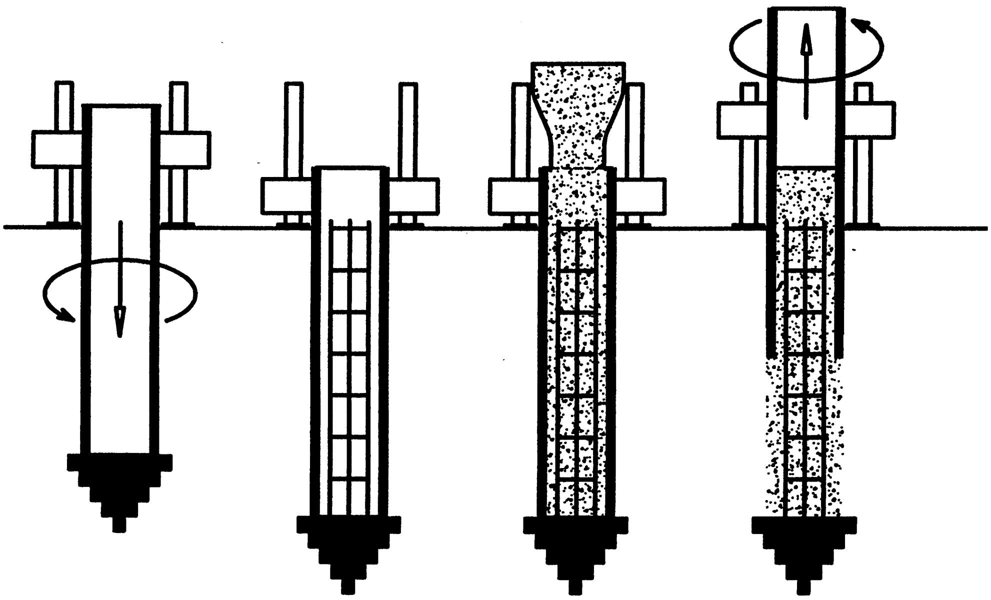
Key

1 special hardened rock point

c) Examples of rockshoe for concrete and tubular steel piles

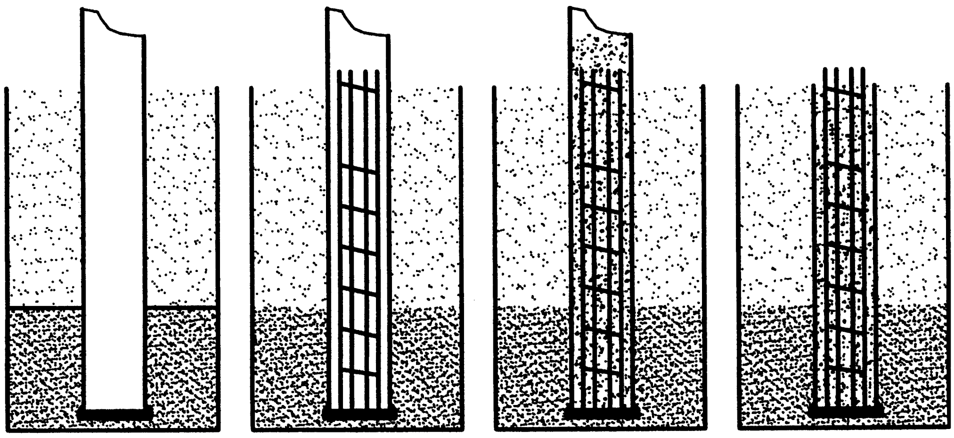
d) Example of rockshoe for sloping rock

Figure A.4 — Examples for toe protection for prefabricated displacement piles



1. Screwing in of drive tube
2. Placing of reinforcement cage
3. Concreting
4. Extraction of drive tube

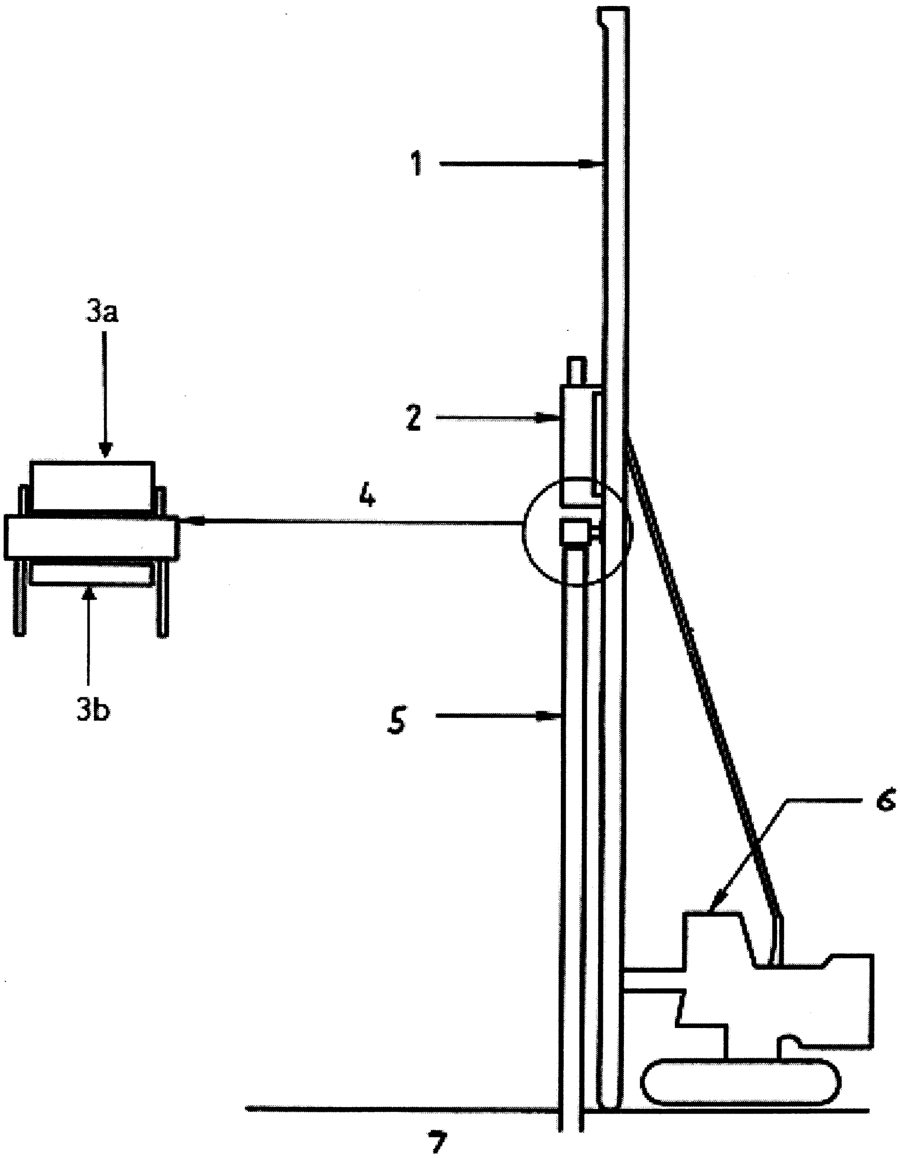
a) Construction of screw cast in place displacement pile



1. Driving in of drive tube
2. Placing of reinforcement cage
3. Concreting and extraction of drive tube
4. Constructed pile

b) Construction of driven cast in place displacement piles

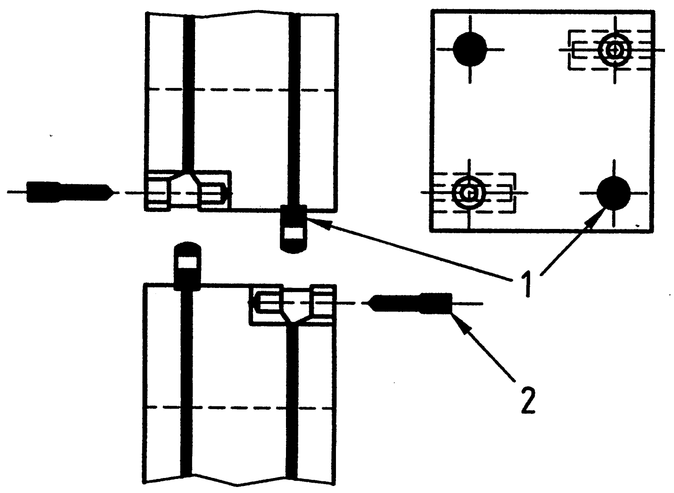
Figure A.5 — Examples of construction of cast in place displacement piles



Key

1	leaders
2	impact hammer
3a	hammer cushion
3b	pile cushion
4	helmet
5	pile
6	base machine
7	piling platform

Figure A.6 — Example of piling rig with impact hammer

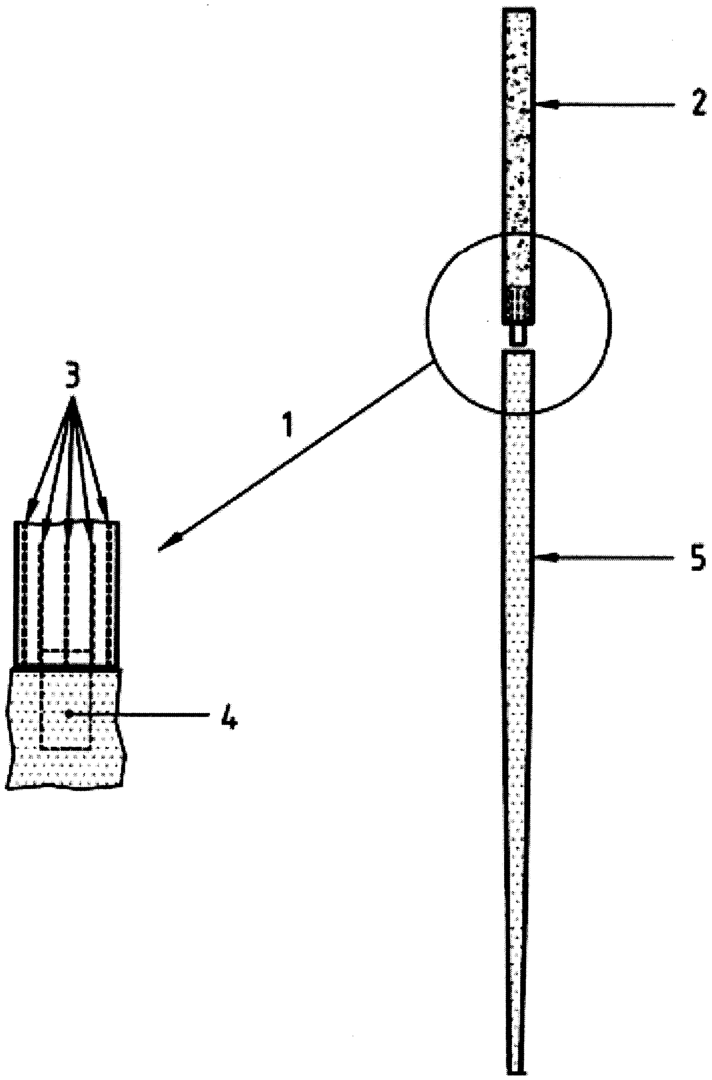


Key

1 locating pin

2 locking plug

Figure A.7 — Example of mechanical joint for prefabricated concrete displacement piles



Key

1 pile joint of steel tube cast into concrete top pile and impact driven into the timber pile

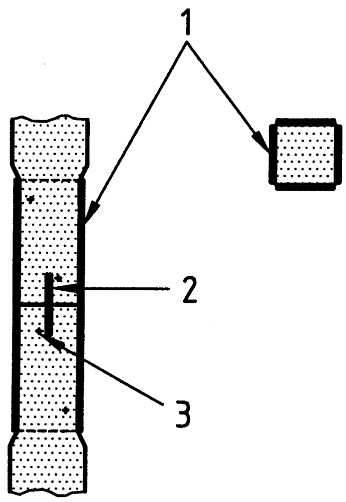
2 concrete pile element

3 reinforcement

4 steel tube

5 timber pile element

Figure A.8 — Example of combined pile



Key

1 plate tarred on inside face

2 dowel

3 screw position

Figure A.9 — Examples of joint in squared timber pile

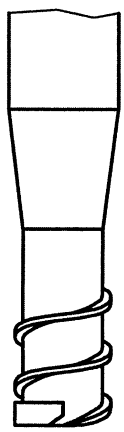
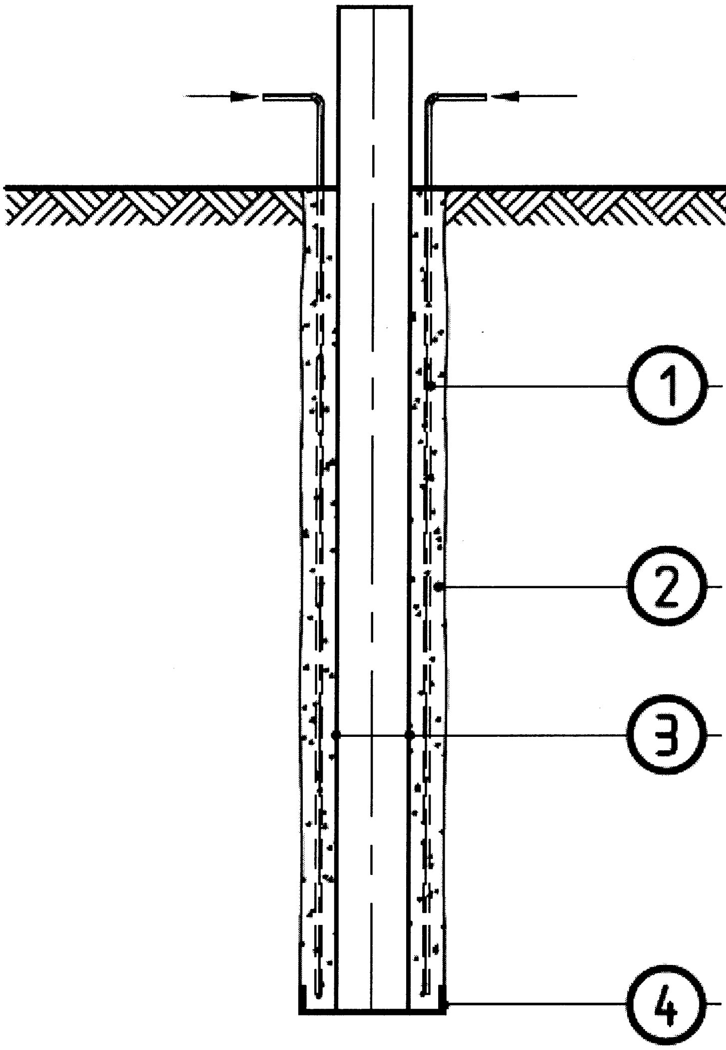


Figure A.10 — Example of tool for screw pile



Key

1 grout pipe

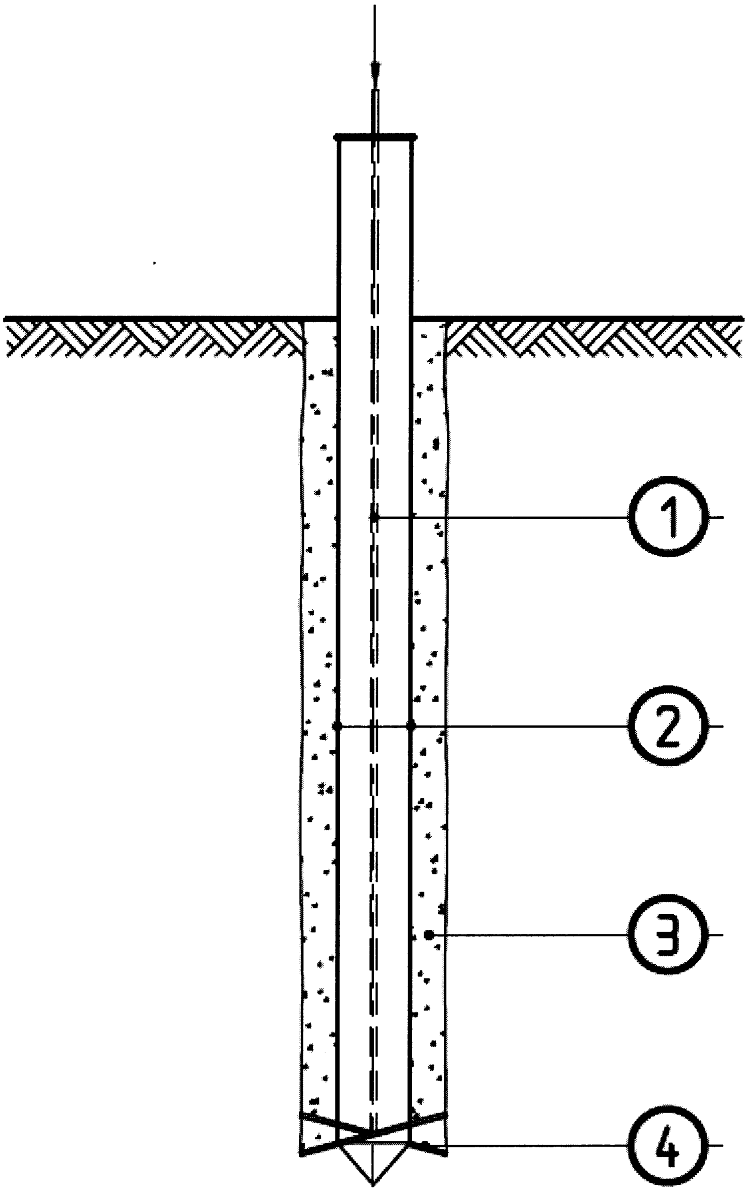
2 grout or mortar

3 prefabricated pile element

4 enlarged shoe

NOTE Grout is injected through a pipe/pipes at shoe level during driving.

a) Example of grouted pile installed by hammering, vibration or pressing



Key

1 grout pipe

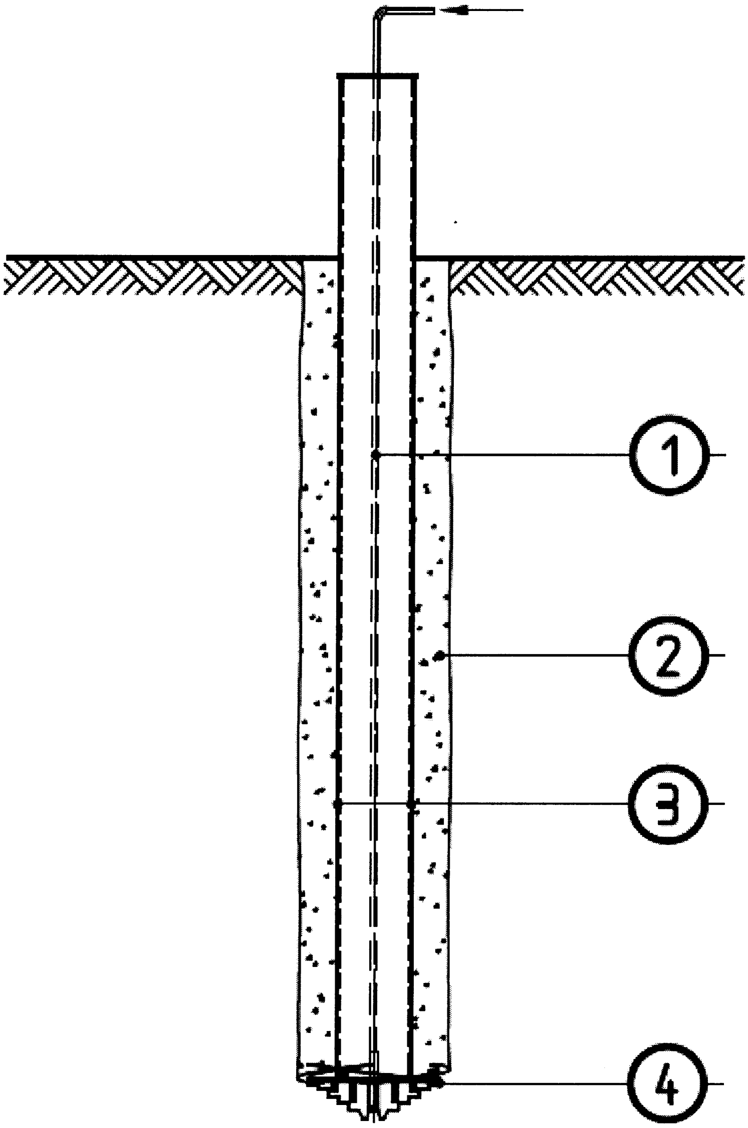
2 permanent casing

3 grout mixed *in situ* granular soil (full saturation of pores with grout)

4 enlarged shoe

NOTE Grout is injected through a pipe/pipes at shoe level during driving.

b) Example of grouted pile with permanent casing, installed by screwing



Key

1 grout pipe

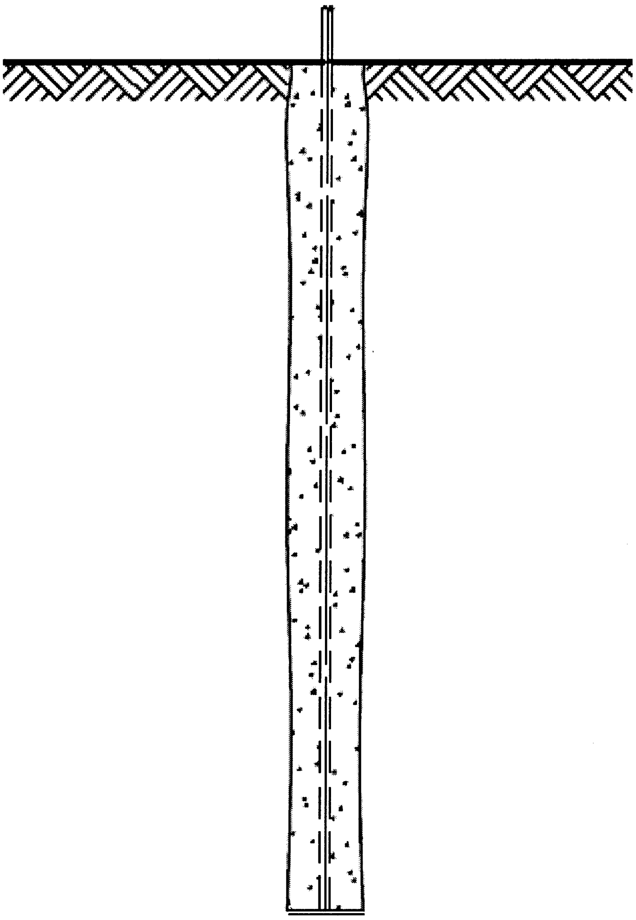
2 grout mixed *in situ* granular soil (full saturation of pores with grout)

3 pile

4 enlarged shoe

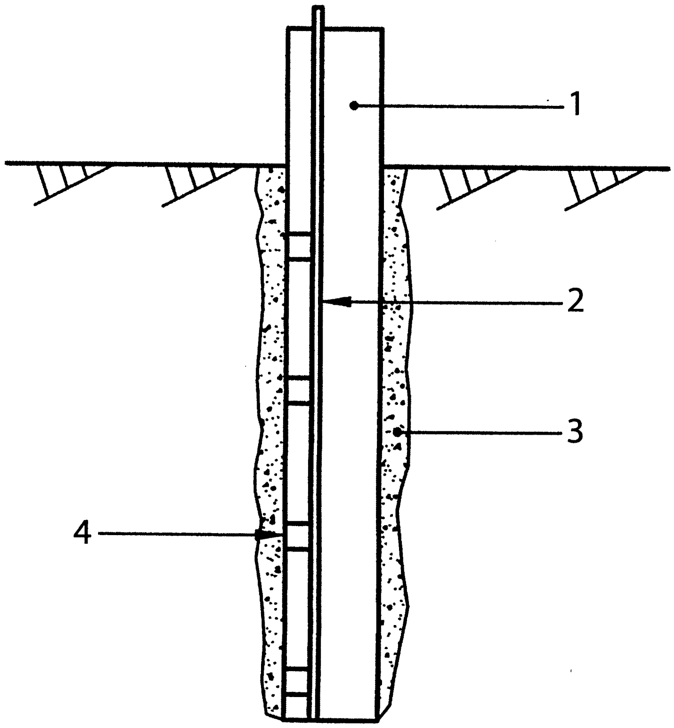
NOTE Grout is injected through a pipe/pipes at shoe level during driving.

c) Example of grouted pile with permanent casing or cast *in situ* pile with temporary casing, installed by screwing



d) Example of cross section for grouted pile with temporary casing and central bar or pipe

Figure A.11



Key

1 displacement pile

2 grout supply line

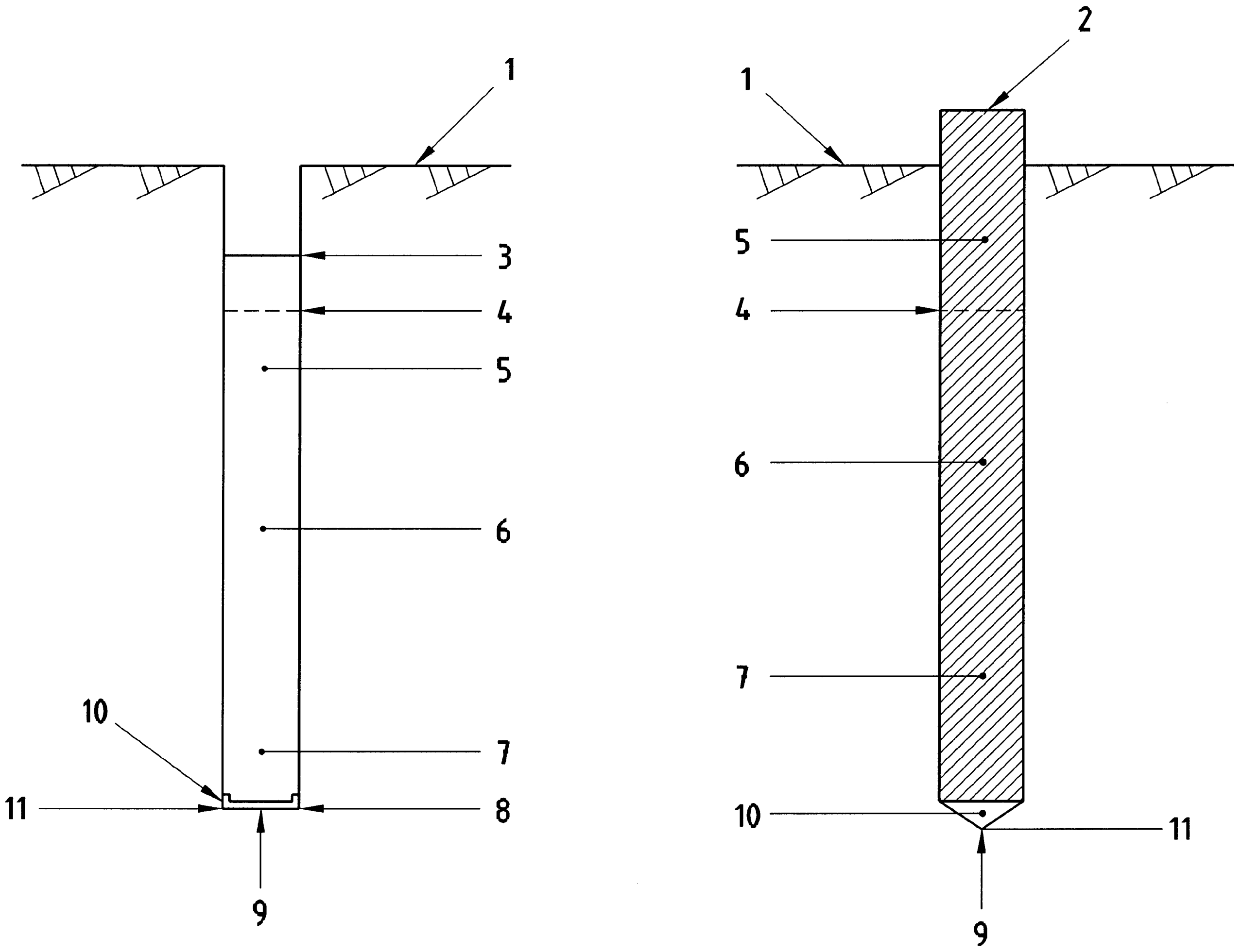
3 grout

4 non return valve

1) displacement pile is driven to final depth

2) high pressure grouting is done after driving

Figure A.12 — Example of post grouted pile



a) Cast in place displacement pile **b) Prefabricated displacement pile**

Key

1 piling platform level

2 pile top

3 casting level

4 cut off level (trim level)

5 pile head

6 pile shaft

7 pile bottom

8 pile base

9 pile toe

10 pile shoe

11 toe level

Figure A.13 — Displacement piles, terms and levels

Annex B
(informative)

Guidance on minimum cover (in mm) for bearing element of low strength steel for cast *in situ* displacement piles

Table B.1

Exposure class[a]	Chemical aggressiveness	Bearing element with grout cover		Bearing element with mortar	
		Compression	Tension	Compression	Tension
X0	with permanent casing	10	10	25	25
X0, XC1 - XC4	Not existing	20[b]	20[b]	35	40
XD1, XD2	Chloride except salt water	20	20	35	40
XS1	Chloride from salt water	20	20	35	40

[a] For other Exposure classes in EN 206 minimum cover are given in EN 1992–1-1:2004, Clause 4, and the valid National Annex.

[b] For service life of maximum 5 years minimum grout cover may be reduced to 10 mm.

Annex C
(informative)

Degree of obligation of the provisions

The provisions are marked corresponding to their degree of obligation:

- RQ: requirement
- RC: recommendation
- PE: permission
- PO: possibility and eventuality
- ST: statement

Clause 1	ST
Clause 2	ST
Clause 3	ST
4.1.1	RQ
4.1.2	RC
4.1.3	RQ
4.2	RQ
5.1.1	RQ
5.1.2	RC
5.1.3	RC
5.1.4	RQ
5.1.5	RQ
5.1.6	RQ
5.2	RQ
6.1	RQ
6.2.1	RQ
6.2.2	RQ
6.2.3	RQ
6.2.4.1	RQ
6.2.4.2	RC
6.2.4.3	RQ
6.2.4.4	RQ
6.2.4.5	RQ
6.3.1.1.1	RQ
6.3.1.1.2	RQ

6.3.1.1.3	RQ
6.3.1.1.4	PE
6.3.1.2	RQ
6.3.1.3.1	RQ
6.3.1.3.2	RC
6.3.1.4	RQ
6.3.1.5	RQ
6.3.1.6	RQ
6.3.1.7	RQ
6.3.1.8	RQ
6.3.1.9.1	RQ
6.3.1.9.2	RQ
6.3.1.9.3	RQ
6.3.1.9.4	RQ
6.3.1.9.5	RC
6.3.1.9.6	PE
6.3.1.9.7	RQ
6.3.1.9.8	RQ
6.3.2.1	RQ
6.3.2.2	RQ
6.3.2.3	PE
6.3.3	RQ
6.4	RQ
7.1.1	RQ
7.1.2	ST
7.1.3	RQ
7.1.4	RC
7.1.5	RQ
7.2.1	RQ
7.2.2	RQ
7.2.3	ST
7.2.4	RQ
7.3.1	RQ
7.4.1	RQ
7.4.2	RQ
7.4.3	RQ
7.4.4	RQ
7.4.5	RC
7.5.1	RQ

7.5.2	RQ
7.5.3	RC
7.6.1.1	RC
7.6.1.2	RC
7.6.1.3	RC
7.6.1.4	RQ
7.6.1.5	RC
7.6.2.1	RC
7.6.2.2	PE
7.6.2.3	RC
7.6.3.1	RC
7.6.3.2	PE
7.6.4.1	RC
7.6.4.2	RC
7.7.1	RC
7.7.2	ST
7.7.2.2	RQ
7.7.2.3	RQ
7.7.2.4	PE
7.7.2.5	RQ
7.7.2.6	RC
7.7.2.7	RQ
7.7.2.8	RQ
7.7.2.9	RQ
7.7.2.10	PE
7.7.2.11	RQ
7.7.2.12	RQ
7.7.2.13	RQ
7.7.2.14	RQ
7.7.2.15	PO
7.7.2.16	RQ
7.7.3.1	RQ
7.7.3.2	RQ
7.7.3.3	RQ
7.7.3.4	RC
7.7.3.5	RQ
7.7.4	RQ
7.7.5	RQ
7.7.6.1	RQ

7.7.6.2	RC
7.7.7	RQ
7.7.8	PO
8.1.1	RQ
8.1.2	RC
8.1.3	RC
8.1.4	RC
8.1.5	RQ
8.2.1	RQ
8.2.2	PE
8.2.3	RQ
8.3	RQ
8.4.1	RQ
8.4.2	RC
8.4.3	RQ
8.4.4	PO
8.5.1	RQ
8.5.2	RQ
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8.6.5	RC

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8.7.2.5.8	RQ
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8.8.2.1	RQ

8.8.2.2	RQ
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8.8.2.4	RQ
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8.10.3	RQ
8.11	PO
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10.1	RQ
10.2	RQ
10.3	RQ
10.4	RC
10.5	PO
10.6	RQ

11.1	RQ
11.2	RQ
11.3	RQ
11.4	RQ
11.5	PO
11.6	RQ
11.7	RC
Annex A	informative
Annex B	informative
Annex C	informative

Bibliography

EN 934-2, *Admixtures for concrete, mortar and grout — Part 2: Concrete admixtures — Definitions, requirements, conformity, marking and labelling*

EN 1536, *Execution of special geotechnical work - Bored piles*

EN 10204, *Metallic products - Types of inspection documents*

EN 12063, *Execution of special geotechnical work - Sheet-pile walls*

EN 14199, *Execution of special geotechnical works - Micropiles*

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