ICS 93.020

SR EN 1538+A1

Standard Român

Noiembrie 2015

Titlu

Execuția lucrărilor geotehnice speciale Pereți mulați

Execution of special geotechnical work - Diaphragm walls

Exécution des travaux géotechniques spéciaux - Parois moulées

Aprobare

Aprobat de Directorul General al ASRO la 27 noiembrie 2015

Standardul european EN 1538:2010+A1:2015 are statutul unui standard român

Înlocuieşte SR EN 1538:2011

Data publicării versiunii române: -

Corespondență

Acest standard este identic cu standardul european EN 1538:2010+A1:2015

ASOCIAȚIA DE STANDARDIZARE DIN ROMÂNIA

✉ Str. Mendeleev nr. 21-25, cod 010362, Bucureşti , 🖳 www.asro.ro

© ASRO

Reproducerea sau utilizarea integrală sau parțială a prezentului standard în orice publicații şi prin orice procedeu (electronic, mecanic, fotocopiere, microfilmare etc.) este interzisă dacă nu există acordul scris prealabil al ASRO

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 1538:2010+A1

June 2015

ICS 93.020

Supersedes EN 1538:2010

English Version

Execution of special geotechnical work - Diaphragm walls

Exécution des travaux géotechniques spéciaux - Parois moulées

Ausführung von Arbeiten im Spezialtiefbau - Schlitzwände

This European Standard was approved by CEN on 2 July 2010 and includes Amendment 1 approved by CEN on 17 April 2015.

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

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

CEN members are the national standards bodies of 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 United Kingdom.



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

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

© 2015 CEN All rights of exploitation in any form and by any means reserved worldwide for CEN national Members.

Ref. No. EN 1538:2010+A1:2015 E

InfoStandard Web 3.0.6-2520

Contents

Page

Foreword ... 4

1 Scope ... 5

2 Normative references ... 7

3 Terms and definitions ... 8

4 Information needed for the execution of the work ... 10
4.1 General ... 10
4.2 Special features ... 10

5 Geotechnical investigation ... 11
5.1 General ... 11
5.2 Specific requirements ... 12

6 Materials and products ... 13
6.1 Constituents ... 13
6.1.1 General ... 13
6.1.2 Bentonite ... 13
6.1.3 Polymers ... 13
6.1.4 Cement ... 13
6.1.5 Aggregates ... 14
6.1.6 Water ... 14
6.1.7 Additions ... 14
6.1.8 Admixtures ... 14
6.2 Support fluids ... 14
6.2.1 Bentonite suspensions ... 14
6.2.2 Polymer solutions ... 15
6.2.3 Fresh hardening slurries ... 16
6.3 Concrete ... 16
6.3.1 General ... 16
6.3.2 Aggregates ... 16
6.3.3 Cement contents ... 16
6.3.4 Water/cement ratio ... 16
6.3.5 Admixtures ... 16
6.3.6 Fresh concrete ... 17
6.3.7 Sampling and testing on site ... 17
6.4 Plastic concrete ... 17
6.5 Hardening slurry ... 18
6.6 Reinforcement ... 18
6.7 Additional inserted products ... 19

7 Considerations related to design ... 19
7.1 General ... 19
7.2 Panel stability ... 20
7.2.1 General considerations ... 20
7.2.2 General principle of design ... 20
7.2.3 Comparable experience ... 20
7.2.4 Stability considerations ... 21
7.2.5 Trial excavation(s) ... 21
7.3 Socketing into rock ... 21
7.4 Precast concrete panels ... 22
7.5 Reinforcement cages ... 22
7.5.1 General considerations ... 22
7.5.2 Design principles ... 22
7.5.3 Vertical reinforcement ... 23
7.5.4 Horizontal reinforcement ... 23
7.5.5 Multiple cages and joints ... 23

InfoStandard Web 3.0.6-2520

7.6 Recesses and perforations 24
7.7 Minimum and nominal cover 24

8 Execution 24
8.1 Construction phases 24
8.2 Construction tolerances 25
8.2.1 Panel 25
8.2.2 Retaining walls 25
8.2.3 Cut-off walls 26
8.2.4 Reinforcement cage 26
8.3 Preliminary works 26
8.3.1 Working platform 26
8.3.2 Guide-walls 26
8.4 Excavation 27
8.4.1 Supporting the walls of the excavation 27
8.4.2 Excavation sequence 28
8.4.3 Loss of support fluid 28
8.5 Cleaning the excavation 28
8.6 Forming the joints 28
8.7 Placing the reinforcement or other elements 29
8.8 Concreting and trimming 29
8.8.1 General 29
8.8.2 Concreting in dry conditions 30
8.8.3 Concreting under support fluid 30
8.8.4 Loss of immersion of tremie pipe 31
8.8.5 Trimming 31

9 Supervision, testing and monitoring 31

10 Records 32

11 Special requirements 32

Annex A (informative) Glossary 34

Annex B (informative) Control schedules during the execution 36

Annex C (informative) Sample concreting record forms for diaphragm walls 42

Annex D (informative) Degree of obligation of the provisions 43

Bibliography 47

InfoStandard Web 3.0.6-2520

Foreword

This document (EN 1538:2010+A1:2015) 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 December 2015, and conflicting national standards shall be withdrawn at the latest by December 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 [A1] EN 1538:2010 [/A1].

This document includes Amendment 1 approved by CEN on 2015-04-17.

The start and finish of text introduced or altered by amendment is indicated in the text by tags [A1] [/A1].

The general scope of TC 288 is the standardisation of the execution procedures for geotechnical works (including testing and control methods), and of the required material properties. WG15 has been charged to revise EN 1538:2000, with the subject area of both retaining and cut-off diaphragm walls. This standard does not address the execution of barrettes, which is covered by EN 1536, *Execution of special geotechnical work — Bored piles*.

The design, planning and execution of retaining and cut-off diaphragm walls call for experience and knowledge in this specialised field. The execution phase requires skilled and qualified personnel and the present standard cannot replace the expertise of specialist contractors.

The document has been prepared to stand alongside EN 1997-1, *Eurocode 7: Geotechnical design — Part 1: General rules* and EN 1997-2, *Eurocode 7: Geotechnical design — Part 2: Ground investigation and testing*. This standard expands on design only where necessary (e.g. the detailing of reinforcement) and provides full coverage of the construction and supervision requirements.

[A2] The amendment became necessary to accord the Standard EN 1538:2010 with EN 206:2013, Concrete – Specification, performance, production and conformity. EN 206:2013 has been revised to contain also the specific requirements for concrete for applications for special geotechnical works, making redundant respective provisions in EN 1538 (e.g. 6.1, 6.3 and 8.8).

Full according with EN 13670, Execution of concrete structures is however still pending. EN 1538:2010+A1:2015 therefore still contains specific requirements for bored piles as a concrete structure, such as the detailing of the reinforcement, the concrete placement and the supervision of concreting process which are complementing the provisions of EN 13670.

In addition, some editorial corrections were made in this amended Standard. [/A1]

According to the CEN-CENELEC Internal Regulations, the national standards organizations 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.

InfoStandard Web 3.0.6-2520

1 Scope

This European Standard establishes general principles for the execution of diaphragm walls as either retaining walls or cut-off walls.

NOTE 1 This standard covers only structures constructed in a trench excavated with a support fluid or in dry conditions, where soil is removed and replaced by concrete or slurry and with wall thickness $B \geq 40$ cm.

NOTE 2 Diaphragm walls can be permanent or temporary structures.

NOTE 3 The following types of structure are considered:

a) retaining walls: usually constructed to support the sides of an excavation in the ground. They include:

   1) cast in situ concrete diaphragm walls;

   2) precast concrete diaphragm walls;

   3) reinforced slurry walls;

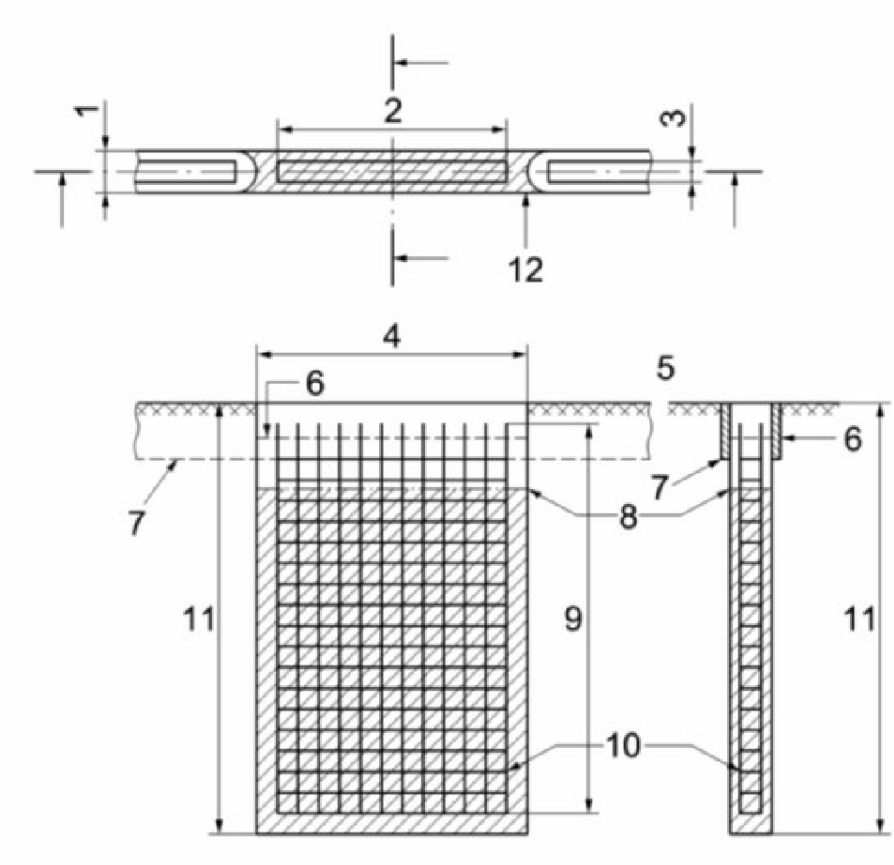
b) cut-off walls: usually constructed to prevent migration of groundwater, clear or polluted, or of other contaminants present in the ground. They include:

   1) slurry walls (possibly with membranes or sheet piles);

   2) plastic concrete walls.

NOTE 4 Walls formed shallow vertical trenches (typically excavations with a ratio of depth over thickness $D/B < 5$ or $D < 5$ m) are not covered by this standard.

InfoStandard Web 3.0.6-2520

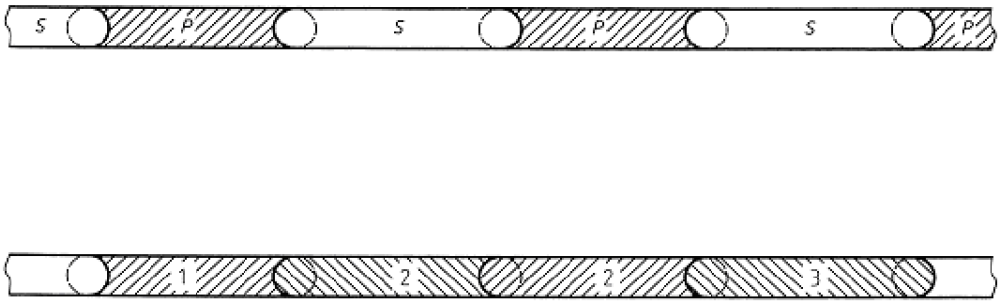


Key

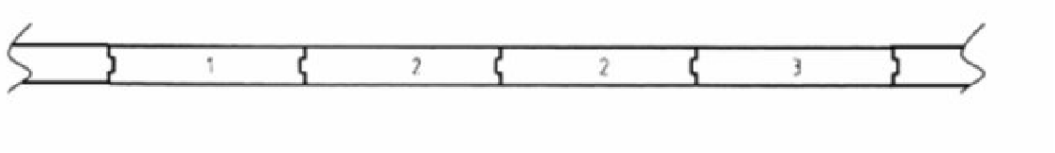
1	Wall thickness (B)	7	Guide-wall
2	Horizontal length of reinforcement cage	8	Cut off level
3	Cage width	9	Vertical length of reinforcement cage
4	Length of panel	10	Reinforcement cage
5	A1 Working platform level A1	11	Depth of excavation (D)
6	Casting level	12	Concave portion of curved joints

Figure 1 — Geometry of a panel

InfoStandard Web 3.0.6-2520



[A1]



[/A1]

Key

P Primary
S Secondary
1 Starter
2 Intermediate
3 Closure

Figure 2 — Schematic examples of different types of panels and joints (plan view)

2 Normative references

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

[A1] *deleted text* [/A1]

[A1] EN 206:2013, *Concrete — Specification, performance, production and conformity* [/A1]

EN 791, *Drill rigs — Safety*

[A1] *deleted text* [/A1]

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 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*

InfoStandard Web 3.0.6-2520

EN 10025-2, *Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels*

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

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

〚A1〛 *deleted text* 〚A1〛

EN 13670, *Execution of concrete structures*

3 Terms and definitions

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

3.1
cast in situ concrete diaphragm wall
fr paroi moulée en béton
de Ortbetonschlitzwand
wall made of plain or reinforced concrete, which is constructed in a trench excavated in the ground

NOTE The excavation is carried out in discrete length to form panels and the concrete is placed through tremie pipes immersed in the fresh concrete. In some cases the excavation and the concreting may be carried out in dry conditions.

3.2
plastic concrete wall
fr paroi moulée en béton plastique
de Tonbetonschlitzwand
wall made of plastic concrete, which is constructed in a trench in the ground

NOTE The excavation is carried out in panels and the concrete is placed through tremie pipes most of the time immersed in a support fluid. In some cases the excavation and the concreting may be carried out in dry conditions.

3.3
precast concrete diaphragm wall
fr paroi préfabriquée en béton
de Fertigteilschlitzwand
wall made of precast elements which are lowered into a trench excavated in the ground containing a hardening slurry

3.4
reinforced slurry wall
fr paroi moulée en coulis armé
de bewehrte Einphasenschlitzwand
wall made from a hardening slurry reinforced by steel beams, steel mesh or other suitable elements

3.5
slurry wall
fr paroi moulée en coulis
de Einphasenschlitzwand
wall made from a hardening slurry

NOTE In most cases, the excavation is carried out using a hardening slurry as the support fluid. Sealing elements such as membranes or sheetpiles may be inserted.

InfoStandard Web 3.0.6-2520

3.6
plastic concrete
fr béton plastique
de Tonbeton
low strength, low Young's modulus concrete capable of sustaining larger strains than normal concrete

NOTE It usually consists of low cement content concrete mixed at a high water cement ratio. It may include bentonite and/or other clay materials and/or other materials such as pulverized fuel ash (PFA) and admixtures.

3.7
hardening slurry
fr coulis autodurcissant
de selbsterhärtende Suspension
slurry which hardens with time

NOTE The slurry is a suspension which contains cement or another binder, and additional materials such as clay (bentonite), ground granulated blast furnace slag (GGBFS) or pulverized fuel ash (PFA), fillers, sand and admixtures. Hardening slurries are generally used in the precast concrete diaphragm wall technique and for slurry walls. They serve as support fluid during excavation, and, together with the fines from the natural ground, form the final, hardened material.

3.8
guide-walls
fr murettes-guides
de Leitwände
shallow depth, parallel temporary walls which are used to provide a guide for the excavating tool, to secure the sides of the trench against collapse at the trench top close to platform level, and to support and to facilitate the positioning of the reinforcement

3.9
panel
fr panneau
de Schlitzwandelement A1 **/ Schlitzwandlamelle** A1
section of a diaphragm wall which is concreted as a single unit

NOTE A diaphragm panel may be linear, T-shaped, L-shaped, or of other configuration.

3.10
support fluid
fr fluide stabilisateur
de Stützflüssigkeit
fluid used during excavation to support the sides of the trench

NOTE It is usually a bentonite suspension, a polymer solution or a hardening slurry.

3.11
concreting pipe
fr colonne de bétonnage
de Betonierrohr
metal pipe comprising several joined lengths, surmounted by a hopper or chute for concreting under dry conditions

3.12
tremie pipe
fr tube plongeur
de Kontraktorrohr
concreting pipe, with watertight joints for submerged concrete placement

InfoStandard Web 3.0.6-2520

3.13
cover
fr enrobage
de Betonüberdeckung
distance between the outside of the reinforcement cage and the nearest concrete surface

NOTE The nearest concrete surface considered is the nearest excavated face as formed by the excavation tool.

3.14
execution specification
fr specifications d'exécution
de bautechnische Unterlagen
set of documents covering all drawings, technical data and requirements necessary for the execution of a particular project

NOTE The execution specification is not one document but signifies the total sum of documents required for the execution of the work as provided by the designer to the constructor. It includes the project specification prepared to supplement and qualify the requirements of this European Standard, as well as referring the national provisions relevant in the place of use.

3.15
project specification
fr spécifications de l'ouvrage
de Projektspezifikationen
project specific document describing the requirements applicable for the particular project

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 site conditions shall cover, where relevant:

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

— the existing underground structures, services, known contaminations, and archeological constraints;

— 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 3.14);

— previous use of the site;

InfoStandard Web 3.0.6-2520

— 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 archeological remains;

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

— [A1] presence of contaminated ground; [A1]

— any specific requirements for the diaphragm wall, in particular those pertaining to tolerances, quality of materials, watertightness, and type of joints;

— where available, previous experience with diaphragm walls or underground works on or adjacent to the site;

— for slurry walls, permeability, strength and deformation properties of the wall material;

— proposed adjacent enabling or advance works such as underpinning, pre-treatment of soil, dewatering;

— diaphragm wall function (i.e. end bearing, retaining wall, cut off wall, environmental barrier, etc.).

4.2.2 Necessity, extent, procedure and content for any survey of the conditions of structures, roads, services, etc. 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 permissions given in this European Standard shall be established and agreed before the commencement of the works and the quality control system shall be suitably amended.

NOTE Such additional or deviating requirements can be:

— reduced or increased geometrical construction deviations;

— application of different or varying construction materials;

— precast concrete elements;

— special anchorage or doweling of diaphragm walls to underlying rock;

— special reinforcement as the use of steel tubes or sections or of steel fibres;

— grouting of diaphragm walls shafts or bases;

— trimming of diaphragm walls heads by mechanical equipment.

5 Geotechnical investigation

5.1 General

5.1.1 The geotechnical investigation shall fulfil the requirements of EN 1997 (all parts).

InfoStandard Web 3.0.6-2520

NOTE 1 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 competent founding stratum is not immediately underlain by a weaker stratum where there is a possibility of a punching failure or excessive movements).

NOTE 2 Relevant experience of the execution of comparable foundation works under similar conditions and/or in the vicinity of the site has to 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 3 Guidance is given in EN 1997-2 on the depth and the contents of investigations.

5.1.2 The geotechnical investigation report shall be available in time, to allow for reliable design and execution of the diaphragm walls (e.g. the choice of method of execution).

5.1.3 The geotechnical investigation shall be checked to see whether if it is sufficient for the design and execution of the diaphragm walls.

5.1.4 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 diaphragm walls:

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

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

— presence of coarse, highly permeable soils or cavities (natural or artificial), which can cause sudden losses of support fluid and instability of the trench, and thus can require special measures;

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

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

— presence, position, strength of hard rock or other hard materials which can cause difficulties during excavation and may require the use of special tools;

— detrimental chemistry of groundwater, soil and rock, and water temperatures if required;

— detrimental chemistry of waste materials;

— presence of pretreated soil, which can have an adverse effect during excavation;

— mining beneath the site;

— site stability problems (slope stability for instance).

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 diaphragm wall.

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 diaphragm wall and to a certain depth below the base depending on the nature of the ground and the function of the wall.

InfoStandard Web 3.0.6-2520

5.2.5 When diaphragm walls are required to reach or penetrate into rock, the level of the rock surface shall be determined in both the longitudinal and transverse directions along the length of the diaphragm wall.

5.2.6 When diaphragm walls are required to reach or penetrate into rock, the properties of the rock, including the degree of weathering and the extent and direction of fissuring, shall be determined.

6 Materials and products

6.1 Constituents

6.1.1 General

6.1.1.1 The constituents 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.

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

6.1.2 Bentonite

6.1.2.1 A distinction should be made between calcium bentonite, natural sodium bentonite and activated bentonite, which is a sodium bentonite produced from natural calcium bentonite by ion exchange.

NOTE 1 Bentonite is a clay containing mainly the mineral montmorillonite.

NOTE 2 Bentonite is used in support fluids, either as a pure bentonite suspension or as an addition to polymer solutions. It is also used as a constituent part of hardening slurries and of plastic concrete.

6.1.2.2 Bentonite used in bentonite suspensions shall not contain harmful constituents in such quantities as can be detrimental to reinforcement or concrete.

6.1.2.3 The chemical and mineralogical composition of the bentonite shall be supplied.

6.1.3 Polymers

Polymers can be used as sole constituent in supporting fluids or as additives to enhance rheological effectiveness.

NOTE 1 Polymers are materials formed of molecules from chained monomeric units.

NOTE 2 There are different types of polymers ranging from natural gums to specially tailored blends of synthetic products.

6.1.4 Cement

A1

6.1.4.1 Cements for diaphragm walls are listed in EN 206:2013, Annex D.

6.1.4.2 The use of CEM II or CEM III cement or the partial replacement of CEM I cement by type II additions is recommended because they have been shown to have beneficial effects on concrete, such as:

— improved workability;

— reduced heat generation during setting;

— improved durability; and

InfoStandard Web 3.0.6-2520

— reduced bleeding rate.

NOTE 1 The use of CEM III cement type or the replacement of CEM I cement type by ground granulated blast furnace slag can result in reduced permeability.

NOTE 2 Bleeding is less likely to be significant with cements with fineness of grind (Blaine) of 3 800 cm^2/g or more. 〈A1〉

〈A1〉

6.1.5 Aggregates

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

6.1.6 Water

Mixing water shall comply with EN 206:2013.

6.1.7 Additions

The use of additions shall comply with EN 206:2013.

6.1.8 Admixtures

Admixtures shall comply with EN 206:2013. 〈A1〉

6.2 Support fluids

6.2.1 Bentonite suspensions

6.2.1.1 A bentonite suspension shall be prepared with either natural or activated sodium bentonite.

6.2.1.2 In certain cases, e.g. when the density of the suspension has to be increased, suitable inert materials may be added.

6.2.1.3 Other than in exceptional circumstances, (see notes) the fresh bentonite suspension shall meet the conditions shown in Table 1 and the "re-use" or "before-concreting" bentonite suspension shall meet the conditions shown in Table 2.

NOTE 1 Special circumstances are for example:

— soils or rock with high permeability or cavities where loss of bentonite can occur;

— high piezometric ground water levels (confined or artesian conditions);

— very loose sand or soft soils (typically with q_c < 300 kPa or C_u < 15 kPa);

— salt water conditions.

NOTE 2 A bentonite suspension with sufficient shear strength can be required, e.g. in order to reduce penetration into the ground.

6.2.1.4 At the stage "before concreting", an upper limit value between 4 % and 6 % for sand content may be used in special cases (e.g. unreinforced walls).

InfoStandard Web 3.0.6-2520

Table 1 — Characteristics for fresh bentonite suspensions

Property[a]	Values
Density in g/cm^3	< 1,10
Marsh value[b] in s	32 to 50
Fluid loss[c] in cm^3	< 30
pH	7 to 11
Filter cake in mm	< 3

[a] See Table 2 , Footnotes a to c for the test procedures.

[b] The Marsh value is the time required for a volume of 946 ml to flow through the orifice of the cone. A volume of 1 000 ml may be used, but in this case, the Marsh value should be adjusted.

[c] The duration of the fluid loss test may be reduced to 7,5 min for routine control tests. However, in this case, the values for fluid loss and filter cake shall be adjusted. The fluid loss for the 7,5 min test will be approximately half of the value obtained in the 30 min test.

Table 2 — Characteristics for bentonite suspensions

Property[a]	Stages	
	re-use	before concreting
Density in g/cm^3	< 1,25	< 1,15
Marsh value[b] in s	32 to 60	32 to 50
Fluid loss[c] in cm^3	< 50	not applicable
pH[d]	7 to 12	not applicable
Sand content in % volume	not applicable	< 4
Filter cake in mm	< 6	not applicable

[a] The Marsh value, the fluid loss, the sand content and the filter cake can be measured, for example, using the tests described in EN ISO 13500.

[b] The Marsh value is the time required for a volume of 946 ml to flow through the orifice of the cone. A volume of 1 000 ml may be used, but in this case, the Marsh value should be adjusted.

[c] The duration of the fluid loss test may be reduced to 7,5 min for routine control tests. However, in this case, the values for fluid loss and filter cake shall be adjusted. The fluid loss for the 7,5 min test will be approximately half of the value obtained in the 30 min test.

[d] Indicative values.

6.2.2 Polymer solutions

6.2.2.1 Polymers may be designed to work in conjunction with bentonite or used as stand alone support fluids.

6.2.2.2 Polymer use shall be based on full-scale trial trenches on the site or on the basis of comparable experience in similar geotechnical conditions.

InfoStandard Web 3.0.6-2520

NOTE EN 1997-1 defines comparable experience as an experience which relates to similar works in similar conditions and is well documented or otherwise clearly established.

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

6.2.3 Fresh hardening slurries

6.2.3.1 Fresh hardening slurries as supporting fluids shall be suitable to ensure the support of the excavated trench during excavation process.

6.2.3.2 A hardening slurry may be prepared with calcium bentonite or activated sodium bentonite as well as cementitious binders.

6.2.3.3 Admixtures may be used to adjust the setting time of the slurry and its consistency during excavation and during any subsequent insertion of elements.

6.2.3.4 The possible effects of temperature and chemical components of the soil and groundwater on the setting time shall be taken into account when admixtures are selected.

6.3 Concrete

A1

6.3.1 General

6.3.1.1 Concrete shall comply with EN 206:2013.

6.3.1.2 Cast in situ concrete shall be composed to minimize segregation during placing, to flow easily around the reinforcement, and when set, to provide a dense and low permeability material.

6.3.1.3 The 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.

6.3.2 Aggregates

Aggregates shall comply with EN 206:2013.

6.3.3 Cement contents

The minimum cement contents shall conform with EN 206:2013, Table D.2.

6.3.4 Water/cement ratio

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

6.3.5 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:

InfoStandard Web 3.0.6-2520

— 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 to cater for any interruptions in the placement process.

NOTE 3 Inappropriate application of admixtures can result into damages.

6.3.6 Fresh concrete

Concrete shall comply with EN 206:2013, Annex D. 〈A1〉

〈A1〉 *deleted text* 〈A1〉

6.3.7 Sampling and testing on site

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

NOTE 1 Conformity testing to confirm that the properties of the concrete comply with the specification is part of producers obligations (see 〈A1〉 EN 206:2013 〈A1〉).

NOTE 2 Additional sampling can be specified in special cases at the point of delivery, just before placing, to check the properties of the concrete (e.g. in case of high stresses or when the concrete is not produced in a certified quality assurance system).

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

6.3.7.3 When the concrete is not produced in a certified quality assurance system, sampling and compressive strength testing shall be carried out.

6.3.7.4 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.

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

NOTE Guidance is given in Annex B in Tables B.1 to B.5.

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

6.4 Plastic concrete

Plastic concrete shall be produced in accordance with the execution specification in order to obtain the specified deformability and permeability, together with adequate workability and strength.

NOTE 1 Plastic concrete is used for cut-off walls when, in addition to low permeability, high deformability is required.

NOTE 2 Their constituent parts are:

— fine grain material (e.g. silt, clay or bentonite);

— cement or another binder;

— well-graded aggregates;

InfoStandard Web 3.0.6-2520

— water;

— and possibly additions and admixtures.

NOTE 3 For plastic concrete limiting w/c ratio does not apply.

[A1] NOTE 4 For plastic concrete it can be more suitable to specify the compressive strength not at 28 days but at a later age more representative of the long-term performance of the structure (see EN 206:2013, 5.5.1.2(3)). Knowledge of the long term strength and deformability can be necessary. [A1]

6.5 Hardening slurry

6.5.1 Hardening slurry shall be produced in accordance with the execution specification in order to obtain the specified deformability and permeability, together with adequate workability and strength.

NOTE 1 Hardening slurries are used for precast concrete diaphragm walls and for cut-off walls when, in addition to low permeability, high deformability is required.

NOTE 2 Their constituent parts are:

— fine grain material (e.g. silt, clay or bentonite);

— cement or another binder;

— water;

— and possibly additions and admixtures.

NOTE 3 These constituents can be delivered as pre-mix products.

[A1] NOTE 4 For hardening slurry it can be more suitable to specify the compressive strength not at 28 days but at an earlier or later age more representative for the long-term performance of the structure and the knowledge of long term strength and deformability can be necessary. [A1]

6.5.2 The characteristics of the hardened material, as needed for the particular applications (e.g. permeability, strength and deformation properties), together with testing methods, shall be specified to satisfy the functional requirements of the wall.

6.6 Reinforcement

6.6.1 Reinforcement material used in diaphragm walls shall comply with the relevant European Standards and the execution specification.

6.6.2 The reinforcement steel cages used in diaphragm walls shall comply with EN 10080.

6.6.3 The steel elements used in diaphragm walls shall comply with EN 10025-2, EN 10210 (all parts), EN 10219 (all parts), EN 10248 (all parts), EN 10249 (all parts) and EN 13670 where relevant.

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

6.6.4 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. .

6.6.5 Unless special precautions are taken, metallic elements used in cast in situ diaphragm walls, such as access pipes for testing purpose, shall not be made of galvanized steel or other metals which can produce electrostatic effects causing electrochemical corrosion of the reinforcement.

NOTE Electrostatic effects can also adversely affect support fluids, for example build up of a bentonite layer using bentonite suspensions or spider web formation in polymer solutions which can inhibit successful concreting.

InfoStandard Web 3.0.6-2520

6.7 Additional inserted products

6.7.1 Inserts such as plastic liner or membranes in hardening slurry shall comply with the relevant European Standards.

6.7.2 Where no relevant European Standards exist, the inserts shall comply with national standards and/or with the specifications of the manufacturer.

7 Considerations related to design

7.1 General

7.1.1 The basic European Standards for the design of diaphragm walls are EN 1990, EN 1991 (all parts), EN 1992 (all parts), EN 1997 (all parts) and EN 1998 (all parts). Clause 7 relates to matters, resulting from the execution of diaphragm walls which can affect the design.

7.1.2 Diaphragm walls design shall take into account the construction tolerances given in 8.2.

7.1.3 The panel dimensions should take into account the dimensions of available excavating equipment, the method and sequence of excavation, panel stability during excavation and concrete supply, as well as the appropriate information in Clause 4.

NOTE The terminology used to define the dimensions and details of panels is shown in Figures 1 and 2.

7.1.4 The width of the excavating tool shall be at least equal to the design wall thickness.

NOTE 1 Except in specific circumstances the panels shall be designed as vertical elements, normally with the same horizontal cross-section throughout their depth.

〚A1〛NOTE 2 In some cases, the horizontal cross-section can be reduced below a certain depth.〚A1〛

7.1.5 The design of the wall shall take into account the discontinuity of the reinforcement at the joints between the panels and between adjacent cages in the same panel.

7.1.6 Space shall be allowed between reinforcement cages of adjacent panels to accommodate the type of joints to be made and to take account of the construction tolerances.

7.1.7 Space shall be allowed in the reinforcement cage for the installation of the tremie pipe.

7.1.8 Space shall be allowed in the reinforcement cage for the installation of inserts, reservations and connectors.

7.1.9 A reinforced concrete capping beam should be constructed along the top of reinforced concrete diaphragm walls, where it is necessary to distribute loads or minimize differential displacements between adjacent panels.

NOTE In exceptional cases where it is necessary to provide structural continuity across the joints, special techniques are available.

7.1.10 Design shall consider that diaphragm walls cannot be expected to be completely watertight, since leakage can occur at joints, at recesses or through the wall material. Damp patches and droplets of water on the surface of the wall cannot be avoided under normal circumstances.

7.1.11 Design should not normally consider continuity of reinforcement between the cages and across the joints, but it may be constructed in exceptional circumstances.

InfoStandard Web 3.0.6-2520

7.2 Panel stability

7.2.1 General considerations

7.2.1.1 The length of the panels and the level of the support fluid shall ensure the stability of the trench during excavation.

7.2.1.2 The excavation tools or procedures, especially where chiselling or blasting are used, can have an influence on the trench stability.

NOTE Special precautions in chiselling and blasting can be necessary, e.g. in loose soil overlying a hard rock.

7.2.1.3 To ensure trench stability the level of the support fluid shall be adjusted with respect to the highest piezometric ground water level anticipated during excavation, and the support fluid level shall always remain at least 1 m above the highest piezometric level.

NOTE 1 In the case of loose sand or soft soils (typically with Q_c < 300 kPa or C_u < 15 kPa), it can be necessary to stabilise the soil by increasing its strength or by raising the level of the support fluid and/or to increase its density during excavation, and to minimize the time during which the trench is left open.

〈A1〉 NOTE 2 in cases where a loss of support fluid can occur (e.g. highly permeable, coarse soils or where there are voids in the ground), special measures can be adopted, for example:

— increasing the flow limit of the fluid by increasing the bentonite content in the suspension;

— adding a filler material to the bentonite suspension, either at the mixing plant or directly in the trench;

— in the case of voids, filling the trench to an appropriate depth with lean mix concrete or other suitable material, and re-excavating;

— grouting the layers concerned before excavating the trench. 〈A1〉

NOTE 3 It can be necessary to consider the risk on trench stability in relation with change in water level due to construction (e.g. case of closing a box). It can also be necessary to consider possible mitigation measures (e.g. dewatering as a way to reduce pore pressure).

7.2.2 General principle of design

7.2.2.1 The stability of the trench shall be determined on the basis of comparable experience (see 7.2.3), stability calculations, or trial excavation(s) on site.

NOTE EN 1997-1 defines comparable experience as an experience which relates to similar works in similar conditions and is well documented or otherwise clearly established.

7.2.2.2 When a comparable experience is established to be insufficient, stability calculations or trial excavation(s) on site shall be adopted.

7.2.3 Comparable experience

In relation to comparable experience, the following items shall be considered:

— soil and rock properties;

— groundwater pressures;

— adjacent structures;

— construction methods.

NOTE Experience gained locally is particularly relevant.

InfoStandard Web 3.0.6-2520

7.2.4 Stability considerations

The stability considerations shall take account of the following factors:

— stabilizing forces due to the support fluid;

— groundwater pressures;

— earth pressures, including the three-dimensional geometry of the problem;

— shear strength parameters of the soils;

— effects of adjacent loads;

— construction details of adjacent structures.

NOTE 1 The trench stability during excavation includes two aspects:

— the local stability of the soil at the walls of the trench;

— the overall stability of the excavation.

NOTE 2 The trench remains stable as a result of the stabilizing forces of the support fluid acting against the walls of the trench:

— in the case of bentonite suspensions, the support effect in fine-grained soils is due to the formation of a filter cake. In coarser soils, this effect is due to a limited penetration into the pores of the soil;

— in the case of polymer solutions, the support effect is caused by the seepage pressure of the liquid flowing into the soil. The penetration depth, which increases with time, is significant in the case of silty or sandy soils, but remains small in the case of clayey soils.

7.2.5 Trial excavation(s)

7.2.5.1 In the case of trial excavation(s), an adequate safety margin shall take into account the variation of the level of the support fluid during the excavation process.

7.2.5.2 The main factors affecting the stability which can be controlled during the execution are:

— the properties of the support fluid;

— the level of the support fluid;

— the length of the panels;

— the time during which the trench is left open, relative to the soil and groundwater conditions (possible loss of shear strength of the soil with time).

7.2.5.3 Ground water level and/or the pore pressure shall be monitored during excavation, where relevant.

7.3 Socketing into rock

7.3.1 Where diaphragm walls are required to be socketed into bedrock, the following shall be taken into account in the design:

— the function of the wall;

— the properties of the rock such as strength, structure (fissuring, bedding, etc.), degree of weathering, and possibly permeability;

InfoStandard Web 3.0.6-2520

— the slope of the rock surface both in transverse and longitudinal directions of the diaphragm wall;

— the ability to penetrate the rock with the tools to be used.

7.3.2 The design can include special solutions such as:

— variable depths along the base of individual panels or between panels;

— doweling into the rock at the base of panels with steel bars, tubes, beams, etc.;

— base grouting.

7.4 Precast concrete panels

7.4.1 The design, execution and supervision of precast concrete panels shall be in accordance with EN 1992 (all parts).

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

〚A1〛 *deleted text* 〚A1〛

7.5 Reinforcement cages

7.5.1 General considerations

7.5.1.1 The following clauses apply to reinforcement cages inserted into cast in situ concrete diaphragm walls, where reinforcement is required by the design.

7.5.1.2 The reinforcement within a panel may comprise one or more cages within the panel length.

7.5.2 Design principles

7.5.2.1 The design of the reinforcement cage(s) shall be in accordance with EN 1992 (all parts).

7.5.2.2 The design shall provide not only adequate strength for the final wall, but also adequate strength and stiffness during construction, in particular for the handling and concreting phases.

7.5.2.3 The design detailing shall allow the fresh concrete to flow easily around all of the walls components.

7.5.2.4 Where full length reinforcement cages are to be provided, dimensions shall be such that the distance between the reinforcement base and the bottom of the excavation is at least 0,2 m.

7.5.2.5 The reinforcement cage shall include:

— vertical reinforcement, usually arranged in either one or two layers on each face of the wall;

— horizontal reinforcement in the form of links, stirrups or other suitable shapes;

— suspension and lifting bars;

and when necessary:

— special reinforcement for anchors, props or other structural elements connected with the diaphragm wall;

— bracing bars to improve the stiffness of the cage for the handling operations;

— formwork for recesses or tubes for anchors, services;

InfoStandard Web 3.0.6-2520

— vertical tubes for grouting, dowel bars, control tests.

7.5.2.6 In the case of welding, only electrical welding and suitable steel quality shall be used.

7.5.2.7 Tack welding may be used for all types of steel for assembly purposes, provided that the mechanical properties of the bars are not affected.

7.5.3 Vertical reinforcement

7.5.3.1 The minimum diameter of the bars shall be 12 mm and there shall be a minimum of three bars per metre on each side of the cage.

7.5.3.2 The horizontal clear space between single bars or groups of bars, parallel to the wall face, shall be at least 100 mm.

7.5.3.3 Provided the maximum size of the aggregates does not exceed 20 mm, this horizontal clear space may be reduced to 80 mm for the lap length.

7.5.3.4 When the cage is made up of several elements in the vertical direction, the junction between bars shall be made either by overlapping or by couplers.

7.5.3.5 When overlapping is used, slippage during handling shall be prevented by tack welding or other suitable means, e.g. wire, [A1] cable clasps [A1], etc.

7.5.3.6 The lap of bars should be located away from the maximum bending area.

7.5.4 Horizontal reinforcement

7.5.4.1 Horizontal reinforcement shall be arranged to prevent movement of the vertical bars and to provide adequate space for the tremie pipe(s).

NOTE In general horizontal reinforcement is not continuous between cages or across joints.

7.5.4.2 The vertical clear space between bars shall be at least 200 mm.

7.5.4.3 Where required the vertical clear space between bars may be reduced to 150 mm provided the maximum size of the aggregates does not exceed 20 mm.

NOTE Stirrup overlap should alternate between both sides of the cage.

7.5.4.4 The horizontal clear space between transverse bars shall be at least 150 mm.

7.5.4.5 The minimum horizontal clear space between transverse bars should be 200 mm to ensure free flow of concrete.

7.5.5 Multiple cages and joints

7.5.5.1 The minimum clear distance between two adjacent cages in a same panel shall be at least 200 mm.

7.5.5.2 The minimum clear distance between two cages in the same panel should be 400 mm.

7.5.5.3 The minimum clear distance between the ends of the cages and the joints formwork including water-stop, if any, shall be 100 mm and shall take into account the verticality tolerances, the shape of the joints and the possible use of water stops.

7.5.5.4 The minimum clear distance between the ends of the cages and the joints formwork, including water-stop if any, should be 200 mm.

InfoStandard Web 3.0.6-2520

7.5.5.5 In the case of the concave portion of curved joints, except special cases, the cage should not enter into the concave portion of the joint.

NOTE This does not apply to the case of diaphragm walls with continuous horizontal reinforcement across the joints.

7.6 Recesses and perforations

7.6.1 All formwork for recesses and tubes shall be securely attached to the reinforcement cage to prevent any movement during concreting.

7.6.2 Recesses and box outs shall be formed to minimize obstruction to the free flow of concrete.

7.6.3 Recesses for slabs shall not exceed the horizontal length of each single reinforcement cage in each panel.

7.6.4 Recesses should not extend behind the first layers of reinforcement.

NOTE Perforations for anchors are normally formed with a tube not exceeding 300 mm in diameter to minimise the effect on the free flow of the concrete.

7.7 Minimum and nominal cover

7.7.1 The minimum cover in relation to environmental condition and to adhesion shall comply with EN 1992 (all parts).

7.7.2 The minimum cover in relation to execution shall not be less than 75 mm.

NOTE The minimum cover in relation to execution (in order to ensure that the concrete flows freely) is specified by reference to target values and not by reference to execution tolerances. So the nominal cover is the greater of the minimum cover in relation to environmental condition and to adhesion and the minimum cover in relation to execution.

7.7.3 Spacers shall be provided to ensure that the correct free flow cover is maintained.

NOTE The spacers can be either vertical tubes, or individual units (pads, rollers, etc.).

7.7.4 The size of the individual spacers shall be adapted to the ground conditions.

7.7.5 For permanent structures, spacers shall be made of a non metallic material, which is at least equivalent to concrete with respect to durability.

NOTE This might not be feasible for heavy cages. Possible solution can be plastic coated steel spacers.

7.7.6 For permanent structures, spacers may be made of a metallic material if they are removed during concreting.

8 Execution

8.1 Construction phases

8.1.1 The phases of execution differ with the type of wall and support fluid used.

NOTE In the general case a support fluid is used.

8.1.2 The basic steps for cast in situ concrete diaphragm walls are:

— excavation, generally with a bentonite suspension or other support fluid;

— cleaning the excavation including recirculation of bentonite;

— placing the joints formwork (stop-ends);

InfoStandard Web 3.0.6-2520

— placing the reinforcement;

— concreting;

— removing the joints formwork (stop-ends);

— trimming.

8.1.3 The basic steps for precast concrete diaphragm walls are:

— excavation, generally with a hardening slurry, sometimes with a bentonite suspension;

— cleaning the excavation. When a bentonite suspension is used, it is replaced by a hardening slurry. If required by the design, a stronger material such as mortar or concrete may be placed at the bottom of the excavation, to support the precast panel and applied loads;

— placing the precast element.

8.1.4 The basic steps for cut-off slurry walls are:

— excavation with a hardening slurry. In some cases (e.g. excavations of long duration), a different support fluid may be used, which has then to be replaced by the hardening slurry;

— when required, placing elements such as membranes, reinforcement or sheet piles;

— trimming and protective capping.

8.1.5 The basic sequences for plastic concrete walls are:

— excavation, generally with a bentonite suspension;

— cleaning the excavation;

— concreting;

— trimming.

8.2 Construction tolerances

8.2.1 Panel

The width and depth of the panel excavation shall not be less than the design values.

8.2.2 Retaining walls

8.2.2.1 Horizontal deviations of the exposed face of a panel, at the top of the guide-walls, shall be less than 25 mm towards the main excavation and 50 mm away from the main excavation for cast in situ panels

8.2.2.2 Horizontal deviations of the exposed face of a precast panel, at the top of the guide-walls shall be less than 10 mm in either direction.

8.2.2.3 Except where otherwise specified, verticality of the panels (including their ends) shall be within 1 % of the depth in both transverse and longitudinal directions.

〚A1〛 NOTE 1 Where boulders or other obstructions are present in the ground, increased tolerances can be necessary. 〚A1〛

NOTE 2 Tighter tolerances can be achieved.

InfoStandard Web 3.0.6-2520

8.2.2.4 Protrusions at the exposed face of cast in situ panels should not exceed 100 mm beyond the plane of tolerance.

NOTE Larger values can be expected in cases where the maximum particle size in the ground exceeds 100 mm or where the ground is soft or loose.

8.2.2.5 When the joint between panels is formed by cutting into the hardened material of the previously cast adjacent panel, it shall be checked that an adequate contact surface is achieved between panels.

NOTE The minimum contact surface depends on the ground type, the depth, the type of material, the cutting tool and the design requirements.

8.2.2.6 The offset between two adjacent panels at their joint location shall be such that it has no adverse effect on the performance of the wall.

8.2.3 Cut-off walls

The deviation of the location of the wall measured with respect to its axis may be larger than for retaining walls and will depend on the project.

8.2.4 Reinforcement cage

8.2.4.1 The tolerance on the total width of the reinforcement cage shall be ± 10 mm.

8.2.4.2 The tolerance on the elevation of the top of the cage after concreting shall be ± 50 mm.

8.2.4.3 When inserts are implemented in the reinforcement, the tolerance on the elevation of inserts (couplers, starter bars, inserts for anchors) after concreting shall be ± 70 mm.

8.2.4.4 The tolerance on the horizontal position of the cage along the axis of the wall after concreting shall be ± 70 mm within a panel.

8.3 Preliminary works

8.3.1 Working platform

8.3.1.1 The working platform shall be stable, above the water table, horizontal and be suitable for traffic of heavy equipment and lorries.

8.3.1.2 The working platform and the access ramps shall be stable under adverse conditions.

8.3.1.3 The area along the line of the wall shall be clear of underground obstructions.

〚A1〛NOTE 1 Special care can be required for excavating and backfilling trenches in case of removal of underground obstructions or disturbed soil.〚A1〛

NOTE 2 Where appropriate, excavation and backfilling should be done symmetrically along the axis of the wall, to a depth corresponding at least to the level of undisturbed soil, with sufficient width and depth with regard to the guide-walls.

8.3.1.4 The top of the working platform should be at least 1,5 m above the highest water-table anticipated during excavation, taking into account possible fluctuations.

8.3.1.5 Material used for the construction of the working platform or for backfilling excavations (see also 8.3.1.3) shall be of suitable quality and well compacted or stabilized.

8.3.1.6 Leakage from nearby drains or pipes, which can affect the construction of the diaphragm wall, shall be stopped or diverted.

8.3.2 Guide-walls

8.3.2.1 Guide-walls shall be designed and constructed:

InfoStandard Web 3.0.6-2520

— to ensure alignment of the diaphragm wall;

— to serve as a guide for the excavating tools;

— to secure the sides of the trench against collapse in the vicinity of the fluctuating level of the support fluid;

— to serve as a support for the reinforcement cages or prefabricated panels or other elements inserted in the excavation until the concrete or hardening slurry has hardened;

— to support the reaction forces of stop end extractors when necessary.

NOTE 1 Guide-walls are usually made of reinforced concrete with a depth normally between 0,7 m and 1,5 m depending on ground conditions.

[A1] In the case of cut-off walls excavated continuously, if ground conditions should permit, guide-walls might not be necessary. [A1]

[A1] NOTE 2 It can be necessary to insert props between the guide-walls. [A1]

8.3.2.2 Guide-walls shall be designed and constructed:

— to resist the loads to which they will be subjected, including the traffic of equipment and adjacent structures, without undue deformation or displacement; and

— to allow the positional tolerances concerning the panel to be met.

8.3.2.3 Guide-walls should be propped apart until the excavation of the panel takes place.

8.3.2.4 The distance between the guide-walls should normally be 20 mm to 50 mm greater than the width of the excavating tool.

[A1] NOTE In the case of polygonal or irregular shaped walls, it can be necessary to increase the distance between the guide-walls. [A1]

8.3.2.5 The top of the guide-walls should normally be horizontal and have the same elevation on both sides of the trench.

NOTE Usually, the inside face of one of the guide-walls is used as the reference face to establish the position of the diaphragm wall.

8.4 Excavation

8.4.1 Supporting the walls of the excavation

8.4.1.1 Except in special ground and site conditions, a support fluid shall be used during excavation.

NOTE In some cases, it can be possible to excavate using water as a support fluid.

8.4.1.2 In certain soils with cohesive properties or in rock, dry excavation may be used, provided the ground strength is sufficient to ensure stability of the sides of the trench.

8.4.1.3 In soils where no comparable experience is available, a trial excavation should be made (see 7.2.5).

8.4.1.4 During excavation, the level of the support fluid will fluctuate, but it shall not be allowed to fall below the level required for excavation stability.

8.4.1.5 The level of the support fluid shall remain above the base of the guide-walls, unless there is no risk of caving of the soil below the guide-walls.

InfoStandard Web 3.0.6-2520

8.4.2 Excavation sequence

8.4.2.1 The excavation may be carried out continuously or in panels.

NOTE The sequence of excavation, panel lengths and distances between panels being excavated, depend on the ground conditions, the type of wall, and the type of excavating tools.

8.4.2.2 The excavation of a panel shall not be started before the concrete, the plastic concrete or the hardening slurry in the adjacent panel or panels has gained sufficient strength.

8.4.2.3 The use of chisels, other tools, or blasting, which affect the nearby panels already filled with concrete or hardening slurry shall not be made before the material in panels has sufficient strength to resist the stresses developed during these construction operations.

8.4.3 Loss of support fluid

8.4.3.1 When a sudden and significant loss of the support fluid occurs during excavation, the excavation shall be refilled immediately with an additional volume of support fluid, possibly containing sealing materials.

8.4.3.2 If this procedure is insufficient, the excavation shall be backfilled as quickly as possible with a material which can be readily re-excavated (e.g. lean concrete).

8.4.3.3 In situations where significant loss of support fluid can occur (e.g. highly permeable soils, cavities), an additional volume of support fluid, and possibly sealing materials or suitable fill, shall be stored in a readily accessible area.

8.5 Cleaning the excavation

8.5.1 When a support fluid has to be replaced by concrete or another material, the bottom of the excavation shall be cleaned and the joints shall be cleaned if necessary.

8.5.2 When a diaphragm wall acts as a vertical bearing structure, special care should be taken for the cleaning of the bottom of the excavation.

8.5.3 Others than in exceptional circumstances, in the case of a bentonite suspension, the properties specified in Table 2, for the phase "before concreting", shall be obtained at the end of the cleaning process.

8.5.4 Where elements such as stop ends or reinforcement cages are to be inserted, cleaning shall be carried out before insertion.

8.5.5 The cleaning procedure, as well as the time between operations, shall be established on the first panels.

8.6 Forming the joints

8.6.1 Stop ends shall be of adequate strength and properly aligned throughout their length.

NOTE The joints are normally formed either by using steel or concrete stop ends or by cutting into the concrete or hardened material of the previously cast adjacent panel. In some cases, waterstops can be incorporated into the joints.

8.6.2 In the case of stop ends which are extracted laterally, the extraction shall be made upon completion of the excavation of the adjacent panel.

8.6.3 In the case of stop ends which are extracted vertically, the extraction shall be made gradually during the setting of the concrete.

8.6.4 In the case of stop ends which are extracted vertically, concrete setting during stop end extraction shall be controlled.

8.6.5 The detailed procedure for forming the joints shall be established during construction of the first panels of each type.

InfoStandard Web 3.0.6-2520

8.7 Placing the reinforcement or other elements

Reinforcement cages, precast concrete panels or other elements (such as sheet piles, membranes) shall not rest on the bottom of the excavation, but shall be suspended from the guide-walls.

NOTE 1 For the design of the reinforcement cages, see 7.5.2.4.

NOTE 2 Vertical distance between spacers of about 3 m to 5 m with at least two spacers per level on each long side, depending on cage stiffness is common practice.

8.8 Concreting and trimming

8.8.1 General

8.8.1.1 Only one structural concrete shall be used in a discrete panel.

8.8.1.2 The time elapsing between the start of excavation and commencement of concreting shall be kept as short as possible.

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

8.8.1.4 When delays are anticipated which adversely affect the quality of the concrete, e.g. due to traffic conditions, an appropriate percentage of retarder may be added to the concrete during the mixing process.

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

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

8.8.1.7 Vibration of the concrete shall not be used.

8.8.1.8 Particular care shall be observed when concreting in dry conditions, to minimize segregation.

〚A1〛 NOTE Specific slump values are required for dry conditions (see EN 206:2013, Table D.3). 〚A1〛

8.8.1.9 The concrete volume placed and the level of concrete inside the excavation shall be checked and recorded (see 9.2 and Annexes B and C).

8.8.1.10 The method and the sequence of the checking and recording shall be in accordance with the project specifications (see 9.3).

〚A1〛

8.8.1.11 Since the top of the cast concrete can be of inferior quality, sufficient concrete shall be placed in the panel to ensure that the concrete below the cut-off level has the specified properties.

8.8.1.12 The required quality of the concrete at the cut-off level shall be achieved by providing a height of concrete above the cut-off level.

NOTE 1 The height of concrete above the cut-off level depends on the cut-off level, the wall dimensions and the number of tremie pipes.

NOTE 2 In cases where the cut-off level is close to the top of the guide-walls, this can be achieved by allowing the concrete to overflow. 〚A1〛

8.8.1.13 After concreting, empty excavations above the concrete level shall be backfilled with lean concrete or other suitable material at least to the bottom of the guide walls.

〚A1〛 *deleted text* 〚A1〛

InfoStandard Web 3.0.6-2520

8.8.2 Concreting in dry conditions

Direct pumping may be used in dry excavations.

8.8.3 Concreting under support fluid

8.8.3.1 The properties of the fluid shall be checked before concrete placement (see 6.2 and Table 2).

8.8.3.2 [A1] Where concreting is carried out under support fluids, the consistency shall be in accordance with EN 206:2013, Table D.3 and a tremie pipe shall be used for the placement. [A1]

NOTE 1 The main purpose of the tremie pipe is the prevention of segregation of the concrete during placement or its contamination by the fluid inside the bore.

NOTE 2 The tremie pipe method is common practice. Others methods, when tested and referenced are also within the acceptable methods.

[A1] NOTE 3 A tremie pipe can be a pump line. [A1]

8.8.3.3 The tremie pipe shall be clean and watertight. Its inner diameter shall be at least 0,15 m and six times the maximum aggregate size. Its outer diameter shall be such that it passes freely through the reinforcement cage.

8.8.3.4 The number of tremie pipes in a panel shall be adjusted to limit the horizontal distance the concrete has to travel.

8.8.3.5 In normal circumstances, the horizontal distance the concrete has to travel should be less than 3,0 m.

8.8.3.6 Where there is more than one cage per panel, at least the same number of tremie pipes should be used.

8.8.3.7 When several tremie pipes are used, they shall be arranged and supplied with concrete in such a way that a reasonably uniform upward and level flow of the concrete is assured.

8.8.3.8 When starting concreting, the support fluid and the concrete in the charged tremie pipe shall be kept separate by a plug of material or by other suitable means.

8.8.3.9 To start concreting, the tremie pipe shall be lowered to the bottom of the trench and then raised approximately 0,1 m.

8.8.3.10 After concreting has started, the tremie pipe shall always remain immersed in the fresh concrete.

8.8.3.11 The tremie pipe shall remain immersed into the fresh concrete for at least 6 m before extracting the first section at the beginning of concreting. Immediately after extracting each single section, the immersion depth shall not fall below 3 m.

[A1] NOTE 1 It can be necessary to reduce the immersion depth when the concrete approaches ground level to facilitate concrete flow. [A1]

NOTE 2 For shallow vertical trenches (D < 6 m), the tremie pipe is extracted only when the concrete has reached the head of the trench.

8.8.3.12 The immersion depth of the tremie pipe should be monitored and reported in the documentation (e.g. see Annex C).

8.8.3.13 In order to ensure concrete integrity, the rate of concrete rising over the full height of the panel should not be less than 3 m/h.

NOTE The difference in flow resistance between concrete and bentonite suspensions increases with increase in the velocity gradient.

InfoStandard Web 3.0.6-2520

8.8.4 Loss of immersion of tremie pipe

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

— concrete into which fresh concrete is to be placed has retained its workability;

— the tremie pipe is re-immersed sufficiently deep into the previously placed concrete;

— no water and no contamination is introduced into concrete which will remain below the final cut-off level.

8.8.4.2 When concreting is performed in submerged conditions and the tremie pipe has to be removed from the bore, its bottom shall be protected by a seal, so the concrete is not mixed with the bentonite suspension, debris or water.

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

8.8.4.4 Integrity tests should be carried out to document the quality of any panel where the tremie pipe was re-immersed or a construction joint was made.

NOTE In the event of loss of immersion of a tremie pipe, a check of the structural integrity of the concrete needs instigating.

8.8.5 Trimming

8.8.5.1 The trimming shall eliminate the polluted and/or dirty concrete and sound concrete above the cut-off level over the full cross-section of the panel shall be exposed.

8.8.5.2 Trimming of the concrete to cut-off level shall be carried out using equipment and methods which will not damage the concrete, reinforcement or any instrumentation installed in the panels.

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

8.8.5.3 Where possible, some trimming above cut-off level may be carried out before the concrete has set.

8.8.5.4 Final trimming to cut-off level shall only be carried out after the concrete has gained sufficient strength.

9 Supervision, testing and monitoring

9.1 The execution of any types of diaphragm wall 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 In accordance with EN 13670, the aim of the supervision and inspection of the work is to check that the construction is completed in accordance with the execution specification and inspection refers to verifying conformity of the properties of products and materials to be used as well as inspection of the execution of the works.

NOTE 3 Clause 9 of this standard gives the additional provisions to take into account for the establishment of the execution specification for the supervision, control and testing of diaphragm walls.

9.2 Control of the execution shall be in accordance with the project specifications and comply with EN 13670 and this standard.

InfoStandard Web 3.0.6-2520

NOTE 1 Examples for details and frequencies for monitoring are given in Tables B.1 to B.5 (Annex B). An example of concrete record for diaphragm wall is given in Annex C.

NOTE 2 Controls for special execution techniques, such as the use of polymers as a support fluid, are not considered in Note 1.

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

a) preliminary work prior to the excavation phase:

   1) location of the wall;

   2) materials;

   3) reinforcement cages and other elements to be inserted;

b) wall construction:

   1) excavation method, dimensions and alignment;

   2) where appropriate verticality and twisting;

   3) cleaning the excavation;

   4) forming the joints;

   5) placing the reinforcements or other elements;

   6) concrete placing record.

NOTE 1 Not all items are applicable to each type of wall.

NOTE 2 Others items may be applicable (e.g. ground conditions and groundwater levels).

9.4 Material testing shall comply with the execution specifications and this standard (see e.g. 6.3.7 and 9.2).

〈A1〉

9.5 Integrity tests can be used to determine the presence of possible anomalies within the diaphragm wall structure.

NOTE Integrity tests can be done either by coring or measuring the acoustic properties of the concrete. 〈A1〉

10 Records

10.1 Site records shall consist of two parts, the first giving the general references and general information pertaining to the concrete and support fluid, the second parts giving detailed information on the execution of each panel.

10.2 The form shown in Annex C is an example of the concreting record for diaphragm walls.

11 Special requirements

11.1 Regarding:

— safety on the site;

— safety of the working practices;

InfoStandard Web 3.0.6-2520

— legality of manual works and inspections inside excavations; and

— operational safety of main and auxiliary equipment and tools,

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

11.2 Equipment shall be in accordance with EN 791.

11.3 Particular attention shall be drawn to:

— all processes requiring men operating alongside heavy equipment and heavy tools;

— the danger of open holes;

— manual working procedures and inspections carried out inside excavations;

— handling operations of the reinforcement cages.

11.4 Nuisance and/or environmental damage that can be caused by the diaphragm wall 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 Regarding nuisance and environmental protection, for each particular situation:

— the national requirements (as long as respective European Standards are not available); and

— the local requirements

shall be observed.

11.7 Rejected materials shall be removed promptly from the site in accordance with local and national requirements.

InfoStandard Web 3.0.6-2520

Annex A
(informative)

Glossary

A.1 clamshell (or grab): excavation tool with two jaws to remove soil, rock or debris from an excavation by an intermittent operation. Jaws are attached to a steel frame. There are two main types of clamshells:

— mechanical grabs using steel cables to open/close the jaws;

— hydraulic grabs using hydraulic circuits to open/close the jaws.

A.2 hydrofraise (or cutter or mill): excavation tool with rotating wheels fitted with steel picks to remove soil, rock or debris from an excavation by a continuous operation.

A.3 chisel: heavy steel tool used to break up obstructions, boulders and hard strata encountered in the excavation or for socketing into hard soil or rock. There are particular types of chisels used to rectify an excavation trajectory, to extract stop ends, etc.

A.4 kelly (bar): shaft, often telescopic, connected between the power drive and the digging tool which allows deep excavation.

A.5 cable(s): steel cable(s) suspending the digging tool which allows deep excavation.

A.6 excavation crane: crane used to handle the excavation tool (clamshell or hydrofraise).

A.7 handling crane: crane used to handle the reinforcement cages and other equipment.

A.8 water stop: special flexible element attached longitudinally to a stop end in such a way that half of the water stop is embedded in concrete in a panel after the concreting and stop end extracting operations. When constructing the adjacent panel, the other half of the water stop is released and also becomes embedded in concrete. As a result, the water stop surrounded in concrete at the contact zone between two panels helps to limit water leakage through this critical surface. Two water stops can be installed at a same joint if required.

A1

A.9 overlap: the distance of a panel excavation into the material of an adjacent panel to ensure diaphragm wall continuity when no stop ends are used. The overlapping technique (no stop ends) is always used for hardening slurry walls, often used for plastic concrete walls and sometimes used for cast-in situ concrete walls where a hydrofraise (hydromill) can be employed to breakdown hard concrete at joints. A1

A.10 filter cake: thin pastelike deposit formed by bentonite particles aggregating as water drains from the suspension to the ground through the edge walls of the excavation during its progress. This filter cake allows the bentonite suspension pressure to be maintained above the ground water pressure such that the excavation edge walls remain stable.

A.11 cutting back: removal of surplus concrete (protrusions, etc.) and bentonite cake when exposing the diaphragm wall panels.

A.12 trimming: removal of contaminated or substandard concrete or surplus concrete from the diaphragm wall head above the designed cut-off level.

A.13 capping beam: reinforced concrete beam built above the cut-off level to connect the cast-in situ diaphragm wall panels together and/or to connect to overlying structural elements.

A.14 air lift: pumping technique in which air is pumped into the base of a suction pipe to cause reduced density of material in the pipe and induce upward flow to evacuate solids and fluids (flushing). The air lift technique may be used to clean/replace the bentonite suspension before concreting.

InfoStandard Web 3.0.6-2520

A.15 pre-blasting: preliminary operation consisting in drilling holes along the alignment of a diaphragm wall to place explosives in very hard material and blast it before commencing the diaphragm wall excavation.

A.16 lean concrete: very low strength, concrete poured in a panel excavation to stop bentonite loss, to fill voids or to fill panel excavation deviation. The characteristics of the lean concrete should allow its re-excavation with normal tools.

A.17 concreting curve: diagram representing the volume of poured concrete versus depth.

A.18 excavation curve: diagram representing the excavation depth versus time.

A.19 desanding unit: plant to remove sand and silt in order to clean the support fluid during excavation and before concreting.

InfoStandard Web 3.0.6-2520

Annex B
(informative)

Control schedules during the execution

Table B.1 — Cast-in situ concrete diaphragm walls

NOTE The controls indicated in Table B.1 also apply to others structures covered by the standard when they are appropriate.

Issue	Parameter	Method and Testing	EN 1538 clauses	Frequency	Project documentation	D-Wall Report
1 – Setting out						
1.1	D-Wall Working platform Guide wall Excavations tools	Survey, geodetical instruments Position and level	8.2 – 8.3	Before casting of guide walls	Lay-out drawings Construction documentation	x
1.2	Joints	Survey, geodetical instruments Position and level (position of joints is to be marked on top of the guide walls)	7 – 8.2		Lay-out drawings Construction documentation	x
2 – Materials and products						
2.1	Bentonite, cement or other binders, additions	Control of delivery documents	6.1 – 6.2	Each delivery	Construction documentation	x
2.2	Fresh concrete (ready mixed)	Control of delivery documents	6.1 – 6.3	Each truck	Construction documentation	x
3 – Excavation						
3.1 – Water						
3.1.1	Water (usually not necessary for tap/ potable water)	Mixing of test suspension	6.1.6	First panel	Construction documentation	x
3.2 – Bentonite suspension (fresh, for re-use and before concreting)						
3.2.1	a) density b) Marsh value c) fluid loss d) pH-value e) sand contents f) filter cake	a) Mud balance or pyknometer b) Marsh-funnel c) Baroid filter press d) pH strips e) Sand content kit f) Baroid filter press	6.2 Tables 1 and 2	Sample from each new mix - sand content not applicable for fresh and re-use suspension - pH-value, Fluid loss and Filter cake not applicable before concreting	Construction documentation	x

continued

InfoStandard Web 3.0.6-2520

3.3 – Polymer solution (fresh, for re-use and before concreting)						
3.3.1	a) density b) Marsh value c) pH-value d) sand contents e) others	a) Mud balance b) Marsh-funnel c) pH strips d) Sand content kit e) as required	6.2 Tables 1 and 2	Sample from each new mix - sand content not applicable for fresh and re-use suspension - pH-value not applicable before concreting	Construction documentation	x
3.4 – Excavation execution						
3.4.1	Panel location	Overlap to previous panels	8.2	each panel at three different positions (two in single excavation cuts)	Construction documentation	x
3.4.2	Tools	Position (especially in the case of continuous excavation process)	8.2 – 8.4	Excavation, continuously	Construction documentation	x
3.4.3	Suspension level	Visual check (depth below top edge of the guide wall)	7.3 – 8.4	Excavation, continuously	Construction documentation	x
3.4.4	Ground profile	Visual inspection of excavated soil	8.4	Each panel, continuously	Soil invertigation report	x
3.4.5	Chiselling and blasting	Survey	8.4	Excavation, continuously	Construction documentation	x
3.4.6	Depth	Depth measurement (using a plummet)	7.3 – 8.2 – 9	Each panel at three different positions	Construction documentation	x
3.4.7	Verticality and twist	Monitoring of the crane cables Inclination measurement by means of electronical systems	8.2	Each panel	Construction documentation	x
3.4.8	Cleaning the excavation	Sounding of the base with plummet	8.5	Each panel	Construction documentation	x
3.4.9	Installation of stop-ends - location - verticality	Survey	8.5	Each element	Construction documentation	x
4 – Reinforcement cages						
4.1 – Delivery						
4.1	Delivery	Visual inspection Survey of vertical and horizontal length/ width Check with drawings	6.6 – 7.4 – 8.2	Each cage	Drawings	x

continued

InfoStandard Web 3.0.6-2520

4.2 – Installation						
4.2.1	Process - height / position - connections - lifting bars - suspension bars	Visual inspection - orientation - location and number of spacers - number of cable clasps for overlap - levelling and position - stiffness	8.7	Each cage	Construction documentation	x
4.2.2	Position after installation and after concreting	- elevation - verticality of the element - horizontal position	8.2 and 8.7	Each element	Construction documentation	x
5 – Concreting and trimming						
5.1 – Concrete (ready mixed)						
5.1.1	Consistence	Sampling for testing (on site) Flow table test F or slump test S (acc. to 〈A1〉 EN 206:2013 〈A1〉) Variation with time	〈A1〉 EN 206:2013, Table D.3 〈A1〉	Visual check: each truck Flow table test or Slump test: min 1 × per panel at beginning	Delivery documents	x
5.1.2	Strength	Sampling for testing (on site)	〈A1〉 6.3.7 〈A1〉	Three cylinders or cubes per day / per 300 m³ (per each concrete cast)	Delivery doc	x
5.2 – Concrete placement						
5.2.1	Immersion depth of tremie pipe(s)	Depth measurement	8.8	Each truck	Construction documentation	x
5.2.2	Placement times	Time keeping	8.8	Each truck		x
5.2.3	Quantity poured	Counting truck volumes	8.8	Each panel		x
5.2.4	Level of head of concrete after pour (rise)	Depth measurement (plumb bob) Concreting curve (example see annex C)	8.8	Each panel - after each truck - after each movement of tremie(s)	Construction documentation	x
5.2.5	Extracting stop-ends	Extraction procedure Extraction time	8.2 – 8.6	Each stop-end	Construction documentation	x
5.3 – Trimming						
5.3.1	Trimming	Concrete quality at cut-off level	8.8	Each panel	Construction documentations	x

Table B.1 (end)

InfoStandard Web 3.0.6-2520

Table B.2 — Specific controls for precast concrete diaphragm walls

NOTE The appropriate controls indicated in Table B.1 (e.g. the setting out controls) also apply.

Issue	Parameter	Method and Testing	EN 1538 clauses	Frequency	Project documentation	D-Wall Report
1 – Setting out (see also Table B.1)						
1.1	Precast element	Survey, geodetical instruments Position and level (position of elements is to be marked on top of the guide walls)	7 – 8.2		Lay-out drawings Construction documentation	
2 – Materials and products (see also Table B.1)						
2.1	Precast elements	Identification of delivered elements	7	Each element	Construction documentation	X
3 – Excavation (see also Table B.1)						
3.1 – Hardening slurry						
3.1.1	Fresh slurry a) density b) Marsh value c) shear strength/flow limit d) fluid loss e) setting time f) bleeding	a) mud balance b) Marsh-funnel c) ball harp d) Baroid filter press e) cyclic stirring f) cylinder at rest	6.2 – 6.5 – 8	Sample from supply container, according to specifications: - at least 1 × per shift/day - better 1 × per panel - sample to be cast in five cylinder specimen per shift/day for later testing	Construction documentation	x
3.1.2	Hardened slurry a) density b) compressive strength c) stiffness/deform. modulus d) permeability	a) weight/volume at 28 days age b) unconfined compressive load test c) oedometer/triaxial test d) triaxial seepage test, usually with tap water	6.2 – 6.5 – 8	a) Five cast cylinder specimen per shift/day: feeding pipe from the hydro mill to desander: b) 3 × per day (age 28 days) c) and d): 1 × per day (seepage beginning at age of 28 days)	Construction documentation	x
3.2 – Excavation execution (see Table B.1)						

continued

InfoStandard Web 3.0.6-2520

4 – Precast elements installation						
4.1 – Location (see Table B.1 – Excavation)						
4.2 – Installation (see also Table B.1 – Reinforcement)						
4.2.1	Process a) geometrie b) orientation c) position of water stops (if any)	a) to c) Visual check a) survey of vertical and horizontal length, width b) with respect to the face of the wall	8.7	Each element before installation	Construction documentation	x
4.2.2	Position after setting of bottom concrete (if any)	Check: - elevation - verticality of the element - horizontal position	8.2	Each element	Construction documentation	x
4.2.3	Removal time of suspending devices	Strength of hardening slurry (Unconfined compressive test): time dependent development of this strength		In case of doubt	Construction documentation: time keeping based on suitability test prior to works	

Table B.2 (end)

Table B.3 — Specific controls for execution of reinforced slurry walls

NOTE The appropriate controls indicated in Table B.1 (e.g. the setting out controls) and in Table B.2 (e.g. the hardening slurry controls) also apply.

Issue	Parameter	Method and Testing	EN 1538 clauses	Frequency	Project documentation	D-Wall Report
1 – Setting out (see Table B.1)						
2 – Materials and products (see also Table B.1)						
2.1	Reinforcement elements (Beams, bars or sheet piles)	Identification of delivered elements welding and coupling	6.6	Each element	Construction documentation	x
3 – Excavation (see Tables B.1 and B.2)						
3.1 – Hardening slurry (see Table B.2)						
3.2 – Excavation execution (see Table B.1)						
4 – Reinforcement elements installation (see Tables B.1 and B.2)						

Table B.3 (end)

InfoStandard Web 3.0.6-2520

Table B.4 — Specific controls for execution of slurry cut-off walls

NOTE The appropriate controls indicated in Table B.1 (e.g. the setting out controls) and in Table B.2 (e.g. the hardening slurry controls) also apply.

Issue	Parameter	Method and Testing	EN 1538 clauses	Frequency	Project documentation	D-Wall Report
1 – Setting out (see Table B.1)						
2 – Materials and products (see also Table B.1)						
2.1	"Watertight" elements (if any): sheet-piles, membranes	Identification of delivered elements	6.6 – 7	Each element	Construction documentation	x
3 – Excavation (see Tables B.1 and B.2)						
3.1 – Hardening slurry (see Table B.2)						
3.2 – Excavation execution (see Table B.1)						
3.3	Topping up	Add fresh slurry		Each panel	Construction documentation	x
4 – "Watertight" elements installation (see Tables B.1 and B.2)						

Table B.4 (end)

Table B.5 — Specific controls for execution of plastic concrete cut-off walls

NOTE The appropriate controls indicated in Table B.1 (e.g. the setting out controls) and in Table B.4 (e.g. the watertight element control, if any) also apply.

Issue	Parameter	Method and Testing	EN 1538 clauses	Frequency	Project documentation	D-Wall Report
1 – Setting out (see Table B.1)						
2 – Materials and products (see also Tables B.1 and B.4)						
2.1	Plastic concrete (ready mixed)	Control of delivery documents	6.1 – 6.4 – 8	Each truck or delivery	Construction documentation	x
3 – Excavation (see Tables B.1 and B.2)						
3.1 – Plastic concrete (see Table B.1 – Concreting and trimming)						
3.2 – Excavation execution (see Table B.1)						
4 – "Watertight" elements installation (see Tables B.1 and B.2)						

Table B.5 (end)

InfoStandard Web 3.0.6-2520

Annex C
(informative)

Sample concreting record forms for diaphragm walls

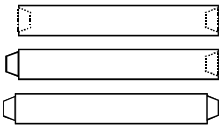
DIAPHRAGM WALL
Concreting record

Date _____
No _____

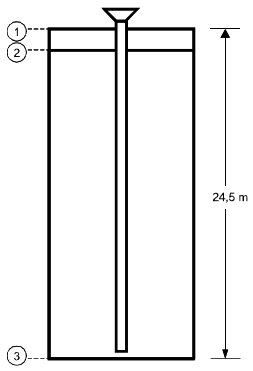
Department _____ **Site** _____

Panel No : _____ Drawing No : _____

Starter panel [X]
Intermediate [ ]
Closure panel [ ]



Excavation length : **4,50 m**



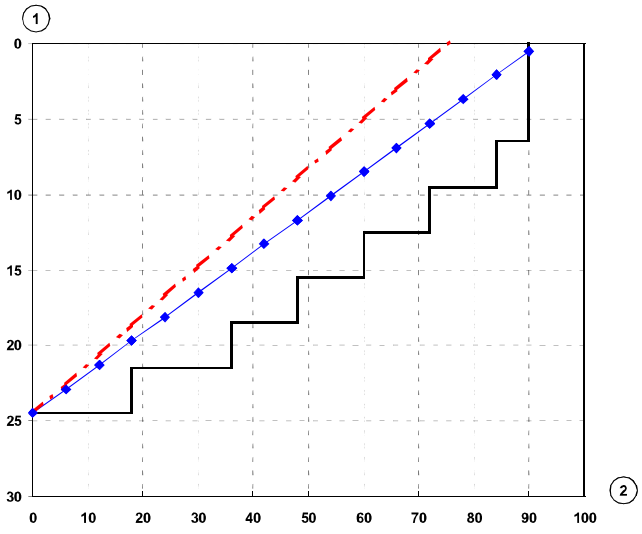
1 - Top of guide wall
+ 3,00 m
2 – Top of concrete :
+ 2,50 m

Width of panel :
0,80 m

Cross section stop end :
0,264 m2

3 – Bottom of panel :
- 21,5 m

No	Time	Concrete (m^3)	Top of concrete below guide wall (m) 1	2	3	Concr. rising	Tremie pipe Length (m) below guide wall	Immersion below guide wall
0	15:30	0,0	24,50	24,30	24,70		24,50	0,00
1	15:45	6,0	22,90	22,70	23,10	1,60	24,50	1,60
2	16:00	12,0	21,30	21,10	21,50	1,60	24,50	3,20
3	16:15	18,0	19,70	19,50	19,90	1,60	24,50	4,80
4	16:30	24,0	18,10	17,90	18,30	1,60	21,50	3,40
5	16:45	30,0	16,50	16,30	16,70	1,60	21,50	5,00
6	17:00	36,0	14,90	14,70	15,10	1,60	21,50	6,60
7	17:15	42,0	13,30	13,10	13,50	1,60	18,50	5,20
8	17:30	48,0	11,70	11,50	11,90	1,60	18,50	6,80
9	17:45	54,0	10,10	9,90	10,30	1,60	15,50	5,40
10	18:00	60,0	8,50	8,30	8,70	1,60	15,50	7,00
11	18:15	66,0	6,90	6,70	7,10	1,60	12,50	5,60
12	18:30	72,0	5,30	5,10	5,50	1,60	12,50	7,20
13	18:45	78,0	3,70	3,50	3,90	1,60	9,50	5,80
14	19:00	84,0	2,10	1,90	2,30	1,60	9,50	7,40
15	19:15	90,0	0,55	0,40	0,55	1,60	6,50	6,00
16								
17								
18								
19								
18								
19								
18								
19								
20								



time used for concreting :
3,45 h
rising of concrete :
6,5 m/h > 3,0 m/h
theorical volume
75,3 m3
Actual volume
90,0 m3
Over consumption
14,7 m3
16,4 %

Key
1 : depth below top of guide wall (m)
2 : concrete (m3)
theorical top of concrete
top of concrete
foot of tremie pipe

Annex D
(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.

1 Scope

(RQ)
NOTES 1 - 4

2 Normative references

(ST)
List

3 Definitions

(ST)
3.1 - 3.15

4 Information needed for the execution of the work

4.1 General

4.1.1 *(RQ)*
4.1.2 *(RC)*
4.1.3 *(RQ)*

4.2 Special features

4.2.1 *(RQ)*
4.2.2 *(RQ)*
4.2.3 *(RQ)*
4.2.4 *(RQ)*
NOTE

5 Geotechnical investigation

5.1 General

5.1.1 *(RQ)*
NOTES 1 - 3
5.1.2 *(RQ)*
5.1.3 *(RQ)*
5.1.4 *(RQ)*

5.2 Specific requirements

5.2.1 *(RQ)*
5.2.2 *(RQ)*
5.2.3 *(RQ)*
5.2.4 *(RQ)*
5.2.5 *(RQ)*
5.2.6 *(RQ)*

6 Materials and products

6.1 Constituents

6.1.1 General

6.1.1.1 *(RQ)*
6.1.1.2 *(RQ)*

6.1.2 Bentonite

6.1.2.1 *(RC)*
NOTES 1 - 2
6.1.2.2 *(RQ)*
6.1.2.3 *(RQ)*

6.1.3 Polymers

(PO)
NOTES 1 - 2

6.1.4 Cement

〚A1〛 6.1.4.1 *(ST)*
6.1.4.2 *(RC)*
NOTES 1 - 2 〚A1〛

6.1.5 Aggregates

(RQ)

6.1.6 Water

(RQ)

6.1.7 Additions

(RQ)

6.1.8 Admixtures

〚A1〛 *(RQ)* 〚A1〛

6.2 Support fluids

6.2.1 Bentonite suspensions

6.2.1.1 *(RQ)*
6.2.1.2 *(PE)*
6.2.1.3 *(RQ)*
NOTES 1 - 2
6.2.1.4 *(PE)*

6.2.2 Polymer solutions

6.2.2.1 *(PE)*
6.2.2.2 *(RQ)*
NOTE
6.2.2.3 *(RQ)*

6.2.3 Fresh hardening slurries

6.2.3.1 *(RQ)*
6.2.3.2 *(PE)*
6.2.3.3 *(PE)*
6.2.3.4 *(RQ)*

6.3 Concrete

6.3.1 General

6.3.1.1 *(RQ)*
6.3.1.2 *(RQ)*
6.3.1.3 *(RQ)*

InfoStandard Web 3.0.6-2520

6.3.2 Aggregates

A1 (RQ) A1

6.3.3 Cement contents

(RQ)

6.3.4 Water/cement ratio

6.3.4.1 (RQ)
6.3.4.2 (RQ)

6.3.5 Admixtures

A1 (RQ)
NOTES 1 - 3 A1

6.3.6 Fresh concrete

A1 (RQ) A1

A1 deleted text A1

A1

6.3.7 Sampling and testing on site

6.3.7.1(RQ)
NOTES 1 - 2
6.3.7.2 (RQ)
6.3.7.3 (RQ)
6.3.7.4 (PE)
6.3.7.5 (RQ)
NOTE
6.3.7.6 (RQ) A1

6.4 Plastic concrete

(RQ)
NOTES 1 - 4

6.5 Hardening slurry

6.5.1 (RQ)
NOTES 1 - 4
6.5.2 (RQ)

6.6 Reinforcement

6.6.1 (RQ)
6.6.2 (RQ)
6.6.3 (RQ)
NOTE
6.6.4 (RQ)
6.6.5 (RQ)
NOTE

6.7 Additional inserted products

6.7.1 (RQ)
6.7.2 (RQ)

7 Considerations related to design

7.1 General

7.1.1 (ST)
7.1.2 (RQ)
7.1.3 (RC)
NOTE
7.1.4 (RQ)
NOTES 1 - 2
7.1.5 (RQ)
7.1.6 (RQ)
7.1.7 (RQ)
7.1.8 (RQ)
7.1.9 (RC)
NOTE
7.1.10 (RQ)
7.1.11 (RC)

7.2 Panel stability

7.2.1 General considerations

7.2.1.1 (RQ)
7.2.1.2 (PO)
NOTE
7.2.1.3 (RQ)
NOTES 1 - 3

7.2.2 General principle of design

7.2.2.1 (RQ)
NOTE
7.2.2.2 (RQ)

7.2.3 Comparable experience

(RQ)
NOTE

7.2.4 Stability considerations

(RQ)
NOTES 1 - 2

7.2.5 Trial excavation

7.2.5.1 (RQ)
7.2.5.2 (PO)
7.2.5.3 (RQ)

7.3 Socketing into rock

7.3.1 (RQ)
7.3.2 (PO)

7.4 Precast concrete panels

7.4.1 (RQ)
7.4.2 (RQ)
7.4.3 (RQ)

7.5 Reinforcement cages

7.5.1 General considerations

7.5.1.1 (RQ)
7.5.1.2 (PE)

7.5.2 Design principles

7.5.2.1 (RQ)
7.5.2.2 (RQ)
7.5.2.3 (RQ)
7.5.2.4 (RQ)
7.5.2.5 (RQ)
7.5.2.6 (RQ)
7.5.2.7 (PE)

7.5.3 Vertical reinforcement

7.5.3.1 (RQ)
7.5.3.2 (RQ)
7.5.3.3 (PE)
7.5.3.4 (RQ)
7.5.3.5 (RQ)
7.5.3.6 (RC)

7.5.4 Horizontal reinforcement

7.5.4.1 (RQ)
NOTE
7.5.4.2 (RQ)
7.5.4.3 (PE)
NOTE
7.5.4.4 (RQ)
7.5.4.5 (RC)

7.5.5 Multiples cages and joints

7.5.5.1 (RQ)
7.5.5.2 (RC)
7.5.5.3 (RQ)
7.5.5.4 (RC)
7.5.5.5 (RC)
NOTE

7.6 Recesses and perforations

7.6.1 (RQ)
7.6.2 (RQ)
7.6.3 (RQ)
7.6.4 (RC)
NOTE

7.7 Minimum and nominal cover

7.7.1 (RQ)
7.7.2 (RQ)
NOTE
7.7.3 (RQ)
NOTE
7.7.4 (RQ)
7.7.5 (RQ)

InfoStandard Web 3.0.6-2520

NOTE
7.7.6 *(PE)*

8 Execution

8.1 Construction phases

8.1.1 *(ST)*
NOTE
8.1.2 *(ST)*
8.1.3 *(ST)*
8.1.4 *(ST)*
8.1.5 *(ST)*

8.2 Construction tolerances

8.2.1 Panel

(RQ)

8.2.2 Retaining walls

8.2.2.1 *(RQ)*
8.2.2.2 *(RQ)*
8.2.2.3 *(RQ)*
NOTES 1 - 2
8.2.2.4 *(RC)*
NOTE
8.2.2.5 *(RQ)*
NOTE
8.2.2.6 *(RQ)*

8.2.3 Cut-off walls

(PE)

8.2.4 Reinforcement cage

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

8.3 Preliminary works

8.3.1 Working platform

8.3.1.1 *(RQ)*
8.3.1.2 *(RQ)*
8.3.1.3 *(RQ)*
NOTES 1 - 2
8.3.1.4 *(RC)*
8.3.1.5 (RQ)
8.3.1.6 *(RQ)*

8.3.2 Guide-walls

8.3.2.1 *(RQ)*
NOTES 1 - 2
8.3.2.2 *(RQ)*
8.3.2.3 *(RC)*
8.3.2.4 *(RC)*
NOTE
8.3.2.5 *(RC)*
NOTE

8.4 Excavation

8.4.1 Supporting the walls of the excavation

8.4.1.1 *(RQ)*
NOTE
8.4.1.2 *(PE)*
8.4.1.3 *(RC)*
8.4.1.4 *(RQ)*
8.4.1.5 *(RQ)*

8.4.2 Excavation sequence

8.4.2.1 *(PE)*
NOTE
8.4.2.2 *(RQ)*
8.4.2.3 *(RQ)*

8.4.3 Loss of support fluid

8.4.3.1 *(RQ)*
8.4.3.2 *(RQ)*
8.4.3.3 *(RQ)*

8.5 Cleaning the excavation

8.5.1 *(RQ)*
8.5.2 *(RC)*
8.5.3 *(RQ)*
8.5.4 *(RQ)*
8.5.5 *(RQ)*

8.6 Forming the joints

8.6.1 *(RQ)*
NOTE
8.6.2 *(RQ)*
8.6.3 *(RQ)*
8.6.4 *(RQ)*
8.6.5 *(RQ)*

8.7 Placing the reinforcement or other elements

(RQ)
NOTES 1 - 2

8.8 Concreting and trimming

8.8.1 General

8.8.1.1 *(RQ)*
8.8.1.2 *(RQ)*
8.8.1.3 *(RQ)*
8.8.1.4 *(PE)*
8.8.1.5 *(RC)*
8.8.1.6 *(RQ)*
8.8.1.7 *(RQ)*
8.8.1.8 *(RQ)*
NOTE
8.8.1.9 *(RQ)*
8.8.1.10 *(RQ)*
8.8.1.11 *(RQ)*
8.8.1.12 *(RQ)*
NOTES 1 - 2
8.8.1.13 *(RQ)*
NOTE

8.8.2 Concreting in dry conditions

(PE)

8.8.3 Concreting under support fluid

8.8.3.1*(RQ)*
8.8.3.2*(RQ)*
NOTES 1 - 3
8.8.3.3 *(RQ)*
8.8.3.4 *(RQ)*
8.8.3.5 *(RC)*
8.8.3.6 *(RC)*
8.8.3.7 *(RQ)*
8.8.3.8 *(RQ)*
8.8.3.9 *(RQ)*
8.8.3.10 *(RQ)*
8.8.3.11 *(RQ)*
NOTES 1 - 2
8.8.3.12 *(RC)*
8.8.3.13 *(RC)*
NOTE

8.8.4 Loss of immersion of tremie pipe

8.8.4.1 *(RQ)*
8.8.4.2 *(RQ)*
8.8.4.3 *(PE)*
8.8.4.4 *(RC)*
NOTE

8.8.5 Trimming

8.8.5.1 *(RQ)*
8.8.5.2 *(RQ)*
NOTE
8.8.5.3 *(PE)*
8.8.5.4 *(RQ)*

9 Supervision, testing and monitoring

9.1 *(RQ)*
NOTES 1 - 3
9.2 *(RQ)*
NOTES 1 - 2
9.3 *(RQ)*
NOTES 1- 2

InfoStandard Web 3.0.6-2520

9.4 *(RQ)*
A1 9.5 *(PO)* A1
NOTE

10 Records

10.1 *(ST)*
10.2 *(ST)*

11 Specific Requirements

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

InfoStandard Web 3.0.6-2520

Bibliography

[1] EN 1536, *Execution of special geotechnical work — Bored piles*

[2] EN ISO 13500, *Petroleum and natural gas industries — Drilling fluid materials — Specifications and tests (ISO 13500:2008)*

InfoStandard Web 3.0.6-2520