BRITISH STANDARD

BS EN 1538:2000

Execution of special geotechnical works — Diaphragm walls

https://geotechnicaldesign.info/en1538-2000.html

The European Standard EN 1538:2000 has the status of a British Standard

ICS 93.020

National foreword

This British Standard is the official English language version of EN 1538:2000.

The UK participation in its preparation was entrusted to Technical Committee B/526, Geotechnics, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 50, an inside back cover and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

This British Standard, having been prepared under the direction of the Sector Committee for Building and Civil Engineering, was published under the authority of the Standards Committee and comes into effect on 15 May 2000

ISBN 0 580 34658 7

Amendments issued since publication

Amd. No.	Date	Comments

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1538

January 2000

ICS 93.020

English version

Execution of special geotechnical works – Diaphragm walls

Exécution de travaux géotechniques spéciaux – Parois moulées

Ausführung von besonderen geotechnischer Arbeiten (Spezialtiefbau) - Schiltzwände

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

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

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

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

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

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

Ref. No. EN 1538:2000 E

Contents

Foreword

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

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by July 2000, and conflicting national standards shall be withdrawn at the latest by July 2000.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

The general scope of TC 288 is the standardization of the execution procedures for geotechnical works, including testing and control methods, and of the required material properties. WG1 has been charged with the subject area of both retaining and cut-off diaphragm walls. The present standard excludes the execution of barrettes, which is covered by prEN 1536, Execution of Special Geotechnical Works: Bored Piles.

The document has been prepared to stand alongside ENV 1997, Eurocode 7 Part 1: Geotechnical Design, General Rules. Clause 8 of this standard covers design aspects of retaining structures and gives guidance on supervision. The present standard expands on design only where necessary (e.g. the detailing of reinforcement) but provides full coverage of the construction and supervision requirements.

This document has been drafted by a working group comprised of delegates from 10 countries and is based on the review of 7 national or international codes of practice.

1 Scope

This European Standard specifies the execution of diaphragm walls and the practical aspects which must be taken into account in the production of the working drawings. Diaphragm walls can be permanent or temporary structures. The following types are concerned:

a) retaining walls: usually made 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 diaphragm walls: usually made to prevent migration of groundwater, clear or polluted, or of other liquids present in the ground. They include:

   1) slurry walls (possibly with membranes or sheetpiles);

   2) plastic concrete walls.

The design, planning and execution of diaphragm walls call for experience and knowledge in this specialized field. The execution phase requires skilled and qualified personnel and this document cannot replace the know-how of specialist personnel and the expertise of experienced contractors.

2 Normative references

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

EN 10080, *Steel for the reinforcement of concrete, weldable ribbed reinforcing steel B500 — Technical delivery conditions for bars, coils and welded fabric.*

ENV 197, *Cement — Composition, specifications and conformity criteria.*

ENV 206:1990, *Concrete — Performance, production, placing and compliance criteria*.

ENV 1991, *Eurocode 1: Basis of Design and Actions on Structures.*

ENV 1992, *Eurocode 2: Design of Concrete Structures.*

ENV 1994, *Eurocode 4: Design of Composite Steel and Concrete Structures.*

ENV 1997, *Eurocode 7: Geotechnical Design*.

ENV 1998, *Eurocode 8: Earthquake Resistant Design of Structures*.

ISO 9690, *Production and control of concrete — Classification of environmental exposure conditions for concrete and reinforced concrete structures.*

3 Terms and definitions

For the purposes of this European Standard, 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 concrete or reinforced concrete, which is constructed in a trench excavated in the ground. The concrete is placed through concreting pipes, beneath the supporting fluid in the case of liquid-supported trenches or in some cases, in dry conditions

3.2
precast concrete diaphragm wall
fr: paroi préfabriquée en béton
de: Fertigteilschlitzwand
wall made of precast elements which are lowered into a trench containing a self-hardening slurry

3.3
reinforced slurry wall
fr: paroi moulée en coulis armé
de: Bewehrte Einphasenschlitzwand
wall made from a self-hardening slurry reinforced by steel beams, steel mesh or other suitable means

3.4
slurry wall
fr: paroi moulée en coulis
de: Einphasenschlitzwand
wall made from a self-hardening slurry. In most cases, the excavation is carried out using a self-hardening slurry as the supporting fluid. Sealing elements such as membranes or sheetpiles may be inserted

3.5
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. The concrete is placed beneath the supporting fluid using concreting pipes in liquid-supported trenches, or in some cases, in dry conditions

3.6
panel
fr: panneau
de: Schlitzwandelement
section of a diaphragm wall which is concreted as a single unit. A diaphragm panel may be linear, T-shaped, L-shaped, or of other configuration

3.7
guide-walls
fr: murettes-guides
de: Leitwände
small, parallel temporary walls which are used to provide a guide for the excavating tool and to secure the sides of the trench against collapse in the vicinity of the fluctuating level of the supporting fluid

3.8
concreting pipe
fr: tube plongeur
de: Betonierrohr
pipe used for placing concrete beneath the supporting fluid, to avoid contamination and segregation

3.9
supporting fluid
fr: fluide d'excavation
de: Stützende Flüssigkeit
fluid used during excavation to support the sides of the trench. It is usually a bentonite suspension, a polymer solution or a self-hardening slurry

3.10
self-hardening slurry
fr: coulis autodurcissant
de: Selbsterhärtende Suspension
slurry which hardens with time. 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, and admixtures

3.11
plastic concrete
fr: béton plastique
de:Tonbeton
a low strength, high plasticity concrete. Here, high plasticity means the ability to sustain larger strains than normal concrete. It is usually made with a low cement content, containing bentonite and/or other clay materials. It may also include other materials such as PFA and admixtures

4 Information required for the execution of the work

The following information is required for the production of the working drawings and the execution of the work:

- site topography;
- previous use of site;
- geotechnical information and data as specified in clause 5;
- information on the adjacent roads and structures, in particular the type of foundation and precautions necessary to ensure their stability;
- location, type and condition of services (gas, electricity, sewers,...);
- presence of obstructions in the ground (old masonry,...);
- presence of archeological remains;
- presence of polluted ground;
- working restrictions if any (vibrations, noise, headroom, working area,...);
- all necessary information for the production of the working drawings;
- any specific requirements for the diaphragm wall, in particular those pertaining to tolerances, quality of materials, watertightness, and type of joints;
- environmental requirements;
- when available, previous experience with diaphragm walls or underground works on or adjacent to the site.

For cut-off walls, permeability, strength and deformation properties of the wall material, together with testing methods, shall be specified.

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.

Continuity of reinforcement between the cages and across the joints is not normally required, but may be specified in exceptional circumstances.

5 Site investigation

5.1 General

Site investigations for the design and execution of diaphragm walls shall be made according to the general rules given in ENV 1997.

All information from the site investigation shall be made available in accordance with the requirements of clause 4.

5.2 Specific aspects

Particular attention shall be paid to the following aspects, which are relevant to the execution of diaphragm walls:

- piezometric levels of all water-tables and permeability of the soils;
- presence of coarse, highly permeable soils or cavities (natural or artificial), which may cause sudden losses of supporting fluid and instability of the trench, and thus may require special measures;
- presence, strength and deformation characteristics of soft soils, such as very soft clay or peat, which may cause difficulties during excavation (deformation or instability);
- presence of boulders or obstructions which may cause difficulties during excavation and, when possible, an assessment of their size and frequency;
- presence, position, strength and hardness of rock or other hard materials which may cause difficulties during excavation and may require the use of special tools;
- detrimental chemistry of groundwater, soil and rock, and water temperatures if required (see ISO 9690);
- detrimental chemistry of waste materials (see ISO 9690);
- presence of pretreated soil, which may have an adverse effect during excavation.

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 may occur during construction of the diaphragm wall. Particular attention shall be paid to artesian conditions.

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.

The grain-size distribution of cohesionless soils shall be determined.

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. The properties of the rock, including the degree of weathering and the extent of fissuring, shall also be determined.

6 Materials

6.1 General

Unless otherwise stated in this European Standard, the materials used shall comply with other relevant European Standards.

6.2 Constituents

Bentonite is used in supporting fluids, either as a bentonite suspension or as an addition to polymers. It is also used as a constituent part of self-hardening slurries.

Bentonite is a clay containing mainly the mineral montmorillonite or similar minerals. 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.

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

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

The type of cement to be used shall take into account the aggressiveness of the soil and groundwater. Cement for concrete shall comply with 4.1 of ENV 206.

6.3 Supporting fluids

This subclause covers only bentonite suspensions, polymer solutions and self-hardening slurries.

6.3.1 Bentonite suspensions

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

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

A self-hardening slurry may be prepared with calcium bentonite or natural or activated sodium bentonite.

Under normal circumstances, the bentonite suspension shall meet the conditions shown in Table 1.

The values in Table 1 may be modified in special circumstances, for example in the case of:

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

— high piezometric levels (artesian conditions);

— very soft soils;

— salt water conditions.

Table 1 — Characteristics for bentonite suspensions

Property	Stages		
	Fresh	Ready for re-use	Before concreting
Density in g/ml	< 1,10	< 1,25	< 1,15
Marsh value in s	32 to 50	32 to 60	32 to 50
Fluid loss in ml	< 30	< 50	n.a.
pH	7 to 11	7 to 12	n.a.
Sand content in %	n.a.	n.a.	< 4
Filter cake in mm	< 3	< 6	n.a.
n.a.: not applicable			

At the stage “before concreting”, an upper limit value between 4 % and 6 % for sand content may be used in special cases (e.g. non-load bearing walls, unreinforced walls).

In order to keep the sand particles in suspension and to reduce penetration into the ground, it is necessary to have a bentonite suspension with sufficient gel strength.

When deemed to be necessary, the gel strength can be checked by using rotational viscometers or other suitable equipment.

The Marsh value, the fluid loss, the sand content and the filter cake can be measured, for example, using the tests described in the American Petroleum Institute document *Recommended Practice Standard Procedure for Field Testing Water-Based Drilling Fluids* (reference: American Petroleum Institute Recommended Practice 13B-1, June 1, 1990).

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 values given in Table 1 shall be adjusted.

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.

NOTE Sand content is the percentage by volume, and not by weight, of particles larger than 74 µm, which is the mesh size of the sand content set.

6.3.2 Polymer solutions

Polymer solutions, possibly with the addition of bentonite, may be used as supporting fluids on the basis of previous experience in similar or worse geotechnical conditions, or after full-scale trial trenches on the site. A reasonable extrapolation of previous experience may be made with the support of laboratory tests and theoretical analysis.

6.4 Self-hardening slurries

Self-hardening slurries are generally used in the precast concrete diaphragm wall technique, for reinforced slurry walls and slurry cut-off walls. They serve as the supporting fluid during excavation, and, together with the fines from the natural ground, form the final, hardened material. The characteristics of the slurry must be suitable to ensure satisfactory performance during execution. Admixtures may have to be used to adjust workability during excavation and the insertion of elements, as well as setting time, taking into account the possible effects of temperature and chemical components of the soil and groundwater. The characteristics of the hardened material, as needed for the particular applications (e.g. permeability, strength and deformation properties), together with testing methods, must be specified to satisfy the functional requirements of the wall.

6.5 Concrete

6.5.1 General

Unless otherwise stated, the concrete used in cast in situ concrete diaphragm walls or in precast concrete diaphragm walls shall comply with ENV 206.

The following subclauses of this section apply to cast in situ concrete and deal only with the properties required for correct execution. The concrete shall be designed to avoid segregation during placing, to flow easily around the reinforcement, and when set, to provide a dense and watertight material. The specified properties of the hardened concrete, related to strength and durability, shall be compatible with the workability requirements.

6.5.2 Aggregates

In order to avoid segregation, the aggregates shall be well-graded. The maximum particle size shall not exceed 32 mm or 1/4 of the clear space between the longitudinal bars, whichever is the smaller.

In the case of a maximum aggregate size of 32 mm, the concrete mix shall have the following characteristics:

— sand content greater than 40 % by weight of the total aggregate;

— silt size particles in the concrete mix (including cement and other fine materials) between 400 kg/m^3 and 550 kg/m^3. These particles are those between 2 μm and 63 μm and they include cement and other fine materials.

6.5.3 Cement

The minimum cement content shall be related to the maximum aggregate size in accordance with Table 2 .

Part of the cement can be replaced by additions such as pulverized fuel ash (PFA) or ground granulated blast furnace slag (GGBFS).

Table 2 — Minimum cement content

Maximum grain size (mm)	**Minimum cement content** (kg/m^3)
32	350
25	370
20	385
16	400

6.5.4 Water/cement ratio

The water/cement ratio should not exceed 0,6.

This value may have to be modified if additions are included in the mix.

6.5.5 Admixtures

In order to ensure that the concrete has the properties required for placing by concreting pipes, admixtures may be used as follows:

— water reducing and plasticizing admixtures including superplasticizers to avoid bleeding or segregation which might occur in some situations;

— retarding admixtures to prolong the workability as required for the duration of the concreting process and to cater for any interruptions.

6.5.6 Fresh concrete

The consistency of the fresh concrete just before concreting shall correspond to a slump value between 160 mm and 220 mm. A value between 180 mm and 210 mm is recommended.

The flow table test may be used instead of the slump test. In this case, the consistency of the fresh concrete just before placing shall correspond to a flow value between 520 mm and 630 mm. A value between 550 mm and 600 mm is recommended.

6.6 Plastic concrete or plastic mortar

Plastic concretes or mortars are used for cut-off walls when, in addition to low permeability, high deformability is required. Their constituent parts are:

- clay or bentonite;
- cement or another binder;
- well-graded aggregates;
- additives;
- water;
- and possibly additions and admixtures.

The term “plastic mortar” applies when the size of the aggregates is limited to that of sand. The mix shall be designed in order to obtain the required deformability and permeability, together with adequate workability and strength.

Typical compositions for plastic concrete and plastic mortar using bentonite are given in annex A.

6.7 Steel

The reinforcement steel used in diaphragm walls shall comply with EN 10080. Unless special precautions are taken, other metallic elements used in cast in situ diaphragm walls, such as tubes, plates, connectors, etc., shall not be made of galvanized steel or other metals which may produce electrostatic effects resulting in a buildup of bentonite cake or may cause electrochemical corrosion of the reinforcement.

7 Design considerations

7.1 General

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

Design shall take into account tolerances given in 8.2.

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

The design wall thickness is equal to the width of the excavating tool. A larger wall thickness may be taken into account provided it is justified by site measurements.

The panels shall be designed as vertical elements, normally with the same horizontal cross-section throughout their depth. In some cases, the horizontal cross-section may be reduced below a certain depth.

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. Sufficient 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.

A reinforced concrete capping beam is usually constructed along the top of reinforced concrete diaphragm walls, where it is necessary to distribute loads or minimize differential displacements. In rare cases where it is necessary to provide structural continuity across the joints, special techniques are available.

7.2 Panel stability during excavation

The length of the panels shall be such as to ensure the stability of the trench during excavation.

The trench stability during excavation includes two aspects:

- the stability of the soil grains at the walls of the trench;
- the overall stability of the excavation.

The trench remains stable as a result of the stabilizing forces of the supporting fluid acting against the walls of the trench. In the case of bentonitic suspensions, the supporting effect in fine-grained soils is due to the formation of a filter cake. In coarser soils, this effect is caused by stagnation of the bentonitic suspension after a limited penetration into the pores of the soil. In the case of polymer solutions, the supporting 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.

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

- the properties of the supporting fluid;
- the level of the supporting 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).

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

The stability of the trench shall be determined on the basis of comparable experience, stability calculations, or trial excavation(s) on site. When the comparable experience is considered to be insufficient, the second or third option shall be adopted.

Comparable experience is defined as experience which relates to similar works in similar conditions. In particular, the following items shall be considered in the comparison:

- soil and rock properties;
- groundwater pressures;
- adjacent structures;
- construction methods.

This experience shall be well documented or otherwise clearly established. Experience gained locally is considered to be particularly relevant.

The stability calculations shall take account of the following factors:

- stabilizing forces due to the supporting fluid;
- groundwater pressures;
- earth pressures, including the three-dimensional geometry of the problem;
- shear strength parameters of the soils;
- effects of adjacent loads.

In the case of trial excavation(s), an adequate safety margin shall be allowed in the design of the diaphragm wall trench.

The level of the supporting fluid shall be adjusted with respect to the highest piezometric level anticipated during excavation, and shall always remain at least 1 m above the highest piezometric level.

In the case of very soft soils, it may be necessary to raise the level of the supporting fluid and/or to increase its density during excavation, and to minimize the time during which the trench is left open.

In the case of highly permeable, coarse soils or where there are voids in the ground, loss of supporting fluid may occur and, as a consequence, special measures should be adopted, for example:

- increasing the shear strength 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.

7.3 Socketting into rock

Where diaphragm walls are required to be socketted 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;
- 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.

The design may need to 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 Reinforcement cages

7.4.1 General

This subclause applies to reinforcement cages inserted into cast in situ concrete diaphragm walls, where reinforcement is required by the design.

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

The design of the reinforcement cage(s) shall be made in accordance with ENV 1992. 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. It shall also allow the fresh concrete to flow easily around each of its components.

The vertical length of a reinforcement cage shall be such that the distance between its base and the bottom of the excavation is at least 0,2 m.

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,...;
- vertical tubes for grouting, dowel bars, control tests, etc.

In the case of welding, only electric welding is permitted, provided that the steel quality is suitable.

Tack welding is permitted for all types of steel for assembly purposes, provided that the mechanical properties of the bars are not affected.

7.4.2 Vertical reinforcement

The minimum diameter of the bars shall be 12 mm and there shall be a minimum of 3 bars per meter on each side of the cage.

The horizontal clear space between single bars or groups of bars, parallel to the wall face, shall be at least 100 mm. This figure can be reduced to 80 mm for the lap length or in the case of heavily reinforced panels, provided the maximum size of the aggregates does not exceed 20 mm.

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. When overlapping is used, slippage during handling shall be prevented by tack welding or other suitable means.

7.4.3 Horizontal reinforcement

The horizontal reinforcement shall be arranged in such a way as to prevent movement of the vertical bars and to provide adequate space for the concreting pipe(s).

The vertical clear space between bars shall be at least 200 mm. This figure can be reduced to 150 mm provided the maximum size of the aggregates does not exceed 20 mm.

The horizontal clear space between transverse bars shall be at least 150 mm. A minimum spacing of 200 mm is recommended to ensure free flow of concrete.

7.4.4 Multiple cages and joints

The minimum clear distance between two cages in the same panel shall be 200 mm.

The minimum clear distance between the ends of the cages and panel joints shall be 100 mm and shall take into account the verticality tolerances, the shape of the joints and the possible use of water stops. In the case of curved joints, the cage shall not enter into the concave portion of the joint. This does not apply to the case of diaphragm walls with continuous horizontal reinforcement across the joints.

7.5 Recesses and perforations

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

Recesses and perforations shall be of limited size and shaped in such a way as to minimize interference with the free flow of the concrete.

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

It is recommended that the recesses do not extend behind the first layers of reinforcement.

Normally perforations for anchors are formed with a tube not exceeding 300 mm in diameter, in order to facilitate the free flow of the concrete. Special precautions may be necessary when perforations greater than 300 mm in diameter are required.

7.6 Concrete cover

The design concrete cover is defined as the distance between the outside of the reinforcement cage and the design position of the face of the panel.

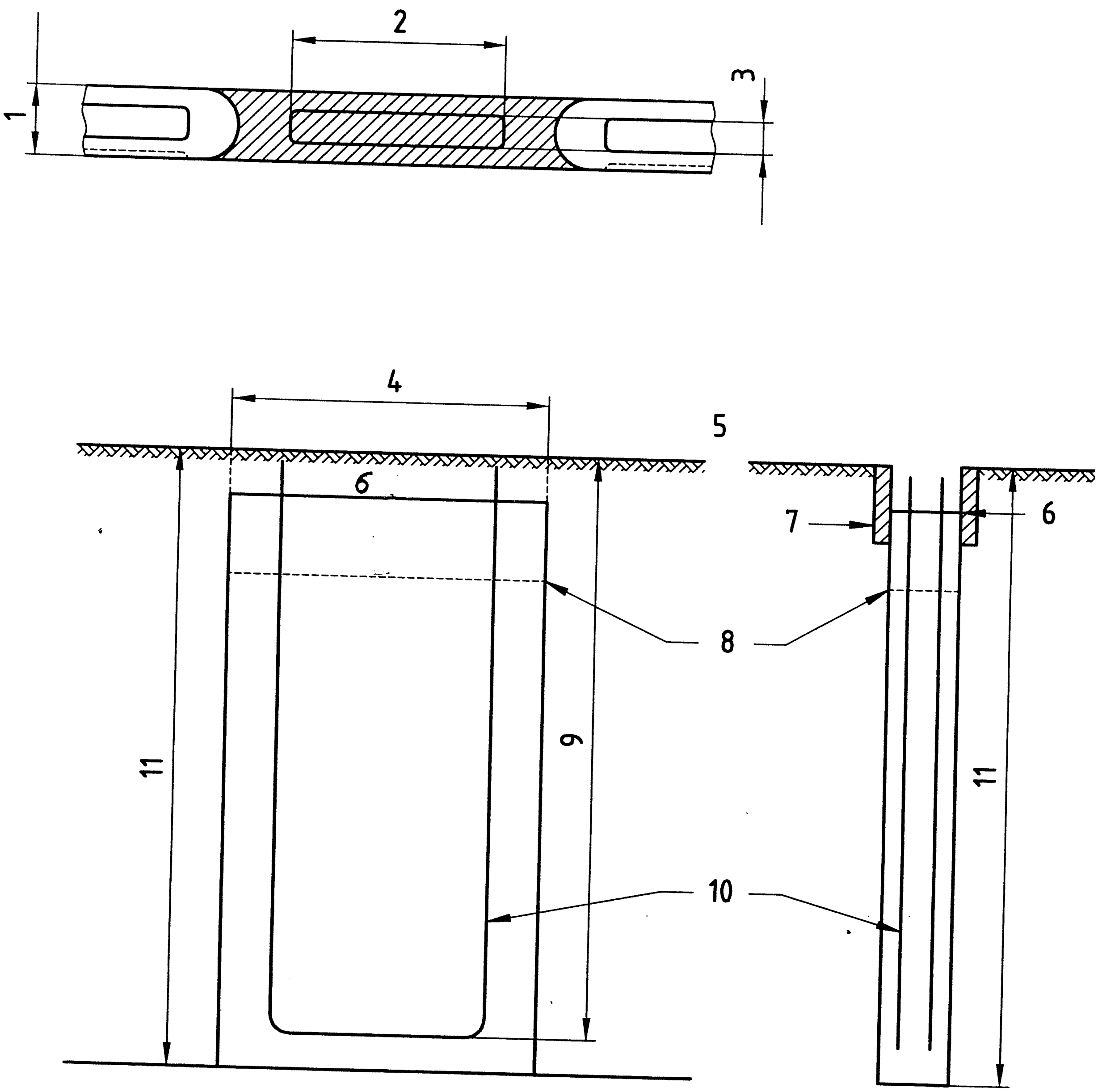
In order to ensure that the concrete flows freely and that the physical concrete cover complies with ENV 1992, the design cover shall be at least 75 mm.

Except in the case of very soft soils, this value can be decreased to 60 mm in the case of non-aggressive ground or temporary walls.

Spacers shall be provided to ensure that the correct concrete cover is maintained.

The spacers can be either vertical tubes, or individual units (pads, rollers,...). The size of the individual units shall be adapted to the ground conditions.

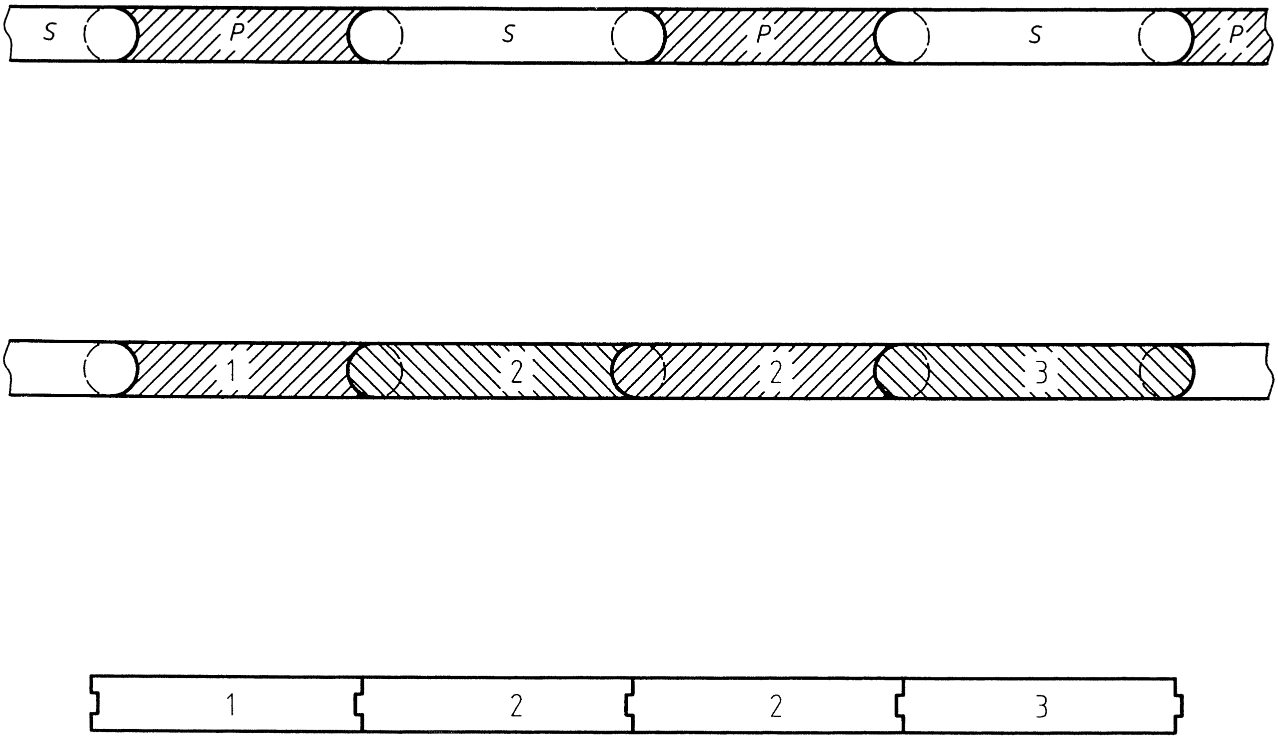
For permanent structures, spacers shall be made of a non-metallic material, which is at least equivalent to concrete with respect to durability, unless they are removed during concreting.



Key

1 Wall thickness
2 Horizontal length of reinforcement cage
3 Cage width
4 Length of panel
5 Platform level
6 Casting level
7 Guide-wall
8 Cut off level
9 Vertical length of reinforcement cage
10 Reinforcement cage
11 Depth of excavation

Figure 1 — Geometry of a panel



Key

P Primary
S Secondary
1 Starter
2 Intermediate
3 Closure

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

8 Execution

8.1 General

The phases of execution differ with the type of wall and the type of supporting fluid used. In the general case where a supporting fluid is used, the basic sequences are:

— for cast in situ concrete diaphragm walls:

1) excavation, generally with a bentonite suspension;

2) cleaning the excavation;

3) placing the reinforcement;

4) concreting;

5) trimming;

— for precast concrete diaphragm walls:

1) excavation, generally with a self-hardening slurry, sometimes with a bentonite suspension;

2) cleaning the excavation. When a bentonite suspension is used, it is replaced by a self-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;

3) placing the precast panel.

— for cut-off slurry walls:

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

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

3) trimming and protective capping.

— for plastic concrete walls:

1) excavation, generally with a bentonite suspension;

2) cleaning the excavation;

3) concreting;

4) trimming.

8.2 Tolerances

8.2.1 Panel

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

For retaining walls, horizontal deviations of the exposed face of a panel, at the top of the guide-walls, shall be less than 20 mm towards the main excavation and 50 mm away from the main excavation for cast in situ panels, and less than 10 mm in either direction for precast panels.

For cut-off walls, the deviation of the location of the wall measured with respect to its axis can be larger than for retaining walls and will depend on the project.

For retaining walls, verticality of the panels (including their ends) shall be within 1 % in both transverse and longitudinal directions.

Where boulders or other obstructions are present in the ground, this tolerance may have to be increased.

When the joint between panels is formed by cutting into the hardened material of the previously cast adjacent panel, it shall be checked that the hardened material is cut over an adequate horizontal distance. The minimum horizontal distance depends on the ground type, the depth, the type of material and the cutting tool.

Protrusions at the exposed face of cast in situ panels should not exceed 100 mm beyond the plane of tolerance. Larger values may have to be allowed in cases where the maximum particle size in the ground exceeds 100 mm or where the ground is soft or loose.

The offset between two adjacent panels at their joint location shall not exceed limits which would have an adverse effect on the performance of the wall.

8.2.2 Reinforcement cage

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

The tolerance on the elevation of inserts (couplers, starter bars, inserts for anchors,...) after concreting shall be ±70 mm.

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

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

8.3 Preliminary works

8.3.1 Working platform

The working platform shall be stable, above the water table, horizontal and be suitable for traffic of heavy equipment and lorries. The area along the line of the wall shall be clear of underground obstructions.

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

In the case of a construction site on a slope, horizontal platforms shall be prepared.

Material used for the construction of the working platform or for backfilling excavations shall be of suitable quality and well compacted or stabilized.

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

The purpose of guide-walls is 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 supporting fluid, and to serve as a support for the reinforcement cages or prefabricated panels or other elements inserted in the excavation until the concrete or self-hardening slurry has hardened. They should also be suitable to support the reaction forces of stop end extractors when necessary.

In the case of cut-off walls excavated continuously with a backhoe, guide-walls may not be necessary, should ground conditions permit.

Guide-walls are usually made of reinforced concrete and constructed in situ, preferably cast against the ground, with a depth normally between 0,7 m and 1,5 m depending on ground conditions.

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.

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

The distance between the guide-walls should normally be between 20 mm and 50 mm greater than the design thickness of the diaphragm wall. In the case of polygonal or irregular shaped walls, it may be necessary to increase the distance between the guide-walls.

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

8.4.1 Supporting the sides of the excavation

A supporting fluid is usually used during excavation. In some cases, it may be possible to excavate using water as a supporting fluid or in dry conditions.

Dry excavation may be used in some soils with cohesive properties or in rock, provided their strength is sufficient to ensure stability of the sides of the trench. In soils where no comparable experience is available, a trial excavation should be made.

During excavation, the level of the supporting fluid will fluctuate, but it shall not be allowed to fall below the level required for excavation stability. In addition, the level of the supporting fluid shall remain above the base of the guide-walls, unless there is no risk of caving of the soil below the guide-walls.

8.4.2 Excavating sequence

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

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

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

8.4.3 Loss of supporting fluid

When a sudden and significant loss of the supporting fluid occurs during excavation, the excavation shall be refilled immediately with an additional volume of supporting fluid, possibly containing sealing materials. If this procedure is impossible or insufficient, the excavation shall be backfilled as quickly as possible with lean concrete or other material which can be excavated later.

In situations where significant loss of supporting fluid may occur (e.g. highly permeable soils, cavities), an additional volume of supporting fluid, and possibly sealing materials, shall be kept available.

8.5 Cleaning the excavation

Cleaning is necessary when a supporting fluid has to be replaced by concrete or another material. The bottom of the excavation and the surface of the joints shall be cleaned and, if necessary, the supporting fluid shall be desanded or replaced. In the case of a bentonite suspension, the properties specified in Table 1, for the phase “before concreting”, shall be obtained. Where elements such as stop ends or reinforcement cages are to be inserted, cleaning shall be carried out before insertion. The cleaning procedure, as well as the time between operations, shall be established on the first few panels.

8.6 Forming the joints

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.

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

In the case of stop ends which are extracted vertically, the extraction shall be made gradually during the setting of the concrete or other material. The detailed procedure for forming the joints shall be established during construction of the first panels of each type. In the case of stop ends which are extracted laterally, the extraction shall be made upon completion of the excavation of the adjacent panel.

8.7 Placing the reinforcement or other elements

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

8.8 Concreting and trimming

In dry excavations, as permitted in 8.4.1, concreting shall be carried out in such a way as to avoid segregation. Direct pumping is permitted in dry excavations. Vibration of the concrete is not permitted when the slump value exceeds 100 mm (class S3, S4, or F3, F4, in ENV 206).

In excavations using supporting fluids, concrete shall be placed beneath the supporting fluid through one or more concreting pipes. Concreting pipes are usually tremie pipes, which are pipes equipped with a hopper at the top, but may also be pipes connected directly to concrete pumps.

The concreting pipe shall be clean and watertight. Its inner diameter shall be at least 0,15 m and 6 times the maximum aggregate size. Its outer diameter shall be such that it passes freely through the reinforcement cage.

The number of concreting pipes to be used in a panel shall be adjusted so as to limit the horizontal distance which the concrete has to travel from the concreting pipe.

In normal circumstances, it is recommended that the horizontal distance the concrete has to travel be less than 2,5 m.

It is recommended that at least one concreting pipe is used per reinforcement cage, where there is more than one cage per panel.

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

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

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

After concreting has started, the concreting pipe shall always remain immersed in the fresh concrete. It is recommended that the minimum immersion should be 3 m, but it can be reduced to 2 m when the level of concrete is accurately known. The immersion depth may have to be reduced when the concrete approaches ground level to facilitate concrete flow.

The average rate of concrete rising over the full height of the panel should not be less than 3 m/h.

When delays are anticipated which may 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.

Since the top of the cast concrete may not be of the required quality, sufficient concrete shall be placed in the panel to ensure that the concrete below the required cut-off level has the specified properties.

The required quality of the concrete at the cut-off level can be achieved by providing an additional height of concrete above the cut-off level, its value depending on the depth to the cut-off level, the wall dimensions and the number of concreting pipes. 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.

After concreting, empty excavations above the concrete level shall be backfilled with lean concrete or other suitable material. It may also be necessary in some circumstances to insert props between the guide-walls.

Trimming of the concrete to cut-off level shall be carried out using equipment which will not damage the concrete, reinforcement or any instrumentation installed in the panels. Final trimming to cut-off level shall only be carried out after the concrete has gained sufficient strength to avoid damage. Where possible, some preliminary trimming above cut-off level may be carried out before the concrete has set.

9 Supervision of execution and monitoring

The execution of any type of diaphragm wall requires careful supervision and monitoring of the work.

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

a) preliminary work prior to the excavation phase:

— position of the wall;

— materials;

— reinforcement cages and other elements to be inserted;

b) wall construction:

— excavation method, dimensions and alignment;

— cleaning the excavation;

— forming the joints;

— placing the reinforcements or other elements;

— concreting.

All items may not be applicable to each type of wall.

Tables 3 to 7 list the controls to be performed for the various types of diaphragm walls.

Control of the execution shall be in accordance with the project specifications.

Controls for special execution techniques, such as the use of polymers as a supporting fluid, are not considered in this clause.

Table 3 — Controls for cast in situ concrete diaphragm walls

Construction phase or item	**Control**	**Comments**
Setting-out	- Position of wall - Position and level of guide-walls - Position of panels and joints	- From lay-out drawings and fixed setting out points - Shall be checked before they are concreted and again after removal of the formwork - The position of the joints shall be marked on the guide-walls
Water	- Suitability for use	- Usually not required for potable water
Bentonite	- Source of supply	- Delivery documents shall be checked for each load
Fresh bentonite suspension	- Fluid loss, filter cake, pH - Density, Marsh value - Gel strength	- Shall be checked at the start of work, and as required thereafter - At least once per shift - To be carried out when deemed to be necessary
Concrete	- Composition, consistency and compressive strength	- Suitability tests according to ENV 206
Delivery of reinforcement cages	- Number, diameter and location of bars - Welds and couplings - Vertical and horizontal lengths, width - Spaces for concreting pipes - Location of formwork	Items to be checked for each cage with respect to the working drawings
Excavation	- Position of tool - Verticality and twist of excavation - Ground profile - Depth of excavation - Bentonite suspension level	- Visual observation - Shall be checked for each panel during and at the end of excavation [a] - Visual observation
Bentonite suspension to be placed in the excavation	- Fluid loss, filter cake, pH, density, Marsh value - Gel strength	- Shall be carried out at least once per panel or shift. See Table 1 (“fresh” or “ready for re-use” characteristics) [b] - To be carried out when deemed to be necessary
Cleaning	- Depth of excavation	- To be checked after cleaning at a minimum of three locations per panel or at specified spacing
Bentonite suspension before inserting reinforcement cage or other elements	- Density, Marsh value, sand content - Gel strength	- Shall be carried out for each panel. See Table 1 (“Before concreting” characteristics) and [c] - To be carried out when deemed to be necessary
Placing stop ends	- Alignment of stop end elements and composition - Verticality, position and depth	- To be checked before insertion - The stop end should be against the end of excavation

continued

Table 3 (continued)

Construction phase or item	**Control**	**Comments**
Lowering reinforcement cages	- Rigidity of cages	- To be checked during lifting for first cage of each type
	Prior to lowering - Reference number - Orientation with respect to the exposed face of the wall - Location and number of the spacers	To be checked for each cage
	During lowering - Position and verticality - Connections between vertical elements	To be checked for each cage, especially the length of laps
	End of lowering - Level and position	To be checked for each cage
Concreting	- Length of the concreting pipes, length and position of each individual element	- To be checked for each panel
	- Concrete delivery certificate	- To be checked for each load. Applies only to ready-mix concrete (in accordance with ENV 206)
	- Concrete appearance	- To be checked by visual observation
	- Concrete consistency	- To be checked at the beginning of each panel and when required (in accordance with ENV 206)
	- Concrete strength	- One sample shall be taken at least every 100 m^3 of concrete from one single source [d]
	- Method of starting concreting	- To be made for each panel according to 8.8. The first load through each concreting pipe shall be placed in its entirety, without interruption
	- Depth of concrete in relation to the volume of concrete poured	- To be checked after each concrete load or set of loads. The top of the concrete at each concreting pipe shall be kept at a uniform level. A corresponding graph should be established for panels of depth greater than 20 m, or when the consumption of concrete is significantly different from the theoretical volume
	- Position and level of the reinforcement cage.	- To be checked in accordance with the tolerances of 8.2.2
	- Concrete level before shortening the concreting pipe(s), number and length of pipe elements being removed, immersion of pipes	- To be checked each time pipes are removed
	- Time between mixing and start of pouring	- To be checked for each load
	- Duration of concreting	- To be recorded for each panel

continued

Table 3 (end)

Construction phase or item	Control	Comments
	- Concrete temperature - Final concrete level	- May be appropriate in the case of extreme weather conditions (see ENV 206) - To be checked for each panel
Extracting stop ends	- Application of the extraction procedure established on the first panels of each type	- Applies to all panels (see 8.6)
Trimming	- Level of cut-off and quality of concrete at cut-off level	- Quality of concrete to be checked for each panel by visual observation
Exposed face	- Protrusions	- To be checked by visual observation

a Verticality and twist of the excavation shall be controlled in order to remain within the required tolerances. The monitoring frequency shall be increased for cases presenting high risk, such as where boulders or obstructions are present in the ground, or where concrete from the adjacent panel is encountered. These controls shall normally be by visual observation or simple measurements (e.g. position of grab cables). Special measures (e.g. inclinometers) to determine the excavated profile may be necessary in some cases, e.g. in deep panels, T-panels or circular cofferdams.

b The control of the characteristics of the bentonite suspension should be more frequent in special cases such as in the presence of organic content in soils, or chemically active groundwater, or when the joint between panels is formed by cutting into the hardened concrete of the previously cast adjacent panel.

c The samples for determining the characteristics of the bentonite suspension before concreting shall be taken near the bottom of the panel. They can be taken either from the desanding circuit or by a sampling device, whichever is more convenient and appropriate to the technique used for excavation and mud replacement.

d Where the concrete is produced under a continuous and nationally certified quality assurance system, different requirements for concrete sampling on site may be agreed. The minimum number of cylinder or cube specimens in a sample is four.

Table 4 — Controls for precast concrete diaphragm walls

Construction phase or item	Control	Comments
Setting-out	- Position of wall	- From lay-out drawings and fixed setting out points
	- Position and level of guide-walls	- Shall be checked before they are concreted and again after removal of the formwork
	- Position of excavation units	- Shall be marked on the guide-walls, and when necessary, the amount of overlap shall be indicated
	- Position of elements	- Shall be marked on the guide-walls
Water	- Suitability for use	- Usually not required for potable water
Bentonite, cement or other binders, additions	- Source of supply	- Delivery documents shall be checked for each load
Self-hardening slurry	- Density, Marsh value	Items to be checked prior to the commencement of work
	- Setting time, bleeding	- Test methods to be specified
	- Compressive strength	- Unconfined compression test (at 28 days)
	- Permeability	- If required. Usually performed with tap water. In special cases, groundwater may need to be used
Delivery of precast elements	- Identification of elements	Items to be checked for each element
	- Geometry and aspect of elements and joints	with respect to the working drawings
Excavation	- Position of tool	- Visual observation
	- Verticality and continuity between excavation units or excavation sections, as appropriate	- Shall be checked for each excavation unit or excavation section, during and at the end of excavation [a]
	- Ground profile	
	- Depth of excavation	
	- Self-hardening slurry level	- Visual observation
	- Position of excavation sections, in the case of a continuous excavation process	- The position of the end of the excavation shall be checked after completion of each excavation section
Self-hardening slurry to be placed in the excavation	- Density, Marsh value, bleeding	- To be checked at least once per shift
Self-hardening slurry taken from excavation	- Setting time	- To be checked every day
	- Compressive strength	- Unconfined compression test (at 28 days). To be checked once per week
	- Ability of hardened slurry (or bottom mortar if any) to support precast element	- To be checked at the beginning of the work and thereafter, once per week

continued

Table 4 (end)

Construction phase or item	**Control**	**Comments**
Installation of precast elements	- Depth of excavation section - Identification of element - Position of water-stops (if any) - Position of suspension devices - Orientation with respect to the exposed face of the wall - Position and verticality of element during lowering - Position, level and verticality of element after installation - Position of the elements after setting of the slurry	- To be checked before insertion, at each element position Items to be checked for each element
Removal of suspension devices	- Time of removal in relation to the strength of the slurry (or bottom mortar if any)	- To be checked for each element
a Verticality and continuity of the excavation shall be controlled in order to remain within the required tolerances. The monitoring frequency shall be increased for cases presenting high risk, such as where boulders or obstructions are present in the ground. These controls shall normally be by visual observation or simple measurements (e.g. position of grab cables).		

Table 5 — Controls for reinforced slurry walls

Construction phase or item	Control	Comments
Setting-out	- Position of wall	- From lay-out drawings and fixed setting out points
	- Position and level of guide-walls (if any)	- Shall be checked before they are concreted and again after removal of the formwork
	- Position of excavation units	- Shall be marked on the guide-walls or on the ground, and when necessary the amount of overlap shall be indicated
	- Position of reinforcing elements	- Shall be marked on the guide-walls or on the ground
Water	- Suitability for use	- Usually not required for potable water
Bentonite, cement or other binders, additions	- Source of supply	- Delivery documents shall be checked for each load
Self-hardening slurry	- Density, Marsh value	Items to be checked prior to the commencement of work
	- Setting time, bleeding	- Test methods to be specified
	- Compressive strength	- Unconfined compression test (at 28 days)
	- Permeability	- If required. Usually performed with tap water. In special cases, groundwater may need to be used
Delivery of reinforcement	- Number, dimensions and location of beams or bars - Welds and couplings	Items to be checked with respect to the working drawings
Excavation	- Position of tool, overlap	- Visual observation
	- Verticality and continuity between excavation units or excavation sections, as appropriate	- Shall be checked for each excavation unit or excavation section, during and at the end of excavation [a]
	- Ground profile	
	- Depth of excavation	
	- Self-hardening slurry level	- Visual observation
	- Position of excavation sections, in the case of a continuous excavation process	- The position of the end of the excavation shall be checked after completion of each excavation section
Self-hardening slurry to be placed in the excavation	- Density, Marsh value, bleeding	- To be checked at least once per shift
Self-hardening slurry taken from excavation	- Setting time	- To be checked every day
	- Compressive strength	- Unconfined compression test (at 28 days), unless otherwise specified. Tests shall be performed on 2 samples taken at different depths. Frequency as specified

continued

Table 5 (end)

Construction phase or item	Control	Comments
Installation of reinforcement	- Depth of excavation section	- At specified spacing along the wall, before insertion
	- Rigidity of reinforcement	- To be checked during lifting of the first reinforcement unit of each type
	- Reference number	
	- Orientation with respect to the exposed face of the wall	
	- Position and verticality during lowering	
	- Connection between vertical elements during lowering	- Especially the length of laps
	- Final level and position	
Topping up	- Slurry level	- Add slurry if necessary
a Verticality and continuity of excavation shall be controlled in order to remain within the required tolerances. The monitoring frequency shall be increased for cases presenting high risk, such as where boulders or obstructions are present in the ground. These controls shall normally be by visual observation or simple measurements (e.g. position of grab cables). Special measures (e.g. inclinometers) to determine the excavated profile may be necessary in some cases, e.g. in deep panels.		

Table 6 — Controls for slurry cut-off walls

Construction phase or item	Control	Comments
Setting-out	- Position of wall	- From lay-out drawings and fixed setting out points
	- Position and level of guide-wall (if any)	- Shall be checked before they are concreted and again after removal of the formwork
	- Position of excavation units	- Shall be marked on the guide-walls or on the ground, and when necessary, the amount of overlap shall be indicated
Water	- Suitability for use	- Usually not required for potable water
Bentonite, cement or other binders, additions	- Source of supply	- Delivery documents shall be checked for each load
Self-hardening slurry	- Density, Marsh value	Items to be checked prior to the commencement of work
	- Setting time	- If required (deep walls, membranes, etc). Test method to be specified
	- Bleeding	- Test method to be specified
	- Gel strength	- When deemed to be necessary
	- Compressive strength	- Unconfined compression test (at 28 days), unless otherwise specified
	- Deformation modulus	- If specified
	- Permeability	- Usually performed with tap water on 28 day samples. In special cases, groundwater may need to be used. Periods greater than 28 days can be used depending on project requirements
Delivery of possible elements to be inserted (sheetpiles, membranes, etc)	- Items to be checked depend on type of element to be inserted	Items to be checked for each element with respect to the working drawings
Excavation	- Position of tool, and when necessary amount of overlap	- Visual observation
	- Verticality and continuity between excavation units or excavation sections, as appropriate	- Shall be checked for each excavation unit or excavation section, during and at the end of excavation [a]
	- Ground profile	
	- Depth of excavation	
	- Self-hardening slurry level	- Visual observation
	- Position of excavation sections, in the case of a continuous excavation process	- The position of the end of the excavation shall be checked after completion of each excavation section
Self-hardening slurry to be placed in the excavation	- Density, Marsh value, bleeding	- To be checked at least once per shift

continued

Table 6 (end)

Construction phase or item	**Control**	**Comments**	
Self-hardening slurry taken from excavation	- Setting time	- To be checked every day, if required (deep walls, membranes, etc.)	
	- Compressive strength - Deformation modulus - Permeability	- Unconfined compression test at 28 days, unless otherwise specified - If specified - If specified. Usually at an age of 28 days	Frequency as specified. Tests shall be performed on 2 samples taken at different depths
Inserting an element (if any)	- Depth of excavation section - Interlocking of elements	- At specified spacing along the wall, before insertion - At every lock, when applicable	
Topping up	- Slurry level	- Add slurry if necessary	
a Verticality and continuity of excavation shall be controlled in order to remain within the required tolerances. The monitoring frequency shall be increased for cases presenting high risk, such as where boulders or obstructions are present in the ground. These controls shall normally be by visual observation or simple measurements (e.g. position of grab cables). Special measures (e.g. inclinometers) to determine the excavated profile may be necessary in some cases, e.g. in deep panels.			

Table 7 — Controls for plastic concrete cut-off walls

Construction phase or item	Control	Comments
Setting-out	- Position of wall - Position and level of guide-walls - Position of panels and joints	- From lay-out drawings and fixed setting out points - Shall be checked before they are concreted and again after removal of the formwork - The position of the joints shall be marked on the guide-walls
Water	- Suitability for use	- Usually not required for potable water
Bentonite	- Source of supply	- Delivery document shall be checked for each load
Fresh bentonite suspension	- Fluid loss, filter cake, pH - Density, Marsh value - Gel strength	- Shall be checked at the start of work, and as required thereafter - At least once per shift - To be carried out when deemed to be necessary
Plastic concrete	- Composition, consistency and compressive strength - Deformation modulus	Suitability tests as specified, similar to those for concrete given in ENV 206
Excavation	- Position of tool, overlapping (in the case of no stop ends) - Verticality and twist of excavation - Ground profile - Depth of excavation - Bentonite suspension level	- Visual observation - Shall be checked for each panel during and at the end of excavation [a] - Visual observation
Bentonite suspension to be placed in the excavation	- Fluid loss, filter cake, pH, density, Marsh value - Gel strength	- Shall be carried out at least once per panel or shift. See Table 1 (“fresh” or “ready for re-use” characteristics) [b] - To be carried out when deemed to be necessary
Cleaning	- Depth of excavation	- To be checked after cleaning at a minimum of three locations per panel or at specified spacing
Bentonite suspension before concreting	- Density, Marsh value, sand content - Gel strength	- Shall be carried out for each panel. See Table 1 (“Before concreting” characteristics) [c] - To be carried out when deemed to be necessary
Placing stop ends (if any)	- Alignment of stop end elements and composition - Verticality, position and depth	- To be checked before insertion - The stop end should be against the end of excavation
Concreting	- Length of the concreting pipes, length and position of each individual element - Plastic concrete delivery certificate - Plastic concrete appearance - Plastic concrete consistency	- To be checked for each panel - To be checked for each load. Applies only to ready-mix plastic concrete - To be checked by visual observation - To be checked at the beginning of each panel and when required (according to ENV 206)

continued

Table 7 (end)

Construction phase or item	Control	Comments
	- Plastic concrete strength	- One sample shall be taken at least every 100 m^3 of concrete from one single source [d]
	- Method of starting concreting	- To be made for each panel according to 8.8. The first load through each concreting pipe shall be placed in its entirety, without interruption
	- Depth of concrete in relation to the volume of concrete poured	- To be checked after each concrete load or set of loads. The top of the concrete at each concreting pipe shall be kept at a uniform level. A corresponding graph should be established for panels of depth greater than 20 m, or when the consumption of concrete is significantly different from the theoretical volume
	- Concrete level before shortening the concreting pipe(s), number and length of pipe elements being removed, immersion of pipes	- To be checked each time pipes are removed
	- Time between mixing and the start of pouring	- To be checked for each load
	- Duration of concreting	- To be recorded for each panel
	- Plastic concrete temperature	- May be appropriate in the case of extreme weather conditions (see ENV 206)
	- Final plastic concrete level	- To be checked for each panel
Extracting stop ends (if any)	- Application of the extraction procedure established on the first panels of each type	- Applies to all panels (see 8.6)
Trimming (when required)	- Level of cut-off and quality of concrete at cut-off level	- Quality of concrete to be checked for each panel by visual observation

a Verticality and twist of the excavation shall be controlled in order to remain within the required tolerances. The monitoring frequency shall be increased for cases presenting high risk, such as where boulders or obstructions are present in the ground, or where concrete from the adjacent panel is encountered. These controls shall normally be by visual observation or simple measurements (e.g. position of grab cables). Special measures (e.g. inclinometers) to determine the excavated profile may be necessary in some cases, e.g. in deep panels.

b The control of the characteristics of the bentonite suspension should be more frequent in special cases such as in the presence of organic content in soils, or chemically active groundwater, or when the joint between panels is formed by cutting into the hardened plastic concrete of the previously cast adjacent panel.

c The samples for determining the characteristics of the bentonite suspension before concreting shall be taken near the bottom of the panel. They can be taken either from the desanding circuit or by a sampling device, whichever is more convenient and appropriate to the technique used for excavation and mud replacement.

d Where the concrete is produced under a continuous and nationally certified quality assurance system, different requirements for concrete sampling on site may be agreed. The minimum number of cylinder or cube specimens in a sample is four.

10 Site records

The site records consist of two sections, the first section giving the general references and general information pertaining to the concrete and supporting fluid. The second section gives detailed information on the execution of the wall.

The forms shown in annex B are examples of the general information and detailed information sheets for the various types of diaphragm walls.

11 Special requirements

Diaphragm walls shall be executed in compliance with the national standards, specifications and statutory requirements, pertaining to:

- health and safety of personnel;
- security of the site;
- safety of the work procedures;
- operational safety of construction equipment and tools;
- nuisance and/or environmental damage.

On site, particular attention shall be paid to:

- all processes requiring men to work alongside heavy equipment and heavy tools;
- the danger of open trenches;
- manual work procedures and inspections performed inside excavations.

Nuisance and/or environmental damage can be caused by:

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

Annex A
(informative)

Typical compositions for plastic concrete and plastic mortar

Typical compositions using bentonite, for one m^3, are as follows:

— plastic concrete:

water:	400 l to 500 l
cement or binder:	50 kg to 200 kg
aggregates:	1 200 kg to 1 500 kg
sodium bentonite:	12 kg to 30 kg
or	
calcium bentonite:	30 kg to 90 kg
or	
clay:	30 kg to 250 kg

— plastic mortar:

water:	400 l to 750 l
cement:	80 kg to 300 kg
sand:	500 kg to 1 000 kg
sodium bentonite:	20 kg to 50 kg
or	
calcium bentonite:	40 kg to 100 kg
or	
clay:	40 kg to 350 kg

Annex B
(informative)

Sample site record forms for diaphragm walls

Tables B.1 to B.11 present samples of the general and detailed information sheets for the various types of diaphragm walls:

— Tables B.1 and B.2 for cast in situ diaphragm walls;

— Tables B.3, B.4 and B.5 for precast concrete diaphragm walls;

— Tables B.6 and B.7 for reinforced slurry walls;

— Tables B.8 and B.9 for slurry cut-off walls;

— Tables B.10 and B.11 for plastic concrete cut-off walls.

Table B.1 — Example of general form for cast in situ diaphragm walls

<table>
<tr><th colspan="2">General information sheet for the execution of cast in situ diaphragm walls</th></tr>
<tr><td><u>Company name</u></td><td><u>Client</u></td></tr>
<tr><td colspan="2"><u>Site information</u>
Job No.:
Location:</td></tr>
<tr><td colspan="2"><u>Key drawings</u>   <u>Reference No.</u>   <u>Title</u></td></tr>
<tr><td><u>Concrete information</u>
<u>Origin:</u> Ready mix ☐
Mixed on site ☐
Ready mix plant
Concrete classification
<u>Composition</u> (mix for 1 m^3)
Cement (kg)
Water (kg)
Aggregates (kg)

Additions (kg)
Admixtures (kg)

Slump ☐
Flow table value ☐ (mm)
Compressive strength (28 days) (MPa)</td><td><u>Notes</u></td></tr>
<tr><td><u>Supporting fluid information</u>
(in the case of bentonite suspension)

<u>Characteristics</u> (specified range)
Fluid loss (30 min): (ml)
Filter cake: (mm)
pH:
Density: (g/ml)
Marsh value: (s)
Shear strength: (Pa)
(when required)</td><td><u>Notes</u></td></tr>
</table>

Table B.2 — Example of detailed form for cast in situ diaphragm walls

<table>
<tr><th colspan="3">Detailed information sheet for the execution of cast in situ diaphragm walls</th></tr>
<tr><td colspan="2">Panel information
Reference No.: Type:</td><td rowspan="9">Levels
Guide-wall
Working platform

Ground profile
(including water levels)</td></tr>
<tr><td>Excavation
Geometry (attach sketch if necessary)
Width: (m)
Length: (m) Depth: (m)</td><td>Date and time
Start: Date Time:
Finish: Date: Time:</td></tr>
<tr><td colspan="2">Equipment used</td></tr>
<tr><td>Obstructions Date/Time
Depth Start Finish</td><td>Loss of supporting fluid Time
Depth Volume Start Finish</td></tr>
<tr><td>Chiselling Time
Depth Start Finish</td><td>Delays Time
Depth Start Finish Reason(s)</td></tr>
<tr><td>Verticality and twist</td><td>Notes</td></tr>
<tr><td>Supporting fluid characteristics
Type
Parameters before concreting
Density
Marsh value
Sand content</td><td>Cleaning of excavation
Start: Date: Time:
Finish: Date: Time:

Depth of panel (at least 3 locations):
Location Depth</td></tr>
<tr><td>Reinforcement cage(s)
Identification No.

Drawing No.</td><td>Type

Placement: Date:
Time:</td></tr>
<tr><td colspan="2">Notes</td></tr>
<tr><td>Panel joints
Type</td><td colspan="2">Dimensions (if applicable)</td></tr>
<tr><td>Concreting
Date:

Time: Start: Finish:</td><td colspan="2">Volume (attach concreting curve if required)

Theoretical (m^3)
Actual (m^3)</td></tr>
<tr><td>Levels: Top of concrete (m)

Cut-off (m)</td><td colspan="2" rowspan="2">Concrete consistency tests
☐ Slump ☐ Flow table value</td></tr>
<tr><td>Interruptions Time
Depth Start Finish Reason(s)</td></tr>
<tr><td colspan="3">Additional notes</td></tr>
<tr><td>Signatures and comments

Contractor: Date: (signature)
Client: Date: (signature)</td><td colspan="2"></td></tr>
</table>

Table B.3 — Example of general form for precast concrete diaphragm walls

General information sheet for the execution of precast concrete diaphragm walls	
Company name	Client
Site information Job No.: Location:	
Key drawings Reference No.	Title
Concrete information Origin: Ready mix Mixed on site Ready mix plant Concrete classification Composition (mix for 1 m^3) Cement (kg) Water (kg) Aggregates (kg) Admixtures (kg) Additions (kg) Compressive strength (28 days) (MPa)	Notes
Supporting fluid information I. Bentonite suspension replaced by self-hardening slurry (complete information for cases A and B) II. Self-hardening slurry only (complete information for case B) Note: The “detailed information sheet” to be used depends on the execution technique (Option I or II)	
A. Bentonite suspension Characteristics (specified range) Fluid loss (30 min): (ml) Filter cake: (mm) pH: Density: (g/ml) Marsh value: (s) Shear strength: (Pa) (when required)	B. Self-hardening slurry Characteristics (specified range) Bleeding: (%) Compressive strength (at 28 days) (MPa) (other duration) (MPa) Marsh value: (s)

Table B.4 — Example of detailed form (Option I) for precast concrete diaphragm walls

<table>
<tr><td colspan="4">Detailed information sheet for the execution of precast concrete diaphragm walls
(Option I: Bentonite suspension replaced by self-hardening slurry)</td></tr>
<tr><td colspan="2">Element information
Reference No.: Type:</td><td rowspan="12">Levels
Guide-wall
Working platform
Ground profile
(including water levels)</td></tr>
<tr><td>Excavation
Geometry (attach sketch if necessary)
Width: (m)
Length: (m)
Depth: (m)
Length of trench beyond end of last element: (m)</td><td>Date and time
Start: Date: Time:
Finish: Date: Time:</td></tr>
<tr><td colspan="2">Equipment used</td></tr>
<tr><td>Obstructions Date/Time
Depth Start Finish</td><td>Loss of supporting fluid Time
Depth Volume Start Finish</td></tr>
<tr><td>Chiselling Time
Depth Start Finish</td><td>Delays Time
Depth Start Finish Reason(s)</td></tr>
<tr><td>Verticality and twist</td><td>Notes</td></tr>
<tr><td>Supporting fluid characteristics
Bentonite suspension
Type
Ready for reuse
Fluid loss
Filter cake
pH
Density
Marsh value
Shear strength
(when required)</td><td>Before substitution of self-hardening slurry
Density
Marsh value
Sand content

Self-hardening slurry
Type
After substitution
Density
Marsh value
Setting time</td></tr>
<tr><td>Bottom filling mortar (if any)</td><td>Cleaning of excavation
Start: Date: Time:
Finish: Date: Time:</td></tr>
<tr><td>Reinforcement cage(s) and joints
Identification No.:
Drawing No.:
Number of cages:
Number of joints:</td><td>Type of waterstop (if any)
Placement: Date:
Time:</td></tr>
<tr><td colspan="2">Notes</td></tr>
</table>

<table>
<tr><td>Precast element information
Identification No.</td><td>Dimensions
Length (m)
Width (m)
Thickness (m)</td></tr>
<tr><td>Concreting of element
Pour: Date: Time:
Form removal: Date: Time:
Date put in storage:</td><td>Volume (m^3)
Concrete strength (MPa)
(before storage)</td></tr>
<tr><td>Element installation
Date element lowered into trench:

Locations of element ends
Theoretical
Actual
Spaces between two adjacent elements</td><td>Levels
Guide wall (each end)
before installation
after installation

Top of each reference bar connected to element
(after installation)</td></tr>
<tr><td colspan="2">Additional notes</td></tr>
<tr><td>Signatures and comments

Contractor: Date: (signature)
Client: Date: (signature)</td><td></td></tr>
</table>

Table B.5 — Example of detailed form (Option II) for precast concrete diaphragm walls

<table>
<tr><td colspan="4">Detailed information sheet for the execution of precast concrete diaphragm walls
(Option II: Self-hardening slurry only)</td></tr>
<tr><td colspan="3">Element information
Reference No. Type:
:</td><td rowspan="10">Levels
Guide-wall

Working platform
Ground profile
(including water levels)</td></tr>
<tr><td>Excavation
Geometry (attach sketch if necessary)
Width: (m)
Length: (m)
Depth: (m)
Length of trench beyond end
of last element: (m)</td><td colspan="2">Date and time
Start: Date: Time:

Finish: Date: Time:</td></tr>
<tr><td colspan="3">Equipment used</td></tr>
<tr><td>Obstructions Date/Time
Depth Start Finish</td><td colspan="2">Loss of supporting fluid Time
Depth Volume Start Finish</td></tr>
<tr><td>Chiselling Time
Depth Start Finish</td><td colspan="2">Delays Time
Depth Start Finish Reason(s)</td></tr>
<tr><td>Verticality and twist</td><td colspan="2">Notes</td></tr>
<tr><td>Supporting fluid characteristics
Self-hardening slurry
Type
Fresh slurry
Density
Marsh value
Setting time
Bleeding</td><td colspan="2">Slurry taken from excavation
Density
Marsh value
Setting time
Bleeding

Bottom filling mortal (if any)</td></tr>
<tr><td>Reinforcement cage(s) and joints
Identification No.:
Drawing No.:
Number of cages:
Number of joints:</td><td colspan="2">Type of waterstop (if any)

Placement: Date:
Time:</td></tr>
<tr><td colspan="3">Notes</td></tr>
</table>

<table>
<tr><td>Precast element information
Identification No.</td><td>Dimensions
Length (m)
Width (m)
Thickness (m)</td></tr>
<tr><td>Concreting of element
Pour: Date: Time:

Form removal: Date: Time:

Date put in storage:</td><td>Volume (m^3)

Concrete strength (MPa)
(before storage)</td></tr>
<tr><td>Element installation
Date element lowered into trench:

Locations of element ends
Theoretical
Actual
Spaces between two adjacent elements</td><td>Levels
Guide wall (each end)
before installation
after installation

Top of each reference bar connected to element
(after installation)</td></tr>
<tr><td colspan="2">Additional notes</td></tr>
<tr><td>Signatures and comments

Contractor: Date: (signature)
Client: Date: (signature)</td><td></td></tr>
</table>

Table B.6 — Example of general form for reinforced slurry walls

General information sheet for the execution of reinforced slurry walls		
Company name		Client
Site information Job No.: Location:		
Key drawings	Reference No.	Title
Self-hardening slurry information Characteristics (specified range) Density: (g/ml) Marsh value: (s) Bleeding: (%) (when required) Setting time: (min) Compressive strength: (MPa) (at 28 days) Shear strength: (Pa) (when required)		Notes

Table B.7 — Example of detailed form for reinforced slurry walls

<table>
<tr><td colspan="3">Detailed information sheet for the execution of reinforced slurry walls</td></tr>
<tr><td colspan="2"><u>Excavation section information</u> Chainage: From:
Reference No.: Type: To:</td><td rowspan="8"><u>Levels</u>
Guide-wall
Working platform

<u>Ground profile</u>
(including water levels)</td></tr>
<tr><td><u>Excavation</u>
<u>Geometry</u> (attach sketch if necessary)
Width: (m)
Length/day: (m)
Depth: (m)
Amount of overlap (m)</td><td><u>Date and time</u>
Start: Date: Time:

Finish: Date: Time:</td></tr>
<tr><td colspan="2"><u>Equipment used</u></td></tr>
<tr><td><u>Obstructions</u> Date/Time
Chainage Depth Start Finish</td><td><u>Loss of supporting fluid</u> Time
Chainage Depth Volume Start Finish</td></tr>
<tr><td><u>Chiselling</u> Time
Chainage Depth Start Finish</td><td><u>Verticality and twist</u></td></tr>
<tr><td colspan="2"><u>Delays</u> Time
Chainage Depth Start Finish Reason(s)</td></tr>
<tr><td colspan="2"><u>Notes</u></td></tr>
<tr><td><u>Supporting fluid characteristics</u>
Type
<u>Fresh slurry</u>
Density
Marsh value
Setting time
Bleeding

<u>Samples taken</u>
No. Chainage Depth</td><td><u>Slurry taken from excavation</u>
Density
Marsh value
Setting time
Bleeding

<u>Samples taken</u>
No. Chainage Depth</td><td></td></tr>
<tr><td><u>Reinforcement</u>
<u>Identification No</u>.

<u>Drawing No</u>.</td><td><u>Type</u>

<u>Placement:</u> Date:
Time:</td><td rowspan="2"></td></tr>
<tr><td colspan="2"><u>Topping up</u>
Settlement of slurry (mm)
Volume of slurry added (m^3)</td></tr>
<tr><td colspan="3"><u>Additional notes</u></td></tr>
<tr><td colspan="2"><u>Signatures and comments</u>

Contractor: Date: (signature)
Client: Date: (signature)</td><td></td></tr>
</table>

Table B.8 — Example of general form for slurry cut-off walls

<table>
<tr><th colspan="3">General information sheet for the execution of slurry cut-off walls</th></tr>
<tr><td colspan="2"><u>Company name</u></td><td><u>Client</u></td></tr>
<tr><td colspan="3"><u>Site information</u>
Job No.:
Location:</td></tr>
<tr><td><u>Key drawings</u></td><td><u>Reference No.</u></td><td><u>Title</u></td></tr>
<tr><td colspan="2"><u>Self-hardening slurry information</u>

<u>Characteristics</u> (specified range)
Density: (g/ml)
Marsh value: (s)
Bleeding: (%)
(when required)

Setting time: (min)
Compressive strength: (MPa)
(at 28 days)

Deformation modulus: (MPa)
Permeability:
(28 days or as specified)

Shear strength: (Pa)
(when required)</td><td><u>Notes</u></td></tr>
</table>

Table B.9 — Example of detailed form for slurry cut-off walls

Detailed information sheet for the execution of slurry cut-off walls		
Excavation section information Reference No.: Chainage: Type: From: To:		Levels Guide-wall (if any) Working platform Ground profile (including water levels)
Excavation Geometry (attach sketch if necessary) Width: (m) Length/day: (m) Depth: (m) Amount of overlap (m)	Date and time Start: Date: Time: Finish: Date: Time:	
Equipment used		
Obstructions Date/Time Chainage Depth Start Finish	Loss of supporting fluid Time Chainage Depth Volume Start Finish	
Chiselling Time Chainage Depth Start Finish	Verticality and twist	
Delays Time Chainage Depth Start Finish Reason(s)		
Notes		
Supporting fluid characteristics Type Fresh slurry Density Marsh value Bleeding Setting time (where applicable) Samples taken No . Chainage Depth	Slurry taken from excavation Density Marsh value Bleeding Setting time (where applicable) Samples taken No. Chainage Depth	
Inserted elements (if any): Identification No.: Drawing No.	Type Placement: Date: Time:	
Topping up Settlement of slurry (m) Volume of slurry added (m^3)		
Additional notes		
Signatures and comments Contractor: Date: (signature) Client: Date: (signature)		

Table B.10 — Example of general form for plastic concrete cut-off walls

<table>
<tr><th colspan="2">General information sheet for the execution of plastic concrete cut-off walls</th></tr>
<tr><td><u>Company name</u></td><td><u>Client</u></td></tr>
<tr><td colspan="2"><u>Site information</u>
Job No.:
Location:</td></tr>
<tr><td colspan="2"><u>Key drawings</u>   <u>Reference No.</u>   <u>Title</u></td></tr>
<tr><td><u>Concrete information</u>

<u>Origin:</u> Ready mix □
Mixed on site □
Ready mix plant
Concrete classification

<u>Composition</u> (mix for 1 m³)
Clay material (kg)
Cement (kg)

Water (kg)
Aggregates (kg)

Additions (kg)
Admixtures (kg)

Slump □
Flow table value □ (mm)
Compressive strength (MPa)
Deformation modulus (MPa)</td><td><u>Notes</u></td></tr>
<tr><td><u>Supporting fluid information</u>
(in the case of bentonite suspension)

<u>Characteristics</u> (specified range)
Fluid loss (30 min):
(ml)
Filter cake: (mm)
pH:
Density: (g/ml)
Marsh value: (s)
Shear strength: (Pa)
(when required)</td><td><u>Notes</u></td></tr>
</table>

Table B.11 — Example of detailed form for plastic concrete cut-off walls

<table>
<tr><th colspan="4">Detailed information sheet for the execution of plastic concrete cut-off walls</th></tr>
<tr><td colspan="3">Panel
Reference No.: Type:</td><td>Levels
Guide-wall
Working platform</td></tr>
<tr><td>Excavation
Geometry (attach sketch if necessary)
Width: (m)
Length/day: (m)
Depth: (m)
Amount of overlap: (m)</td><td colspan="2">Date and time
Start: Date: Time:
Finish: Date: Time:</td><td rowspan="2">Ground profile
(including water levels)</td></tr>
<tr><td colspan="3">Equipment used</td></tr>
<tr><td>Obstructions Date/Time
Depth Start Finish</td><td colspan="2">Loss of supporting fluid Time
Depth Volume Start Finish</td><td></td></tr>
<tr><td>Chiselling Time
Depth Start Finish</td><td colspan="2">Delays Time
Depth Start Finish Reason(s)</td><td rowspan="2"></td></tr>
<tr><td>Verticality and twist</td><td colspan="2">Notes</td></tr>
<tr><td>Supporting fluid characteristics
Type
Parameters before concreting
Density
Marsh value
Sand content</td><td colspan="2">Cleaning of excavation
Start: Date: Time:
Finish: Date: Time:
Depth of panel (m)</td><td></td></tr>
<tr><td colspan="2">Concreting:
Date:
Time: Start: Finish:</td><td colspan="2">Volume (attach concreting curve if required)
Theoretical (m^3)
Actual (m^3)</td></tr>
<tr><td colspan="2">Levels Top of concrete (m)
Cut-off (m)</td><td colspan="2">Concrete consistency tests:
□ Slump □ Flow table value</td></tr>
<tr><td colspan="2">Interruptions Time
Depth Start Finish Reason(s)</td><td colspan="2"></td></tr>
<tr><td colspan="4">Additional notes</td></tr>
<tr><td colspan="2">Signatures and comments
Contractor: Date: (signature)
Client: Date: (signature)</td><td colspan="2"></td></tr>
</table>

Annex C
(informative)

Bibliography

Recommended Practice Standard Procedure for Field Testing Water-Based Drilling Fluids, (reference: American Petroleum Institute Recommended Practice 13B-1, June 1, 1990).

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: ST
2 Normative references: ST
3 Definitions
3.1 – 3.11: ST
4 Information required for the execution of the work
1st para: RQ
2nd para: RQ
3rd para: PO
4th para: PO
5 Site investigation
5.1 General: RQ
5.2 Specific aspects: RQ
6 Materials
6.1 General: RQ
6.2 Constituents
1st para: ST
2nd para: ST
3rd para: RQ
4th para: RQ
5th para: RQ
6.3 Supporting fluids
6.3.1 Bentonite suspensions
1st para: RQ
2nd para: PO
3rd para: PO
4th para: RQ
5th para: PE
6th para: PE
7th para: RQ
8th para: PO
9th para: PO
10th para: PO
11th para: PO
Note: ST
6.3.2 Polymer solutions: PO
6.3 Self-hardening slurries
1st sentence: ST
2nd sentence: ST
3rd sentence: RQ
4th sentence: PO
5th sentence: RQ
6.5 Concrete
6.5.1 General
1st para: RQ
2nd para: RQ
6.5.2 Aggregates
1st para: RQ
2nd para: RQ
6.5.3 Cement
1st para: RQ
2nd para: PE
6.5.4 Water/cement ratio
1st para: RC
2nd para: RC
6.5.5 Admixture: PE
6.5.6 Fresh concrete
1st sentence: RQ
2nd sentence: RC
3rd sentence: PO
4th sentence: RQ
5th sentence: RC
6.6 Plastic concrete or plastic mortar
1st para: ST
2nd para, 1st sentence: ST
2nd para, 2nd sentence: RQ
3rd para: PO
6.7 Steel: RQ
7 Design considerations
7.1 General
1st para: ST
2nd para: RQ
3rd para: RC
4th para, 1st sentence: RQ
4th para, 2nd sentence: PE
5th para, 1st sentence: RQ
5th para, 2nd sentence: PE
6th para: RQ
7th para: PO
7.2 Panel stability during excavation
1st para: RQ
2nd para: RQ
3rd para: ST
4th para: ST
5th para: ST
6th para: RQ
7th para: RQ
8th para: RQ
9th para: RQ
10th para: RQ
11th para: RQ
12th para: PO
13th para: PO
7.3 Socketting into rock
1st para: RQ
2nd para: PO
7.4 Reinforcement cages
7.4.1 General
1st para: ST
2nd para: PO
3rd para: RQ
4th para: RQ
5th para: RQ
6th para: RQ
7th para: PE
7.4.2 Vertical reinforcement
1st para: RQ
2nd para, 1st sentence: RQ
2nd para, 2nd sentence: PE
3rd sentence: RQ
7.4.3 Horizontal reinforcement
1st para: RQ
2nd para, 1st sentence: RQ
2nd para, 2nd sentence: PE
3rd para, 1st sentence: RQ
3nd para, 2nd sentence: RC
7.4.4 Multiple cages and joints
1st para: RQ
2nd para, 1st sentence: RQ
2nd para, 2nd sentence: RQ

2nd para, 3rd sentence: PO
7.5 Recesses and perforations
1st para: RQ
2nd para: RQ
3rd para: RQ
4th para: RC
5th para: RC
7.6 Concrete cover
1st para: ST
2nd para: RQ
3rd para: PE
4th para: RQ
5th para, 1st sentence: PO
5th para, 2nd sentence: RQ
6th para: RQ
8 Execution
8.1 General: ST
8.2 Tolerances
8.2.1 Panel excavation
1st para: RQ
2nd para: RQ
3rd para: PE
4th para: RQ
5th para: PE
6th para, 1st sentence: RQ
6th para, 2nd sentence: ST
7th para: RC
8th para: RQ
8.2.2 Reinforcement cage RQ
8.3 Preliminary works
8.3.1 Working platform
1st para: RQ
2nd para: RC
3rd para: RQ
4th para: RQ
5th para: RQ
8.3.2 Guide-walls
1st para: ST
2nd para: PE
3rd para: RC
4th para: RQ
5th para: RC
6th para: RC
7th para: RC
8.4 Excavating
8.4.1 Supporting the sides of the excavation
1st para: ST
2nd para, 1st sentence: PE
2nd para, 2nd sentence: RC
3rd para: RQ
8.4.2 Excavating sequence
1st para: ST
2nd para: RQ
3rd para: RQ
8.4.3 Loss of supporting fluid RQ
8.5 Cleaning the excavation RQ
8.6 Forming the joints
1st para: ST
8.7 Placing the reinforcement or other elements: RQ
8.8 Concreting and trimming
2nd para: RQ
3rd para: RQ
1st para, 1st sentence: RQ
1st para, 2nd sentence: PE
1st para, 3rd sentence: RQ
2nd para, 1st sentence: RQ
2nd para, 2nd sentence: PO
3rd para: RQ
4th para: RQ
5th para: RC
6th para: RC
7th para: RQ
8th para: RQ
9th para: RQ
10th para, 1st sentence: RQ
10th para, 2nd sentence: RC
10th para, 3rd sentence: RC
11th para: RC
12th para: PE
13th para: RQ
14th para: PO
15th para, 1st sentence: RQ
15th para, 2nd sentence: PO
16th para, 1st sentence: RQ
16th para, 2nd sentence: RQ
16th para, 3rd sentence: PE
9 Supervision of execution and monitoring
1st para: RQ
2nd para: RQ
3rd para: ST
4th para: RQ
5th para: RQ
6th para: ST
10 Site records
1st para: RQ
2nd para: PO
11 Special requirements
1st para: RQ
2nd para: RQ
3rd para: ST

Annex A (informative)
Annex B (informative)
Annex C (informative)

blank

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: 020 8996 9000. Fax: 020 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: 020 8996 9001. Fax: 020 8996 7001.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: 020 8996 7111. Fax: 020 8996 7048.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: 020 8996 7002. Fax: 020 8996 7001.

Copyright

BSI
389 Chiswick High Road
London
W4 4AL