

Execution of special geotechnical work — Sheet pile walls

ICS 93.020

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 55 and a back cover.

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 August 1999

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ISBN 0 580 32288 2

Amendments issued since publication

Amd. No.	Date	Comments

ICS 93.020

Descriptors: soils, construction, structures, sheet pilings, definitions, informations, wood, steels, welding, design, setting-up conditions, thrust boring, anchorages, tests, inspection

English version

Execution of special geotechnical work — Sheet pile walls

Exécution de travaux géotechniques spéciaux —
Rideaux de palplanches

Ausführung von besonderen geotechnischen
Arbeiten — (Spezialtiefbau) —
Spundwandkonstruktionen

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European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

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

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Foreword

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

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of an identical text or by endorsement, at the latest by August 1999, and conflicting national standards shall be withdrawn at the latest by August 1999.

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 present standard expands on design only when necessary, but provides full coverage of the execution and supervision requirements for sheet pile wall structures.

It has been drafted on the basis of existing Codes of Practice and general available expertise which can be found in specialized literature.

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1 Scope

This standard specifies requirements, recommendations and information concerning the execution of permanent or temporary sheet pile wall structures in accordance with 2.4 of ENV 1991-1:1994 and the handling of equipment and materials.

It does not give requirements and recommendations for the installation of specific parts of the structure such as ground anchorages and piles which are covered by other codes.

It applies only to steel sheet pile walls, combined walls and wooden sheet pile walls.

Composite structures such as Berliner walls and sheet pile walls in combination with shotcrete, are not the subject of this standard.

2 Normative references

This 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 standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 287-1:1992 + A1:1997, *Approval testing of welders — Fusion welding — Part 1: Steels.*

EN 288-2:1992 + A1:1997, *Specification and approval of welding procedures for metallic materials — Part 2: Welding procedures specification for arc welding.*

EN 288-3:1992 + A1:1997, *Specification and approval of welding procedures for metallic materials — Part 3: Welding procedure tests for the arc welding of steels.*

EN 499:1994, *Welding consumables — Covered electrodes for manual metal-arc welding of non-alloy and fine grain steels — Classification.*

EN 996:1995, *Piling equipment — Safety requirements.*

prEN 1537, *Execution of special geotechnical work — Ground anchors.*

ENV 1991-1:1994, *Eurocode 1: Basis of design and actions on structures — Part 1: Basis of design.*

ENV 1992-1-1:1994, *Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules and rules for buildings.*

ENV 1993-1-1:1994, *Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings.*

ENV 1993-5:1998, *Eurocode 3: Design of steel structures — Part 5: Piling.*

ENV 1997-1:1994, *Eurocode 7: Geotechnical design — Part 1: General rules.*

EN 10020:1988, *Definitions and classification of grades of steel.*

EN 10079:1992, *Definition of steel products.*

EN 10219-1:1997, *Cold formed structural welded hollow sections of non-alloy and fine grain steels — Part 1: Technical delivery requirements.*

EN 10219-2:1997, *Cold formed welded structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimensions and sectional properties.*

EN 10248-1:1995, *Hot rolled sheet piling of non-alloy steels — Part 1: Technical delivery conditions.*

EN 10248-2:1995, *Hot rolled sheet piling of non-alloy steels — Part 2: Tolerances on shape and dimensions.*

EN 10249-1:1995, *Cold formed sheet piling of non-alloy steels — Part 1: Technical delivery conditions.*

EN 10249-2:1995, *Cold formed sheet piling of non-alloy steels — Part 2: Tolerances on shape and dimensions.*

EN 24063:1992, *Welding, brazing, braze welding and soldering of metals — Nomenclature of processes and reference number for symbolic representation on drawings.*

(ISO 4063:1990)

EN 25817:1992, *Arc-welded joints in steel — Guidance on quality levels for imperfections.*

(ISO 5817:1992)

EN 29692:1994, *Metal-arc welding with covered electrode, gas-shielded metal-arc welding and gas welding — Joint preparations for steel.*

(ISO 9692:1992)

ISO 1106-1:1984, *Recommended practice for radiographic examination of fusion welded joints — Part 1: Fusion welded butt-joints in steel plates up to 50 mm thick.*

3 Definitions

For the purposes of this standard, the following definitions apply.

3.1

anchorage

anchoring system for the sheet pile wall, for example anchor plates or anchor walls including the connecting rods (tie rods), screw anchors, ground and rock anchors, driven ground anchors, anchoring piles and anchors with grouted or expanded bodies

3.2

auxiliary structures

all structures necessary for the proper and safe execution of the sheet piling works

3.3

bracing

a system of walings and struts to support the structure

3.4

combined wall

retaining wall composed of primary and secondary elements. The primary elements can be steel tubes, beams, or box piles. The secondary elements are normally U or Z-shaped steel sheet piles.

Figure 1 shows examples of combined walls

3.5

comparable experience

documented, or other clearly established information related to the ground and installation conditions, involving similar types of soil and rock and for which similar behaviour is expected. Information gained locally is considered to be particularly relevant

3.6

cushion

material, fitted into a recess in the driving cap, which smoothes the impact force of the falling hammer on the driving cap and on the head of the sheet pile (see Figure 2)

3.7

de-clutching

disconnection of the interlock during sheet pile driving

3.8

de-clutching detector

instrument for determining whether or not the interlocks of adjacent sheet piles are fully engaged during driving

3.9

driving cap

device, placed on the top of the sheet pile which transmits the blow of the hammer evenly, thereby preventing damage of the sheet pile head (see Figure 2)

3.10

driving

any method of installing the sheet piles to the required depth

3.11

driving method

method of driving such as panel driving, pitch and drive, staggered driving by means of impact, vibration pressing or by a combination of these

3.12

driving assistance

method to reduce the penetration resistance during driving, such as jetting or pre-augering

3.13

fish plate, splice plate

steel plate which joins two lengths of sheet pile together (see Figure B.2)

3.14

guide frame

frame consisting of one or more stiff guide beams, normally of steel or wood, to position and maintain the alignment of sheet piles during pitching and driving

3.15

hammer

part of piling equipment for driving sheet piles by percussion impact

3.16

leader

beam or similar, attached to the driving rig to lead the sheet pile and the hammer (or the vibrator) during driving (see Figures 2, 3 and 5)

3.17

leader slide

guiding device connecting the drive cap and/or the hammer to the leader (see Figures 2 and 3)

3.18

leading system

whole system to guide the sheet pile and the hammer (or the vibrator) during driving (see Figure 3)

3.19

rock dowel

rod protruding from the toe of the sheet pile, used for fixing sheet piles to the bed-rock (see Figure 13)

3.20

screw anchor

rod with a screw blade at the end, which is rotated into the natural ground behind the sheet piles to provide an anchorage

3.21

shackle

device for lifting sheet piles from the ground and placing them in the vertical position (see Figure A.7)

3.22

sheet pile

individual element of a sheet pile wall (single, double or multiple sheet pile)

3.23

sheet pile wall

screen of sheet piles which forms a continuous wall. For steel sheet piles continuity is provided by interlocking of the joints, fitting of longitudinal grooves or by means of special connectors and for timber sheet piles, by tongue and groove

3.24

sheet pile wall structure

structure, consisting of sheet piles, soil and rock, anchorages, bracings and walings, which retains ground and water. The elements are shown in Figure 4

3.25

site inspection

inspection of the construction site and its surroundings

3.26

site investigation

geotechnical investigations on and near the construction site

3.27

slippage

relative longitudinal displacement between the interlocks of adjacent sheet piles

3.28

strut

long compression member, usually of steel, wood or reinforced concrete, for the support of the sheet pile walls and normally connected to the walings

3.29

template

specific type of guide frame, used for positioning curved or angled sheet pile walls. They often incorporate a working platform or access staging for piling operatives

3.30

threader

device fixed to the toe of a sheet pile in order to guide the sheet pile into the interlock of a sheet pile already placed in the guide frame (see Figure A.8)

3.31

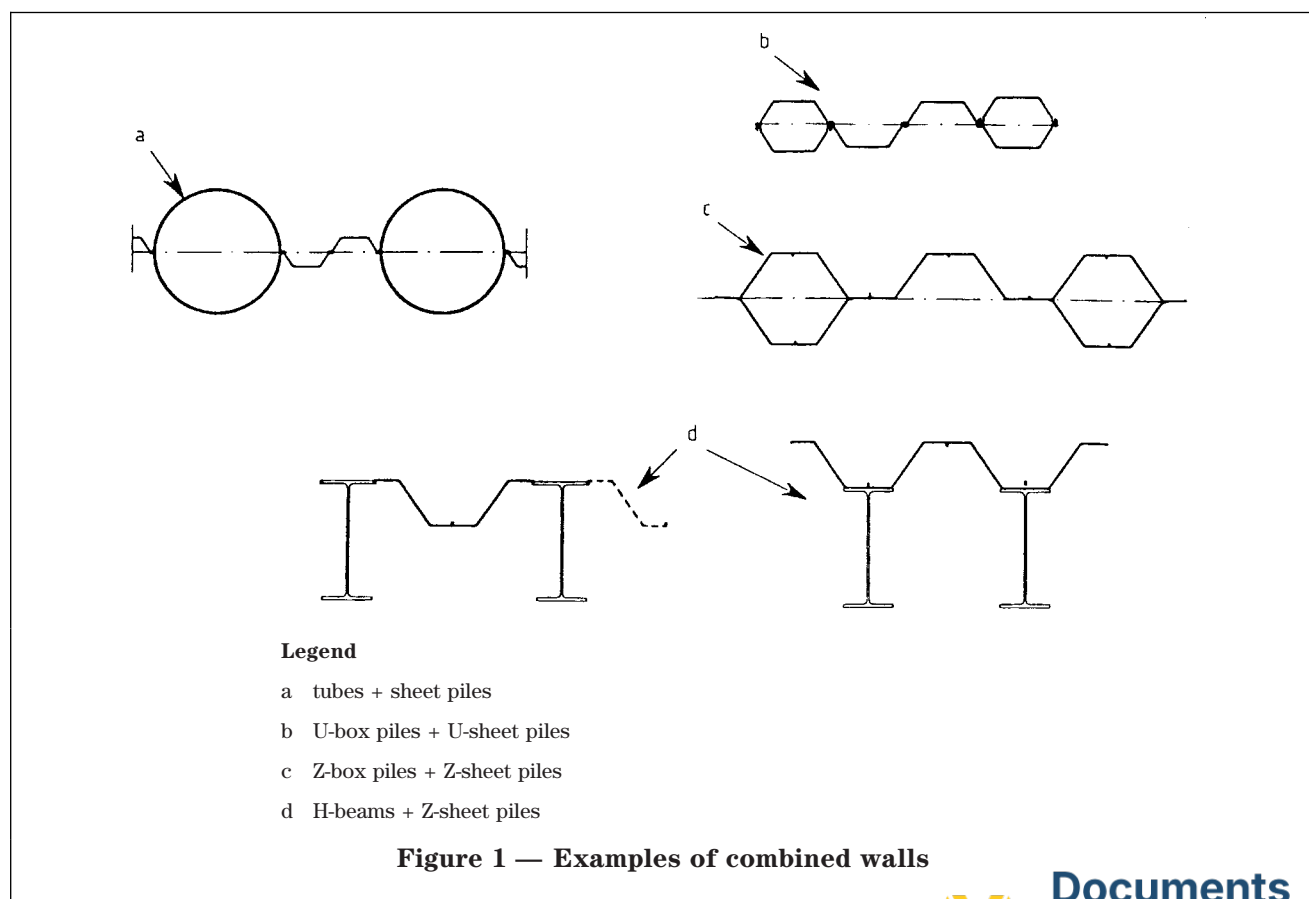
vibrator

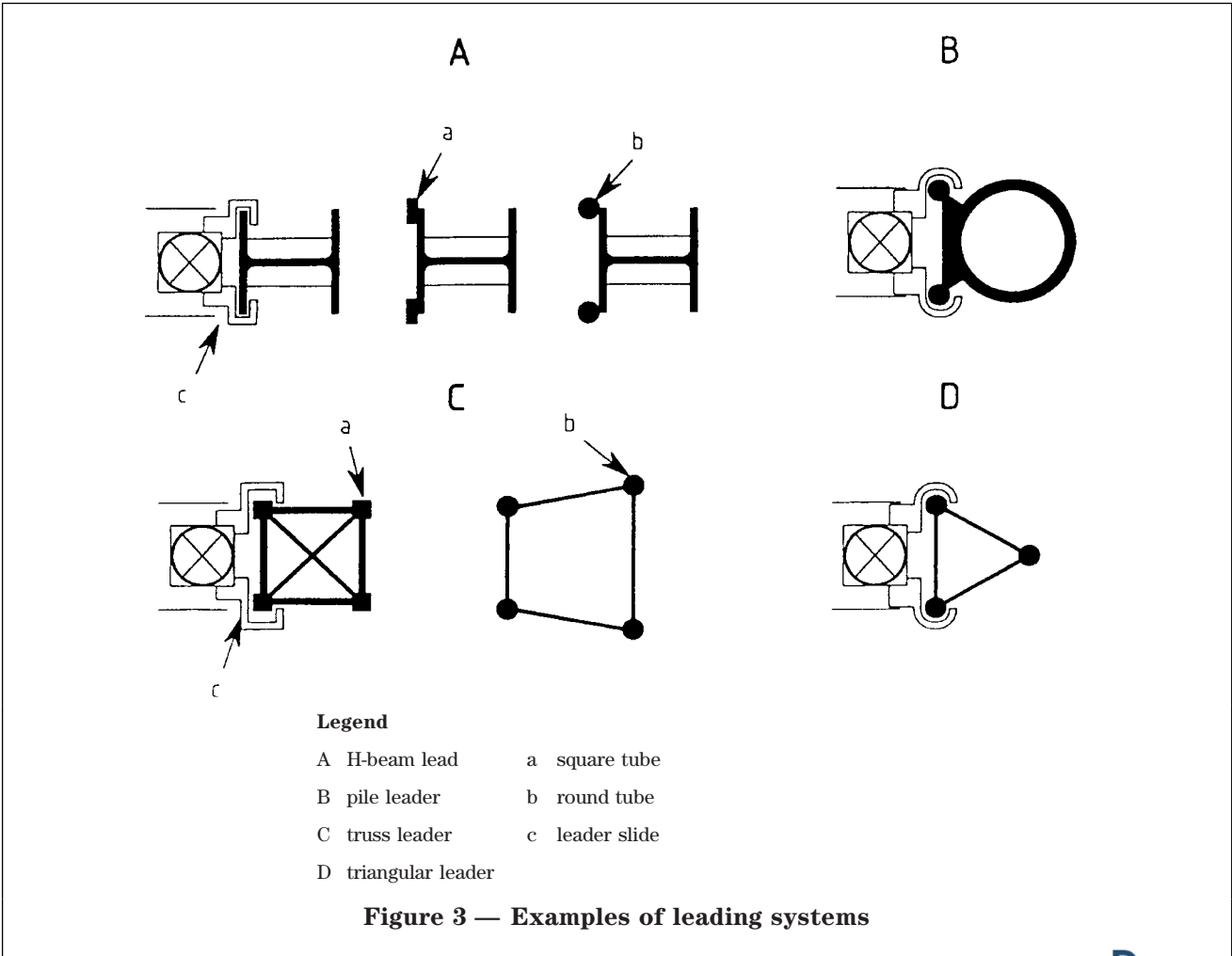
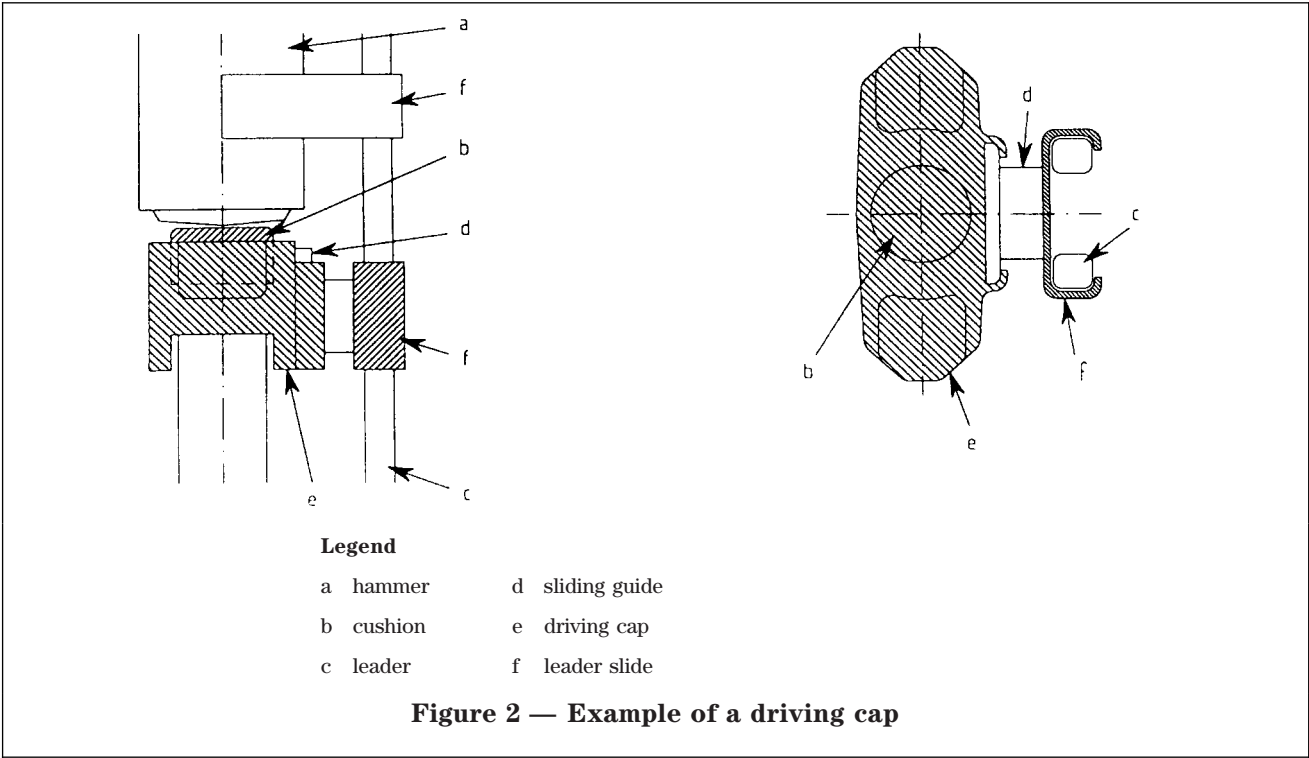
vibrating unit for the driving and extraction of the sheet piles and the primary and secondary elements of a combined wall

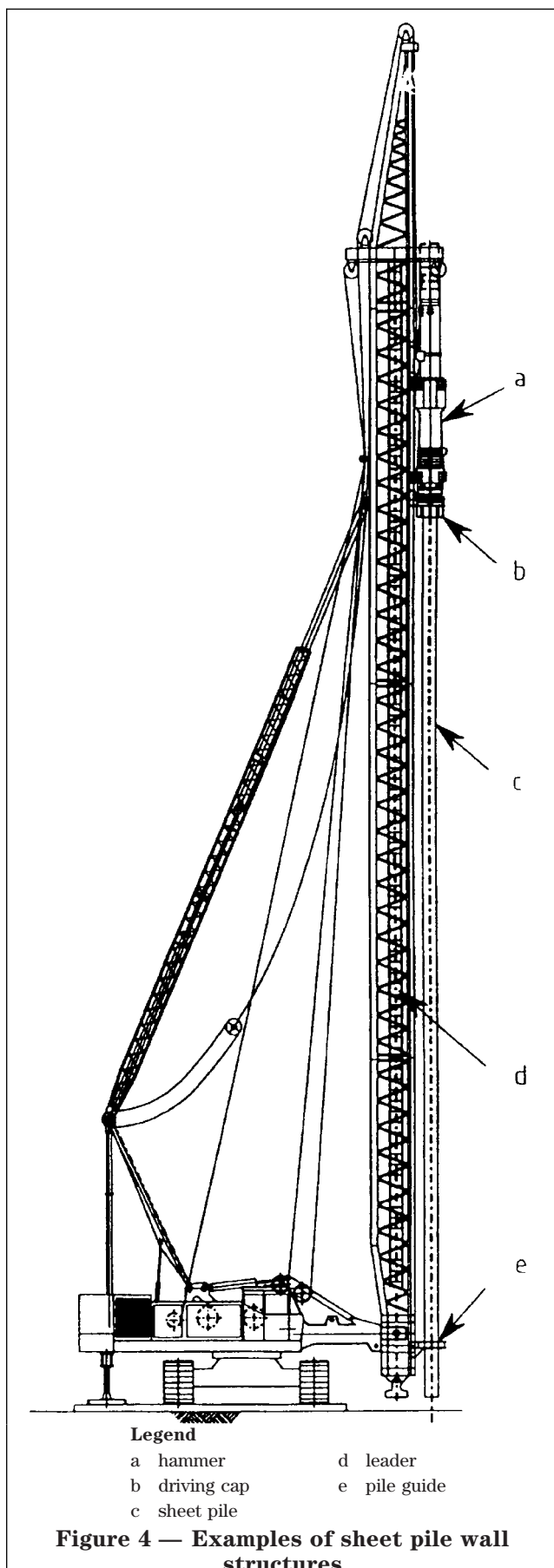
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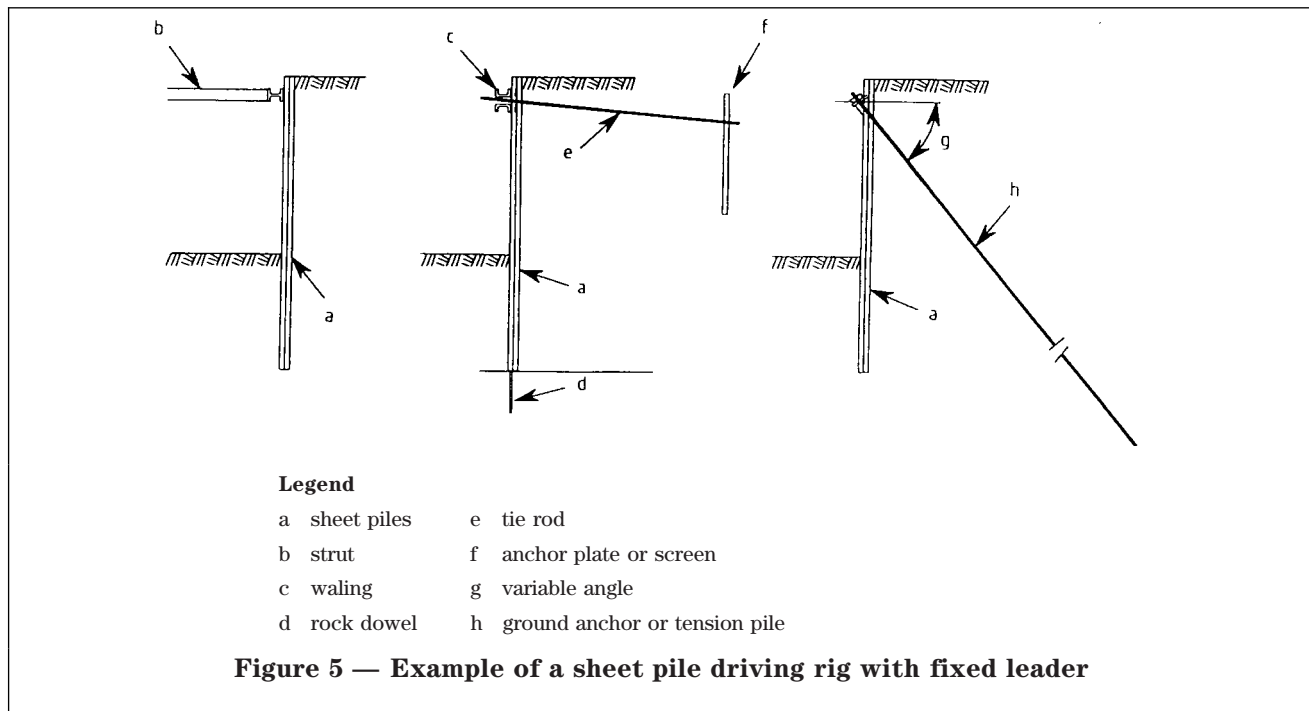
waling

horizontal beam, usually of steel or reinforced concrete, fixed to the sheet pile wall and connected to the anchorage or struts, in order to distribute the applied anchor or strut forces equally over the sheet pile wall









4 Information needed for the execution of sheet pile walls

4.1 General

The following information shall be made available before the execution of the sheet pile wall structure commences:

- location maps of the construction site, including access roads and possible hindrances;
- level and position of fixed reference points at or near the construction site;
- limitations concerning the access for equipment and materials;
- location of all services such as electricity, telephone, water and gas supply pipes and sewers;
- geotechnical data of the construction site;
- composition and stratification of the ground and its variation across the site;
- strength and deformation properties of the soil and rock layers;
- the possible presence of stones and boulders in the ground;
- the possibility of cohesive soils adhering to the piles when extracted (see 8.11);
- hydrogeological data of the area in which the construction site will be situated;
- specifications of the sheet pile walls, including all details such as type, profile, grade, protection and preservation systems and also whether any fixings of the interlocks are required to ensure transmission of the longitudinal shear forces;
- presence of sensitive buildings and/or installations in the vicinity of the construction site;
- restrictions concerning noise and vibrations;
- restrictions concerning driving method and driving assistance;
- restrictions regarding the permeability of the sheet pile wall for water or other fluids;

- various stages of the execution of the sheet pile wall structure required by the design;
- in the case of waterfront structures; the water levels and their fluctuations (amplitude, frequency and the cause of the fluctuations, e.g. discharge of a barrage, tide etc.);
- data regarding possible soil contamination;
- a list of any identified specific items to be investigated (see 4.2).

4.2 Specific

4.2.1 The following specific information shall be made available before the beginning of the works:

- all specific design information which is important to the execution;
- restrictions related to the presence, at or near the site, of ground anchors, cathodic protection devices and similar;
- the history of the building site: presence of foundation remnants or other artificial elements in the ground.

4.2.2 Information about the following matters should be made available before the beginning of the work:

- special aspects particular to the project, such as corrosion and abrasion problems;
- comparable experience from works in the neighbourhood or from similar works carried out under similar conditions;
- the condition of nearby buildings, structures or installations and the nature and depth of their foundation;
- data about adverse weather conditions, for example, wind conditions and frequency;
- severe frost action in the ground, where this can lead to overstressing of the sheet pile wall

5 Site investigations

5.1 Soils and rock investigation

When additional soils and rock data are required for the selection of driving methods, procedures, equipment, auxiliary structures etc. or for checking the execution, the investigation shall comply with clause 3 of ENV 1997-1:1994.

5.2 Driveability of sheet piles

5.2.1 When driveability is investigated, account shall be taken of any restrictions in the design regarding techniques to assist driving (for instance jetting or pre-augering).

5.2.2 When no comparable experience exists, it is recommended that one or more driving tests are carried out before the sheet pile work commences.

NOTE The driving data obtained from the test is used to improve the efficiency of the driving operations and to confirm the choice of the profile. It indicates if driving assistance is necessary and what the influence on soil properties and other important matters might be. A driving test can also indicate if it is possible to use rock dowels.

6 Materials and products

6.1 Steel sheet piles

6.1.1 New sheet piles shall comply with EN 10248-1:1995 and EN 10248-2, EN 10249-1:1995 and EN 10249-2:1995 and EN 10079:1992.

6.1.2 Re-used sheet piles shall, as a minimum, comply with the design specifications concerning type, size, quality and steel grade.

6.1.3 Tubes used for primary elements of a combined wall shall comply with EN 10219-1:1997 and EN 10219-2:1997.

6.1.4 Special connectors such as those shown in Figure B.4, shall comply with EN 10248-1:1995 and EN 10248-2:1995.

6.2 Timber sheet piles

Permanent timber sheet pile wall structures in water bearing soils shall be of a high durability class such as tropical hard wood and pine wood which is impregnated (see annex F).

6.3 Other materials and products

All other materials and products (including the backfill), shall meet the design specifications.

6.4 Corrosion protection for steel sheet piles and preservation of wooden sheet piles

Paints, coatings and other means of corrosion protection of the steel elements and the preservation treatment of wooden sheet piles, shall comply with the design specifications.

6.5 Sealings for interlocks

6.5.1 Sealing materials for reducing the permeability of the interlocks when required, shall comply with the design specifications.

6.5.2 When permeability requirements are very strict it should be demonstrated by realistic tests on sealed interlocks, that the proposed product satisfies the design specifications.

7 Design considerations

7.1 General

The basis standards for the design of all elements of sheet pile wall structures are:

- ENV 1991-1:1994, Eurocode 1 — *Basis of design and actions on structures — Part 1: Basis of design*;
- ENV 1992-1-1:1994, Eurocode 2 — *Design of concrete structures — Part 1-1: General rules and rules for buildings*;
- ENV 1993-1-1:1994, Eurocode 3 — *Design of steel structures — Part 1: General rules and rules for buildings*;
- ENV 1993-5:1998, Eurocode 3 — *Design of steel structures — Part 5: Piling*;
- ENV 1997-1:1994, Eurocode 7 — *Geotechnical design — Part 1: General rules*.

7.2 Selection of sheet pile

7.2.1 The selection of sheet pile types, profile and quality, as well as the dimensions of the primary elements of combined walls shall, as a minimum, comply with the general design considerations.

For steel sheet piles account shall be taken of the cross-section classification in accordance with ENV 1993-5:1998.

The selection shall ensure adequate driveability as established in 5.2.

7.2.2 When shear forces cannot fully be transmitted by the interlocks, this shall be taken into account in accordance with ENV 1993-5:1998 when selecting the sheet pile profiles.

7.2.3 In the case of combined walls the sheet pile profile for the secondary elements shall be selected not only on the basis of strength considerations but also on flexibility and driveability. Account shall be taken of the tolerances which can occur after driving the primary elements, as indicated in Figure 6 (see 8.6.2).

NOTE The danger of de-clutching depends mainly on the following conditions:

- accuracy of positioning and verticality of the primary elements;
- soil conditions;
- the deformation behaviour of the sheet piles.

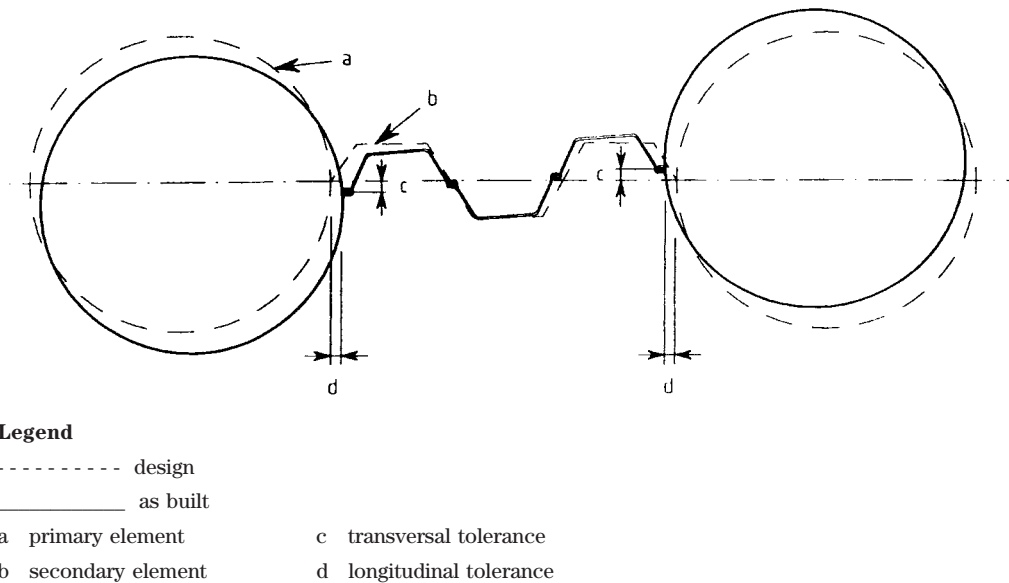


Figure 6 — Examples of tolerances for combined walls

7.3 Other structural elements

7.3.1 In addition to the sheet pile wall itself, the selection of the elements which are necessary for the sheet pile wall structure, such as anchorages, struts and walings, shall take account of adverse loading and site conditions.

7.3.2 Ground anchorages shall comply with prEN 1537.

7.4 Sequence of execution

7.4.1 The various stages of the works shall be established in accordance with the design.

7.4.2 The criteria for progressing from one stage to the next shall be defined.

As a minimum for each stage of the execution works, this involves the following:

- the levels and tolerances for filling and excavation;
- the levels and tolerances of the groundwater and the free water;
- the characteristics of the materials and the quality of the fill along both sides of the sheet pile wall and in front of the anchor plates;
- the displacements of the sheet pile wall, as anticipated at the end of the various stages;
- restrictions regarding surcharges.

7.5 Specific design considerations

The following matters should be specified in the design if appropriate:

- method of fixing the interlocks;
- method of attaching the connectors to the primary elements of a combined wall, taking into consideration Table 15 of EN 10248-2:1995;
- quality of the weldings;
- method of cutting steel elements;

— method to assist driving and the depth to which it may be applied;

— shape of rock shoe and other measures necessary to secure the toe of the sheet piles in the bed-rock;

— in soft clays, overlying bed-rock, the method of preventing the clay from squeezing through the gap between the pile toe and the bed-rock;

— quality of the backfill or the method of placement thereof;

— pre-stressing of the struts or anchorages in order to reduce displacements in the ground behind the sheet pile wall;

— time restraints during critical execution sequences;

— methods and levels of de-watering;

— type, kind and method of coating steel elements and preserving wooden parts;

— cathodic protection methods;

— compatibility of the interlock sealant and the coating material;

— special requirements regarding the permeability of the sheet pile wall, including performance criteria for materials, procedures and testing;

— the method to secure the position of the toe of sheet piles when close excavation in rock is carried out;

— consequences of extracting the sheet piles on adjacent buildings, installations and services, on settlements of the soil surface and on the creation of a link between soil layers with different groundwater regimes;

— measurements needed to check settlements, displacements and vibrations.

8 Execution of sheet pile wall structures

8.1 General

8.1.1 The sequence of executing the sheet pile wall structure shall be carried out in accordance with 7.4.

8.1.2 If the agreed sequence of the works cannot be maintained, a revision that meets the requirements of 7.4 shall be established in compliance with the design.

8.1.3 Each sheet pile should be referenced.

8.2 Site preparation

8.2.1 The site shall be prepared in such a way that operations can be carried out safely and efficiently.

8.2.2 The execution and use of auxiliary structures shall be in accordance with 7.3.

NOTE Access roads and mooring facilities to the construction site may have to comply with special regulations of the statutory authority.

8.3 Storage and handling of the sheet piles

Information regarding the storage and handling of steel sheet piles is given in annex A.

8.3.1 Handling and storage of the sheet piles on the site shall be carried out in such a way that significant damage to the straightness of the sheet piles, to the interlocks and to the coatings, does not occur.

8.3.2 The specific directives given by the sheet pile suppliers for handling and storing the sheet piles should be followed.

8.3.3 Sheet piles should be stored in such a way that they can be lifted easily in the sequence of use.

8.3.4 Sheet piles of different types and steel grade shall be stored separately and marked properly.

8.3.5 Storage and handling of straight web sheet piles shall be carried out with utmost care in order to avoid distortion of the profiles.

8.3.6 When storing pre-coated steel sheet piles, spacers shall be inserted between the individual sheet piles in a stack (see annex A).

8.3.7 Primary elements for a combined sheet pile wall shall be stored and supported on wood or a similar soft material placed between the elements in order to avoid permanent distortion of the profiles.

8.3.8 Primary elements of a combined wall should be handled using non-metallic straps or slings in order to prevent damage to the coating and to the connectors fixed to these elements.

8.3.9 The length and stiffness of the individual sheet piles shall be taken into account when assessing the number and positions of the supports to a stack of sheet piles to avoid sagging which may cause permanent deformations.

8.3.10 Special devices for lifting and positioning the sheet piles should be used, such as shackles, welded lifting hooks and similar, in order to avoid damage to the sheet piles and in particular to the interlocks.

8.3.11 When remote release shackles for lifting the sheet piles are used, their operation shall be verified before use.

8.3.12 Friction grip devices can release unexpectedly and therefore shall not be used for the handling of sheet piles unless additional safety measures are taken.

8.3.13 If preservation or corrosion treatment of sheet piles and other elements is carried out at the construction site, precautions shall be taken to ensure that storage and application of products and materials shall be in accordance with local regulations on health, safety and environmental aspects.

8.4 Welding and cutting of steel elements

Information regarding welding is given in annex B.

8.4.1 Welding and cutting of sheet piles and the preparation of primary elements for combined walls shall comply with the quality specified in the design.

8.4.2 Edge preparation and cutting of the steel elements shall be carried out in such a manner that embrittlement due to flame cutting does not have a significant adverse effect on the quality of the joint. The dimensional tolerances of EN 29692:1994, or in Figure 7j shall be complied with. The prepared piles shall be in accordance with EN 10248-2:1995, EN 10249-2:1995 and EN 10219-2:1997.

8.4.3 Unless specified otherwise, joint preparation, welding processes and the description or the qualification of the welding procedure shall be in accordance with Table 1.

For tubular primary elements it shall be ensured that the distance between the connector and a longitudinal seam of the element is ≥ 300 mm and that the circular and spiral seams on the elements are levelled at the position of the connector.

Table 1 — Welding requirements for steel sheet piles

Welding							Testing and inspection of welds		
Type of welded assembly	Type of joint	Type of weld	Joint preparation	Allowable welding processes	Description/qualification of welding procedure		Quality level according to EN 25817: 1992	Type of testing	Extent of testing [%]
					BS (EN 10248-1:1995) ²⁾ S235 JRC, S275 JRC, S355 JOC according to EN 10249-1:1995 and grades according to EN 10219-1:1997 ³⁾	QS (EN 10248-1:1995) ⁴⁾ and grades given in EN 10219-1:1997 according to ⁵⁾			
Lengthened piles — straight web pile — bending resistant pile	butt-joint ¹⁾ (see Figure 7a)/ lap-joint (see Figure 7b) butt-joint ¹⁾	EN 29692:1994	EN 29692:1994	⁶⁾	—	EN 288-2:1992 + A1:1997	D	visual	100
	(see Figure 7c)/ lap-joint (see Figure 7d)	EN 29692:1994	EN 29692:1994	⁶⁾	— ⁷⁾	EN 288-2:1992 + A1:1997 ⁷⁾	D ⁸⁾	visual ⁹⁾	100 ⁹⁾
	lap-joint (see Figure 7e)	EN 29692:1994	EN 29692:1994	⁶⁾	—	—	D	visual	100
Junctions/junction piles — all, except straight web junction piles — straight web junction piles	(oblique) T-joint (see Figure 7f + 7g)/ corner-joint (see Figure 7h)/ lap-joint (+ butt-joint) (see Figure 7i) (oblique) T-joint (see Figure 7j)	EN 29692:1994	EN 29692:1994	⁶⁾	— ⁷⁾	EN 288-2:1992 + A1:1997 ⁷⁾	D ⁸⁾	visual ⁹⁾	50 ⁹⁾
		half V-weld/double half V-weld	according to Figure 7j	⁶⁾	EN 288-3:1992 + A1:1997	EN 288-3:1992 + A1:1997	D ⁸⁾	US + visual	10 (US) ¹⁰⁾ + 100 (visual)
Box piles — contiguous interlock — connected interlock — others	butt-joint (see Figure 7k)	butt-weld between curved elements	—	⁶⁾	—	EN 288-2:1992 + A1:1997	D	visual	100
	lap-joint (see Figure 7l)	EN 29692:1994	—	⁶⁾	—	EN 288-2:1992 + A1:1997	D	visual	100
	T-joint (see Figure 7m) lap-joint (see Figure 7n)	EN 29692:1994	EN 29692:1994	⁶⁾	—	EN 288-2:1992 + A1:1997	D	visual	100

Table 1 — Welding requirements for steel sheet piles (*continued*)

Welding							Testing and inspection of welds		
Type of welded assembly	Type of joint	Type of weld	Joint preparation	Allowable welding processes	Description/qualification of welding procedure		Quality level according to EN 25817: 1992	Type of testing	Extent of testing [%]
					BS (EN 10248-1:1995) ²⁾ S235 JRC, S275 JRC, S355 JOC according to EN 10249-1:1995 and grades according to EN 10219-1:1997 ³⁾	QS (EN 10248-1:1995) ⁴⁾ and grades given in EN 10219-1:1997 according to ⁵⁾			
Welded interlocks (fixing, sealing)	butt-joint (see Figure 7o)	butt-weld between curved elements	—	6)	—	EN 288-2:1992 + A1:1997	D	visual	100

¹⁾ For different thicknesses, the shape of the butted ends shall be in accordance with the design specifications.

²⁾ BS = Base Steel according to **5.1.1** of EN 10020:1998.

³⁾ Steel grades according to Tables A.1, B.1 and B.2, except S420xxx and S460xxx.

⁴⁾ QS = Quality Steel according to **5.1.2** of EN 10020:1988.

⁵⁾ Steel grades S420xxx and S460xxx.

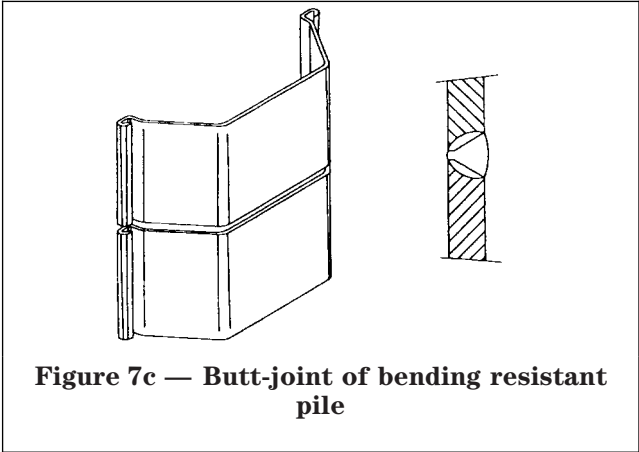
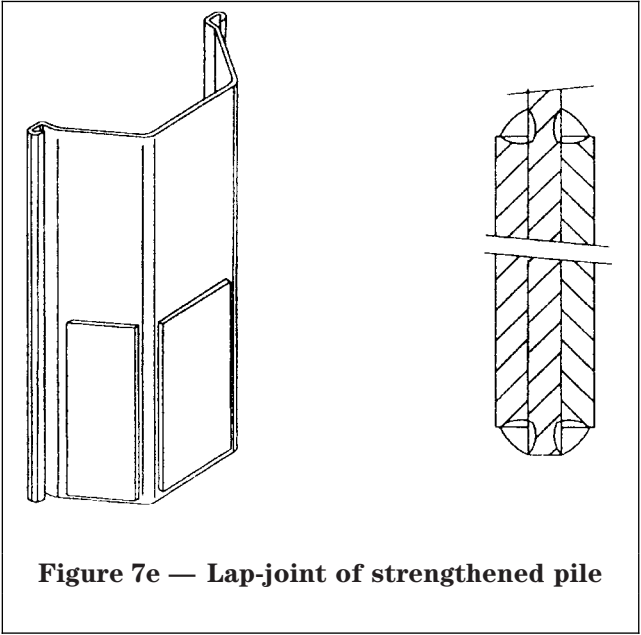
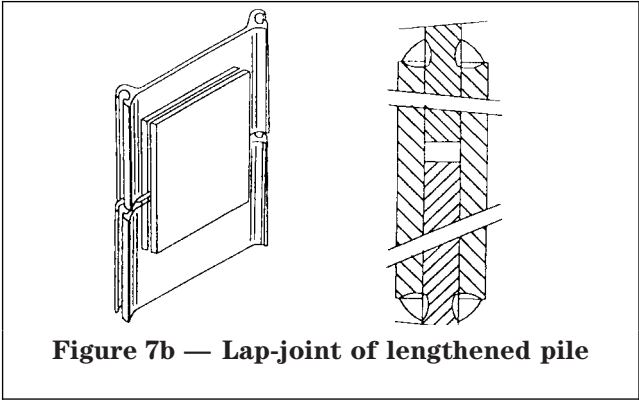
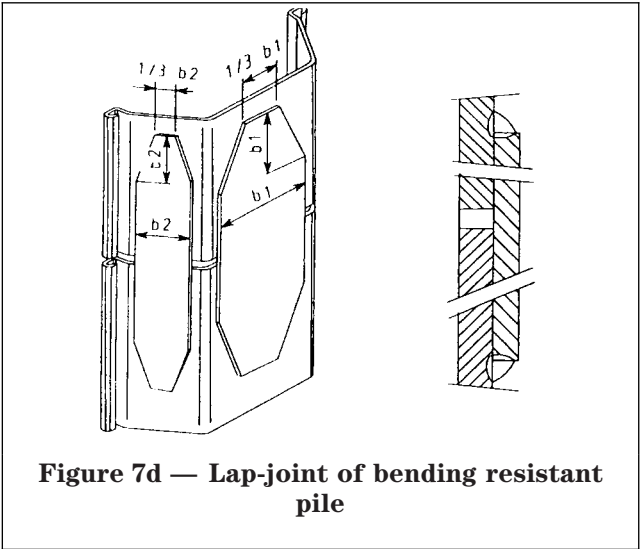
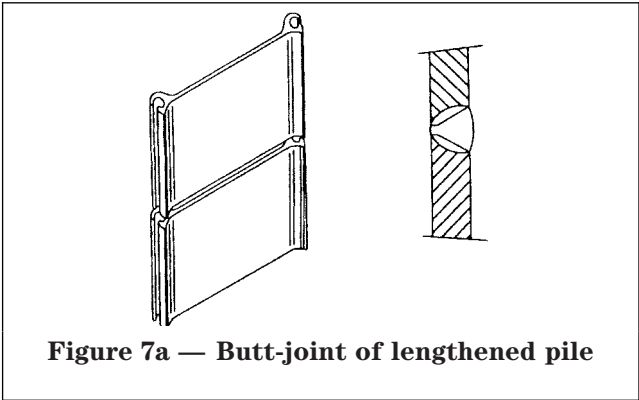
⁶⁾ All processes described in 111, 114, 121, 122, 131, 135 and 136 of EN 24063:1992, are permitted.

⁷⁾ In the case of acceptance class C, EN 288-3:1992 + A1:1997 shall be applied.

⁸⁾ Acceptance class C if requested by the design.

⁹⁾ In the case of acceptance class C, one X-ray test according to ISO 1106-1:1984 on 10 % of the sheet piles or primary elements and 100 % visual inspection or US tests on 10 % of the sheet piles or primary elements over the whole length of the weld and 100 % visual inspection.

¹⁰⁾ 10 % of the sheet piles or primary elements over the whole length of the weld.



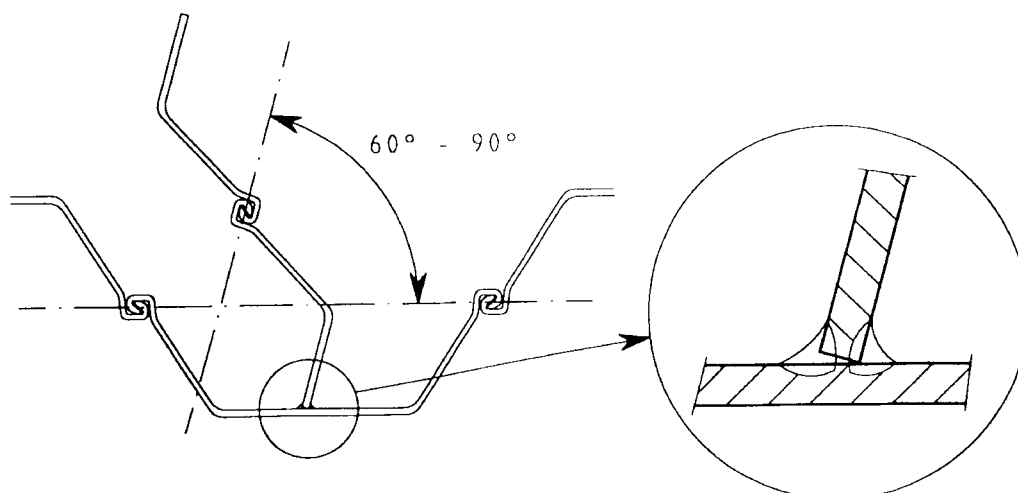


Figure 7f — Oblique T-joint of function pile

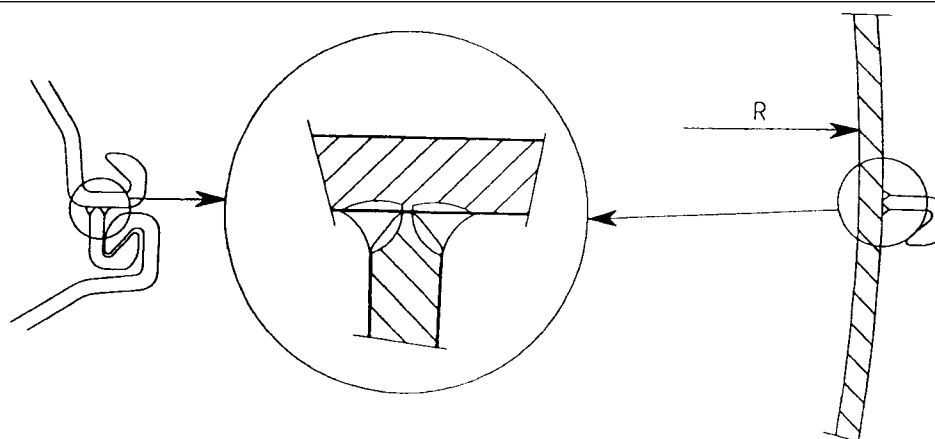


Figure 7g — T-joint junction

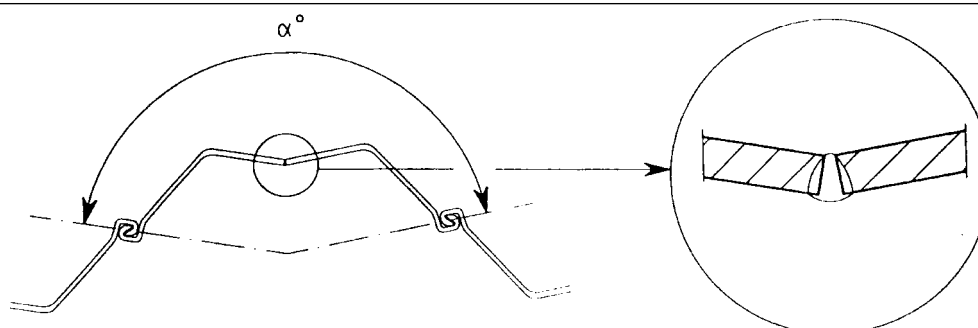


Figure 7g — Corner joint junction pile

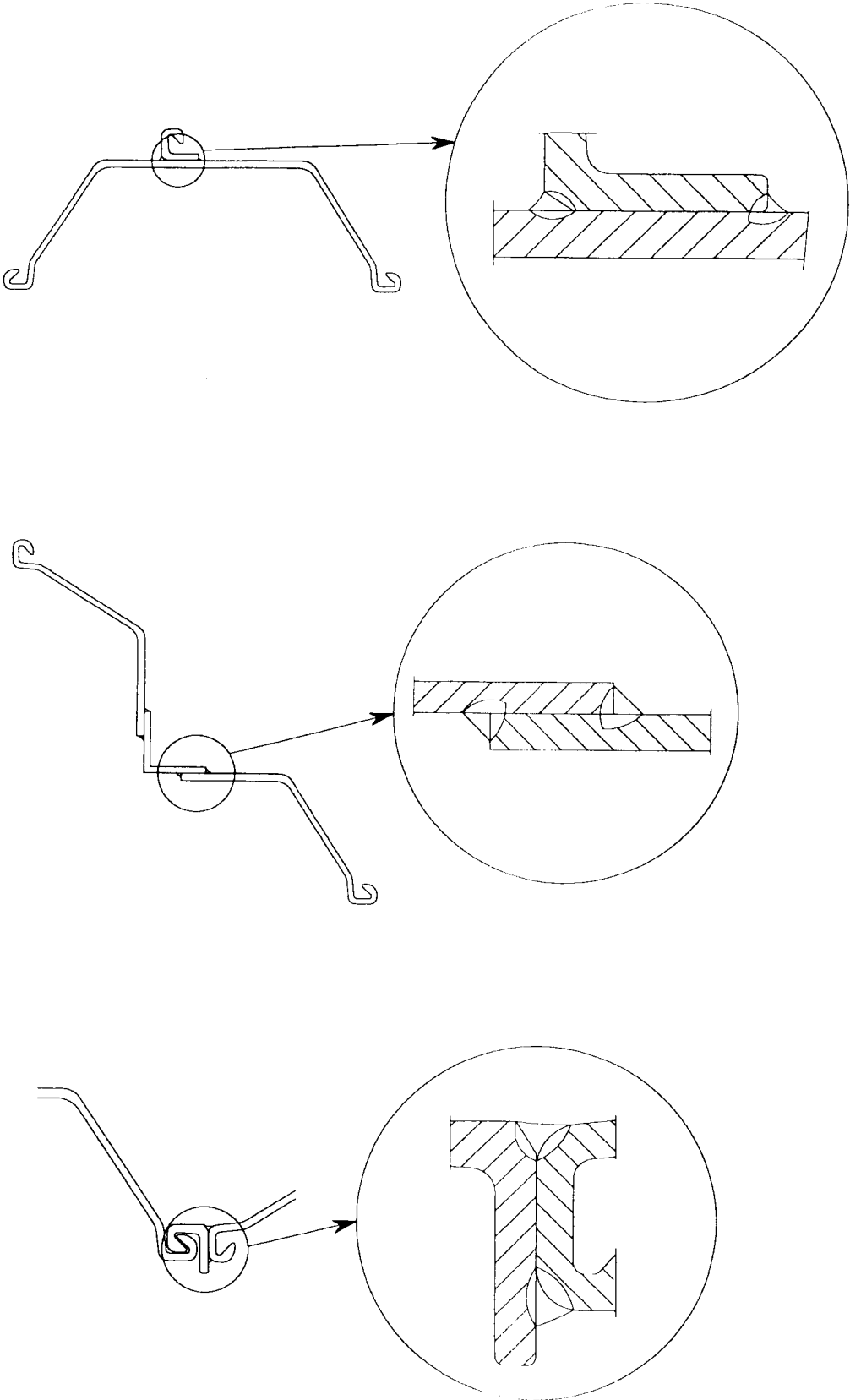


Figure 7i — Lap-joint (+ butt-joint) of junction pile