SLOVENSKI STANDARD
SIST EN 1993-5:2007

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Evrokod 3: Projektiranje jeklenih konstrukcij - 5. del: Pilotiranje

Eurocode 3 - Design of steel structures - Part 5: Piling

Eurocode 3 - Bemessung und Konstruktion von Stahlbauten - Teil 5: Pfähle und Spundwände

Eurocode 3 - Calcul des structures en acier - Partie 5: Pieux et palplanches

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ICS:

91.010.30	Tehniļ ni vidiki	Technical aspects
91.080.10	Kovinske konstrukcije	Metal structures

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Eurocode 3 - Design of steel structures - Part 5: Piling

Eurocode 3 - Calcul des structures en acier - Partie 5: Pieux et palplanches

Eurocode 3 - Bemessung und Konstruktion von Stahlbauten - Teil 5: Pfähle und Spundwände

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

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Foreword

This European Standard EN 1993-5, "Eurocode 3: Design of steel structures: Part 5 Piling", has been prepared by Technical Committee CEN/TC250 « Structural Eurocodes », the Secretariat of which is held by BSI. CEN/TC250 is responsible for all Structural Eurocodes.

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of an identical text or by endorsement, at the latest by August 2007, and conflicting National Standards shall be withdrawn at latest by March 2010.

This Eurocode supersedes ENV 1993-5:1998.

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

Background to the Eurocode programme

In 1975, the Commission of the European Community decided on an action programme in the field of construction, based on article 95 of the Treaty. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications.

Within this action programme, the Commission took the initiative to establish a set of harmonised technical rules for the design of construction works which, in a first stage, would serve as an alternative to the national rules in force in the Member States and, ultimately, would replace them.

For fifteen years, the Commission, with the help of a Steering Committee with Representatives of Member States, conducted the development of the Eurocodes programme, which led to the first generation of European codes in the 1980's.

In 1989, the Commission and the Member States of the EU and EFTA decided, on the basis of an agreement[1] between the Commission and CEN, to transfer the preparation and the publication of the Eurocodes to the CEN through a series of Mandates, in order to provide them with a future status of European Standard (EN). This links de facto the Eurocodes with the provisions of all the Council's Directives and/or Commission's Decisions dealing with European standards (e.g. the Council Directive 89/106/EEC on construction products - CPD - and Council Directives 93/37/EEC, 92/50/EEC and 89/440/EEC on public works and services and equivalent EFTA Directives initiated in pursuit of setting up the internal market).

The Structural Eurocode programme comprises the following standards generally consisting of a number of Parts:

EN 1990	Eurocode: Basis of structural design
EN 1991	Eurocode 1: Actions on structures
EN 1992	Eurocode 2: Design of concrete structures
EN 1993	Eurocode 3: Design of steel structures
EN 1994	Eurocode 4: Design of composite steel and concrete structures
EN 1995	Eurocode 5: Design of timber structures
EN 1996	Eurocode 6: Design of masonry structures
EN 1997	Eurocode 7: Geotechnical design
EN 1998	Eurocode 8: Design of structures for earthquake resistance
EN 1999	Eurocode 9: Design of aluminium structures

1 Agreement between the Commission of the European Communities and the European Committee for Standardisation (CEN) concerning the work on EUROCODES for the design of building and civil engineering works (BC/CEN/03/89).

Eurocode standards recognise the responsibility of regulatory authorities in each Member State and have safeguarded their right to determine values related to regulatory safety matters at national level where these continue to vary from State to State.

Status and field of application of Eurocodes

The Member States of the EU and EFTA recognise that Eurocodes serve as reference documents for the following purposes:

- as a means to prove compliance of building and civil engineering works with the essential requirements of Council Directive 89/106/EEC, particularly Essential Requirement N°1 – Mechanical resistance and stability - and Essential Requirement N°2 - Safety in case of fire;
- as a basis for specifying contracts for construction works and related engineering services;
- as a framework for drawing up harmonised technical specifications for construction products (ENs and ETAs)

The Eurocodes, as far as they concern the construction works themselves, have a direct relationship with the Interpretative Documents[2] referred to in Article 12 of the CPD, although they are of a different nature from harmonised product standard[3]. Therefore, technical aspects arising from the Eurocodes work need to be adequately considered by CEN Technical Committees and/or EOTA Working Groups working on product standards with a view to achieving a full compatibility of these technical specifications with the Eurocodes. The Eurocode standards provide common structural design rules for everyday use for the design of whole structures and component products of both a traditional and an innovative nature. Unusual forms of construction or design conditions are not specifically covered and additional expert consideration will be required by the designer in such cases.

National Standards implementing Eurocodes

The National Standards implementing Eurocodes will comprise the full text of the Eurocode (including any annexes), as published by CEN, which may be preceded by a National title page and National foreword, and may be followed by a National Annex (informative).

The National Annex (informative) may only contain information on those parameters which are left open in the Eurocode for national choice, known as Nationally Determined Parameters, to be used for the design of buildings and civil engineering works to be constructed in the country concerned, i.e.:

- values for partial factors and/or classes where alternatives are given in the Eurocode,
- values to be used where a symbol only is given in the Eurocode,
- geographical and climatic data specific to the Member State, e.g. snow map,
- the procedure to be used where alternative procedures are given in the Eurocode,
- references to non-contradictory complementary information to assist the user to apply the Eurocode.

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2 According to Art. 3.3 of the CPD, the essential requirements (ERs) shall be given concrete form in interpretative documents for the creation of the necessary links between the essential requirements and the mandates for hENs and ETAGs/ETAs.

3 According to Art. 12 of the CPD the interpretative documents shall:
(a) give concrete form to the essential requirements by harmonising the terminology and the technical bases and indicating classes or levels for each requirement where necessary;
(b) indicate methods of correlating these classes or levels of requirement with the technical specifications, e.g. methods of calculation and of proof, technical rules for project design, etc.;
(c) serve as a reference for the establishment of harmonised standards and guidelines for European technical approvals.
The Eurocodes, de facto, play a similar role in the field of the ER 1 and a part of ER 2.

Links between Eurocodes and product harmonised technical specifications (ENs and ETAs)

There is a need for consistency between the harmonised technical specifications for construction products and the technical rules for works[4]. Furthermore, all the information accompanying the CE Marking of the construction products which refer to Eurocodes should clearly mention which Nationally Determined Parameters have been taken into account.

Additional information specific to EN 1993-5

EN 1993-5 gives design rules for steel sheet piling and bearing piles to supplement the generic rules in EN 1993-1.

EN 1993-5 is intended to be used with Eurocodes EN 1990 - Basis of design, EN 1991 - Actions on structures and Part 1 of EN 1997 Geotechnical Design.

Matters that are already covered in those documents are not repeated.

EN 1993-5 is intended for use by

- committees drafting design related product, testing and execution standards,
- clients (e.g. for the formulation of their specific requirements)
- designers and constructors
- relevant authorities.

Numerical values for partial factors and other parameters are recommended as basic values that provide an acceptable level of safety. They have been selected assuming that an appropriate level of workmanship and quality management applies.

Annex A and Annex B have been prepared to complement the provisions of EN 1993-1-3 for class 4 steel sheet piles.

Annex C gives guidance on the plastic design of steel sheet pile retaining structures.

Annex D gives one possible set of design rules for primary elements of combined walls.

Reference should be made to EN 1997 for geotechnical design which is not covered in this document.

National Annex for EN 1993-5

This standard gives alternative procedures, values and recommendations for classes with notes indicating where national choices may have to be made. Therefore the National Standard implementing EN 1993-5 should have a National Annex containing all Nationally Determined Parameters to be used for the design of buildings and civil engineering works to be constructed in the relevant country.

National choice is allowed in EN 1993-5 through clauses:

3.7 (1)	5.2.2 (13)	7.2.3 (2)
3.9 (1)P	5.2.5 (7)	7.4.2 (4)
4.4 (1)	5.5.4 (2)	A.3.1 (3)
5.1.1 (4)	6.4 (3)	B.5.4 (1)
5.2.2 (2)	7.1 (4)	D.2.2 (5)

4 See Art. 3.3 and Art. 12 of the CPD, as well as clauses 4.2, 4.3.1, 4.3.2 and 5.2 of ID 1.

1 General

1.1 Scope

(1) Part 5 of EN 1993 provides principles and application rules for the structural design of bearing piles and sheet piles made of steel.

(2) It also provides examples of detailing for foundation and retaining wall structures.

(3) The field of application includes:

- steel piled foundations for civil engineering works on land and over water;
- temporary or permanent structures needed to carry out steel piling work;
- temporary or permanent retaining structures composed of steel sheet piles, including all kinds of combined walls.

(4) The field of application excludes:

- offshore platforms;
- dolphins.

(5) Part 5 of EN 1993 also includes application rules for steel piles filled with concrete.

(6) Special requirements for seismic design are not covered. Where the effects of ground movements caused by earthquakes are relevant see EN 1998.

(7) Design provisions are also given for walings, bracing and anchorages, see section 7.

(8) The design of steel sheet piling using class 1, 2 and 3 cross-sections is covered in sections 5 and 6, whereas the design of class 4 cross-sections is covered in annex A.

NOTE: The testing of class 4 sheet piles is covered in annex B.

(9) The design procedures for crimped U-piles and straight web steel sheet piles utilise design resistances obtained by testing. Reference should be made to EN 10248 for testing procedures.

(10) Geotechnical aspects are not covered in this document. Reference is made to EN 1997.

(11) Provisions for taking into account the effects of corrosion in the design of piling are given in section 4.

(12) Allowance for plastic global analysis in accordance with 5.4.3 of EN 1993-1-1 is given in 5.2.

NOTE: Guidance for the design of steel sheet pile walls allowing for plastic global analysis is given in Annex C.

(13) The design of combined walls at ultimate limit states is covered in section 5 including general provisions for the design of primary elements.

NOTE: Guidance for the design of both tubular piles and I-sections used as primary elements is given in Annex D.

1.2 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 1990 Eurocode: Basis of structural design

EN 1991 Eurocode 1: Actions on structures

EN 1992 Eurocode 2: Design of concrete structures

EN 1993 Eurocode 3: Design of steel structures

- Part 1.1: General rules: General rules and rules for buildings;
- Part 1.2: General rules: Structural fire design;
- Part 1.3: General rules: Supplementary rules for cold formed thin gauge members and sheeting;
- Part 1.5: General rules: Plated structural elements;
- Part 1.6: General rules: Strength and stability of shell structures
- Part 1.8: General rules: Design of joints
- Part 1.9: General rules: Fatigue
- Part 1.10: General rules: Material toughness and through-thickness properties
- Part 1.11: General rules: Design of structures with tension components made of steel

EN 1994 Eurocode 4: Design of composite steel and concrete structures

EN 1997 Eurocode 7: Geotechnical design

EN 1998 Eurocode 8: Earthquake resistant design of structures;

EN 10002 Metallic materials; tensile testing;

EN 10027 Designation systems for steel;

EN 10210 Hot finished structural hollow sections of non-alloy fine grain structural steels;

EN 10219 Cold formed structural hollow sections of non-alloy fine grain structural steels;

EN 10248 Hot rolled sheet piling of non alloy steels;

EN 10249 Cold formed sheet piling of non alloy steels;

EN 1536 Execution of special geotechnical work - Bored piles;

EN 1537 Execution of special geotechnical work - Ground anchors;

EN 12063 Execution of special geotechnical work - Sheet-pile walls;

EN 12699 Execution of special geotechnical work - Displacement piles;

EN 14199 Execution of special geotechnical work - Micro piles;

EN 10045 Metallic materials; Charpy impact test;

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

1.3 Assumptions

(1) In addition to the general assumptions in EN 1990 the following assumptions apply:

Installation and fabrication of steel piles and steel sheet piles are in accordance with EN 12699, EN 14199 and EN 12063.

1.4 Distinction between principles and application rules

(1)P Reference shall be made to 1.4 of EN 1990.

1.5 Definitions

For the purpose of this standard, the following definitions apply:

1.5.1 foundation: Part of a construction work including piles and possibly their pile cap.

1.5.2 retaining structure: A construction element including walls retaining soil, similar material and/or water, and, where relevant, their support systems (e.g. anchorages).

1.5.3 soil-structure interaction: The mutual influence of deformations on soil and a foundation or a retaining structure.

1.6 Symbols

(1) In addition to those given in EN 1993-1-1, the following main symbols are used:

c Slant height of the web of steel sheet piles, see Figure 5-1;

α Inclination of the web, see Figure 5-1.

(2) In addition to those given in EN 1993-1-1, the following subscripts are used:

red Reduced.

(3) In addition to those given in EN 1993-1-1, the following major symbols are used:

A_v Projected shear area, see Figure 5-1;

F_{Ed} Design value of the anchor force;

$F_{Q,Ed}$ Additional horizontal force resulting from global buckling to be resisted by the toe of a sheet pile to allow for the assumption of a non-sway buckling mode, see Figure 5-4;

$F_{t,Rd}$ Design tension resistance of an anchor;

$F_{t,Ed}$ Design value of the circumferential tensile force in a cellular cofferdam;

$F_{t,ser}$ Axial force in an anchor under characteristic loading;

$F_{ta,Ed}$ Design tensile force in the arc cell of a cellular cofferdam;

$F_{tc,Ed}$ Design tensile force in the common wall of a cellular cofferdam;

$F_{tg,Rd}$ Design tensile resistance of shafts of anchors;

$F_{tm,Ed}$ Design tensile force in the main cell of a cellular cofferdam;

$F_{ts,Rd}$ Design tensile resistance of simple straight web steel sheet piles;

$F_{tt,Rd}$ Design tensile resistance of threads of anchors;

$R_{c,Rd}$ Design resistance of a sheet pile to a local transverse force;

$R_{tw,Rd}$ Design tensile resistance of the webs of a sheet pile to the introduction of a local transverse force;

$R_{Vf,Rd}$ Design shear resistance of the flange of a sheet pile to the introduction of a local transverse force;

$p_{m,Ed}$ Design value of the internal pressure acting in the main cell of a cellular cofferdam;

r_a Initial radius of the arc cell in a cellular cofferdam;

r_m Initial radius of the main cell in a cellular cofferdam;

t_f Nominal flange thickness of a steel sheet pile;

t_w Nominal web thickness of steel sheet piles;

β_B Factor accounting for the possible reduction of the section modulus of U-piles due to insufficient shear force transmission in the interlocks;

β_D Factor accounting for the possible reduction of the bending stiffness of U-piles due to insufficient shear force transmission in the interlocks;

β_R Factor accounting for the interlock resistance of straight web steel sheet piles;

β_T Factor accounting for the behaviour of a welded junction pile at ultimate limit states;

$\beta_{o,I}$ Factor accounting for the reduction of the second moment of area about the wall axis due to the ovalisation of the tube;

ρ_P Factor accounting for the effects of differential water pressure on transverse local plate bending.

(4) Further symbols are defined where they first occur.

1.7 Units

(1) S.I. units should be used in accordance with ISO 1000.

(2) The following units are recommended for use in calculations:

- forces and loads: kN, kN/m, kN/m^2;
- unit mass: kg/m^3;
- unit weight: kN/m^3;
- stresses and strengths: N/mm² (MN/m^2 or MPa);
- bending moments: kNm;
- torsional moments: kNm.

1.8 Terminology

For the purposes of this Standard, the following terminology is used:

NOTE: Figure 1-1 to Figure 1-10 are only examples and are provided in order to enhance the understanding of the wording of the terminology used. The examples are by no means exhaustive and they do not represent any preferred detailing.

1.8.1 Anchorage

The general expression used to describe the anchoring system at the back of a retaining wall, such as dead-man anchors, anchor plates or anchor screens, screw anchors, ground anchors, anchor piles and expanded bodies. Examples of connections between anchors and a sheet pile wall are shown in Figure 1-1.

1.8.2 Anchored wall

A wall whose stability depends upon penetration of the sheet piling into the ground and also upon one or more anchor levels.

1.8.3 Bearing piles

Structural elements (hollow type, H-type, cruciform or X-type cross-sections) incorporated into the foundations of building or civil engineering works and used for resisting axial compressive or tensile forces, moments and transverse (shear) forces (see Table 1-1). The bearing resistance is achieved by base resistance or shaft friction or a combination of both.

1.8.4 Bracing

Struts perpendicular or at an angle to the front face of a retaining wall, supporting the wall and usually connected to the walings (see Figure 1-2).

1.8.5 Cantilever wall

Wall whose stability depends solely upon the penetration of the sheet piling into the ground.

1.8.6 Cellular cofferdams

Cofferdams constructed of straight web profiles with interlock tensile strength sufficient to resist the circumferential tension developed in the cellular walls due to the radial pressure of the contained fill (see Figure 1-3). The stability of these cells is obtained by the self-weight of the fill. Two basic types of cellular cofferdams are:

- Cellular cofferdams involving circular cells: This type of cofferdam consists of individual cells of large diameter connected together by arcs of smaller diameter (see Figure 1-4a);

- Cellular cofferdams involving diaphragm cells: This type of cofferdam consists of two rows of circular arcs connected together by diaphragms perpendicular to the axis of the cofferdam (see Figure 1-4b).

1.8.7 Combined walls

Retaining walls composed of primary and secondary elements. The primary elements are normally steel tubular piles, I-sections or built up box types, spaced uniformly along the length of the wall. The secondary elements are generally steel sheet piles of various types installed in the spaces between the primary elements and connected to them by interlocks (see Figure 1-5).

1.8.8 Double U-pile

Two threaded single U sheet piles with a crimped or welded common interlock allowing for shear force transmission.

1.8.9 Driveability

The ability of a sheet pile or bearing pile to be driven through the ground strata to the required penetration depth without detrimental effects.

1.8.10 Driving

Any method for installing a pile into the ground to the required depth, such as impact driving, vibrating, pressing or screwing or by a combination of these or other methods.

1.8.11 High modulus wall

A high strength retaining wall formed by interlocking steel elements that have the same geometry. The elements may consist of fabricated profiles, see Figure 1-6, to obtain a high section modulus.

1.8.12 Interlock

The portion of a steel sheet pile or other sheeting that connects adjacent elements by means of a thumb and finger or similar configuration to make a continuous wall. Interlocks may be described as

- Free: Threaded interlocks that are neither crimped nor welded;
- Crimped: Interlocks of threaded single piles that have been mechanically connected by crimped points;
- Welded: Interlocks of threaded single piles that have been mechanically connected by continuous or intermittent welding.

1.8.13 Jagged wall

Special sheet pile wall configuration in which the single piles are arranged either to enhance the moment of inertia of the wall (see example in Figure 1-7) or to suit special applications (see example in Figure 1-8).

1.8.14 Pile coupler

A mechanical friction sleeve used to lengthen a steel tubular or X shaped pile.

1.8.15 Propped wall

A retaining wall whose stability depends upon penetration of the sheet piling into the ground and also upon one or more levels of bracing.

1.8.16 Soldier or king pile wall

Soldier or king pile walls consist of vertical piles (king, master or soldier piles) driven at intervals, supporting intermediate horizontal elements (boarding, planks or lagging), see Figure 1-9. The king or master piles may be rolled or welded I-sections, tubular or box sections.

1.8.17 Steel box piles

Piles with a non-circular hollow shape formed from two or more hot-rolled sections continuously or intermittently welded together in longitudinal direction (see Table 1-1).

1.8.18 Steel tubular piles

Piles of circular cross-section formed by the seamless, longitudinal or helical welding processes (see Table 1-1).

1.8.19 Steel sheet pile

The individual steel elements of which a sheet pile wall is composed. The types of steel sheet piles covered in this Part 5 are given in Table 1-2: Z-shaped, U-shaped and straight web profiles, and in Table A-1 of

Annex A for cold formed sheet piling. The interlocks of the Z-piles are located on the extreme fibres of the wall, whereas the interlocks of U-shaped and straight web profiles are located on the axis of the retaining wall.

1.8.20 Steel sheet pile wall

The screen of sheet piles that forms a continuous wall by threading of the interlocks.

1.8.21 T-connection

Special element, see Figure 1-10, to connect two cellular cofferdams by arcs of smaller diameter, see Figure 1-3.

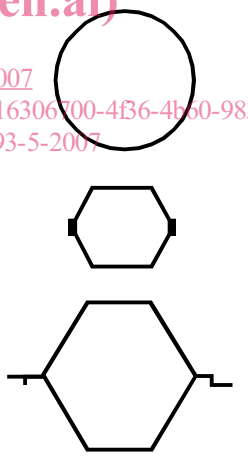
1.8.22 Triple U-pile

A sheet pile consisting of three threaded single U sheet piles with two crimped or welded common interlocks allowing for shear force transmission.

1.8.23 Waling

Horizontal beam, usually of steel or reinforced concrete, fixed to the retaining wall and used to transmit the design support force for the wall into the tie rods or struts.

Table 1-1: Examples of cross-sections of steel bearing piles

Type of cross-section	Representation
Hollow type (examples), *see Note*	
H type	
X type	
Note: Reference should be made to EN 12699 and EN 14199 for execution details.	