



BSI Standards Publication

Eurocode 2 - Design of concrete structures

Part 4: Design of fastenings for use in concrete

National foreword

This British Standard is the UK implementation of EN 1992-4:2018. It supersedes DD CEN/TS 1992-4-3:2009, DD CEN/TS 1992-4-2:2009, DD CEN/TS 1992-4-4:2009, DD CEN/TS 1992-4-1:2009 and DD CEN/TS 1992-4-5:2009, which are withdrawn.

Where a normative part of this EN allows for a choice to be made at the national level, the range and possible choice will be given in the normative text, and a note will qualify it as a Nationally Determined Parameter (NDP). NDPs can be a specific value for a factor, a specific level or class, a particular method or a particular application rule if several are proposed in the EN.

To enable EN 1992-4 to be used in the UK, the NDPs will be published in a National Annex, which will be made available by BSI in due course, after public consultation has taken place.

The UK participation in its preparation was entrusted to Technical Committee B/525/2, Structural use of concrete.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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English Version

Eurocode 2 - Design of concrete structures - Part 4: Design of fastenings for use in concrete

Eurocode 2 - Calcul des structures en béton - Partie 4 :
Conception et calcul des éléments de fixation pour
béton

Eurocode 2 - Bemessung und Konstruktion von
Stahlbeton- und Spannbetontragwerken - Teil 4:
Bemessung der Verankerung von Befestigungen in
Beton

This European Standard was approved by CEN on 9 March 2018.

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

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European foreword

This document (EN 1992-4:2018) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

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 March 2019 and conflicting national standards shall be withdrawn at the latest by March 2019.

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

This document supersedes CEN/TS 1992-4-1:2009, CEN/TS 1992-4-2:2009, CEN/TS 1992-4-3:2009, CEN/TS 1992-4-4:2009 and CEN/TS 1992-4-5:2009.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association.

This document differs from CEN/TS 1992-4-1:2009, CEN/TS 1992-4-2:2009, CEN/TS 1992-4-3:2009, CEN/TS 1992-4-4:2009 and CEN/TS 1992-4-5:2009 as follows:

- The content of the CEN/TS 1992-4 series is condensed and completely revised to be published as one single standard covering the design of the different types of cast-in situ and post-installed fastening systems.
- Normative references are updated. Some standards given in the CEN/TS 1992-4 series are moved to an added Bibliography.
- 1.2 (5) and Fig.1.2: The configurations of fastenings with headed or post-installed fasteners covered by EN 1992-4 are described in more detail.
- 1.3 (1), 1.3(2) and 7.3: Provisions on fasteners for fastening statically indeterminate non-structural systems are added. Details of the design method are given in CEN/TR 17079, *Design of fasteners for use in concrete - Redundant non-structural systems*.
- 4.4.2.2 and Table 4.1: Partial material safety factors for accidental design situations are introduced which are about 15% smaller than for permanent and transient design situations.
- 6.2.1 (2): More specific conditions to ensure a rigid fixture are given and provisions in case of an elastic, but flexible fixture are added.
- 7 to 11: The verifications are based on the characteristic concrete cylinder strength and not cube strength and the factors k_i for calculating the basic characteristic resistances for the different failure modes are adjusted accordingly.
- 7.2.1.4 (1), Formula (7.1) and 7.2.1.4 (7): The factor $\psi_{M,N}$ is introduced to take into account the favorable effect of a compression force between fixture and concrete in case of bending moments with or without axial force on the concrete cone resistance.
- 7.2.1.6 (2), Formula (7.14): The product dependent factor ψ_{sus} is introduced to take account of the influence of sustained load on the bond strength of post-installed bonded fasteners for the verification of combined pull-out and concrete failure
- 7.2.2.5 (13) and Clause 7.4.2.5 (7): The factor $\psi_{re,V}$ to take into account the effect of edge reinforcement and closely spaced stirrups or wire mesh on the characteristic resistance for concrete edge failure is limited to cracked concrete.

- 7.4.1.3 (2) and 7.4.2.3 (2): For the verification of anchor channels for local flexure of channel lips under tension loads and shear loads without lever arm the influence of closely spaced channel bolts is considered.
- 7.4.1.7, Formula (7.69): For the verification of anchor channels for concrete blow-out failure the factor $\psi_{g,Nb}$ is deleted.
- 7.4.2.3.1 and Table 7.5: For the verification of anchor channels subjected to shear forces without lever arm in case of steel failure the failure modes 'anchor' and 'connection between anchor and channel' are added.
- 7.4.2.5 (2): Formula (7.78) is modified. The influence of edge distance on the basic characteristic resistance in case of concrete edge failure is taken into account with $c_1^{4/3}$ instead with $c_1^{1,5}$.
- 7.4.3 and Table 7.6: In case of interaction of shear and tension loads acting on anchor channels provisions are given for the different modes of steel failure and for failure modes other than steel failure.
- Clause 8: The values for the characteristic fatigue resistance in case of concrete related failure modes for $2 \cdot 10^6$ load cycles are reduced.
- Clause 9 and Annex C: The verifications for seismic loading are completely revised.
- Clause 10: Provisions for the verification for fire resistance are added. Informative Annex D provides a design method for cast-in-place headed fasteners, anchor channels and post-installed fasteners exposed to fire.
- Normative Annex E: Characteristics for the design of fastenings to be provided by European Technical Product Specifications are added.
- Annex F: Product specific Sections of the CEN/TS 1992-4 series on assumptions for design provisions regarding execution of fastenings are condensed in this normative Annex.
- Annex G: The design provisions of the CEN/TS 1992-4 series for post-installed fasteners using simplified methods are moved to this informative Annex.
- Annex B of CEN/TS 1992-4:1 "Plastic design approach" is moved to CEN/TR 17081, *Design of fastenings for use in concrete – Plastic design of fastenings with headed and post-installed fasteners*.

EN 1992 is composed of the following parts:

- EN 1992-1-1, *Eurocode 2: Design of concrete structures — Part 1-1: General rules and rules for buildings*;
- EN 1992-1-2, *Eurocode 2: Design of concrete structures — Part 1-2: General rules — Structural fire design*;
- EN 1992-2, *Eurocode 2 — Design of concrete structures — Concrete bridges — Design and detailing rules*;
- EN 1992-3, *Eurocode 2 — Design of concrete structures — Part 3: Liquid retaining and containment structures*;
- EN 1992-4, *Eurocode 2 — Design of concrete structures — Part 4: Design of fastenings for use in concrete*.

The numerical values for partial factors and other reliability parameters are recommended values. The recommended values apply when:

- a) the fasteners comply with the requirements of 1.2 (3), and
- b) the installation complies with the requirements of 4.6.

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

National Annex for EN 1992-4

This EN gives values with Notes indicating where national choices may have to be made. When this EN is made available at national level it may be followed by a National Annex containing all Nationally Determined Parameters to be used for the design of fastenings according to this EN for use in the relevant country.

National choice of the partial factors and reliability parameters is allowed in design according to this EN in the following sections:

4.4.1(2);

4.4.2.2(2);

4.4.2.3;

4.4.2.4;

4.7(2);

C.2(2);

C.4.4(1);

C.4.4(3);

D.2(2).

1 Scope

1.1 General

(1) This European Standard provides a design method for fastenings (connection of structural elements and non-structural elements to structural components), which are used to transmit actions to the concrete. This design method uses physical models which are based on a combination of tests and numerical analysis consistent with EN 1990:2002, 5.2.

Additional rules for the transmission of the fastener loads within the concrete member to its supports are given in EN 1992-1-1 and Annex A of this EN.

Inserts embedded in precast concrete elements during production, under Factory Production Control (FPC) conditions and with the due reinforcement, intended for use only during transient situations for lifting and handling, are covered by CEN/TR 15728.

(2) This EN is intended for safety related applications in which the failure of fastenings may result in collapse or partial collapse of the structure, cause risk to human life or lead to significant economic loss. In this context it also covers non-structural elements.

(3) The support of the fixture can be either statically determinate or statically indeterminate. Each support can consist of one fastener or a group of fasteners.

(4) This EN is valid for applications which fall within the scope of the EN 1992 series. In applications where special considerations apply, e.g. nuclear power plants or civil defence structures, modifications can be necessary.

(5) This EN does not cover the design of the fixture. Rules for the design of the fixture are given in the appropriate Standards meeting the requirements on the fixture as given in this EN.

(6) This document relies on characteristic resistances and distances which are stated in a European Technical Product Specification (see Annex E). At least the characteristics of Annex E are given in a European Technical Product Specification for the corresponding loading conditions providing a basis for the design methods of this EN.

1.2 Type of fasteners and fastening groups

(1) This EN uses the fastener design theory¹⁾ (see Figure 1.1) and applies to:

- a) cast-in fasteners such as headed fasteners, anchor channels with rigid connection (e.g. welded, forged) between anchor and channel;
- b) post-installed mechanical fasteners such as expansion fasteners, undercut fasteners and concrete screws;
- c) post-installed bonded fasteners and bonded expansion fasteners.

(2) For other types of fasteners, modifications of the design provisions can be necessary.

(3) This EN applies to fasteners with established suitability for the specified application in concrete covered by provisions, which refer to this EN and provide data required by this EN. The suitability of the fastener is stated in the relevant European Technical Product Specification.

1) In fastener design theory the concrete tensile capacity is directly used to transfer loads into the concrete component.

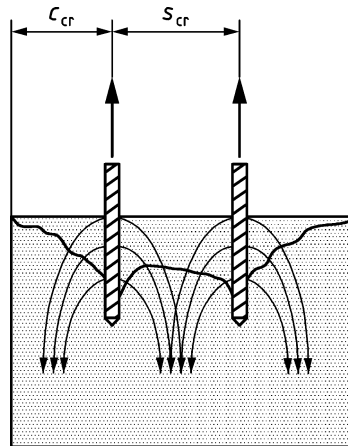


Figure 1.1 — Fastener design theory — Example

- (4) This EN applies to single fasteners and groups of fasteners. In a group of fasteners, the loads are applied to the individual fasteners of the group by means of a common fixture. In a group of fasteners, this European Standard applies only if fasteners of the same type and size are used.
- (5) The configurations of fastenings with cast-in place headed fasteners and post-installed fasteners covered by this EN are shown in Figure 1.2.
- (6) For anchor channels, the number of anchors is not limited.
- (7) Post-installed ribbed reinforcing bars used to connect concrete members are covered by a European Technical Product Specification.

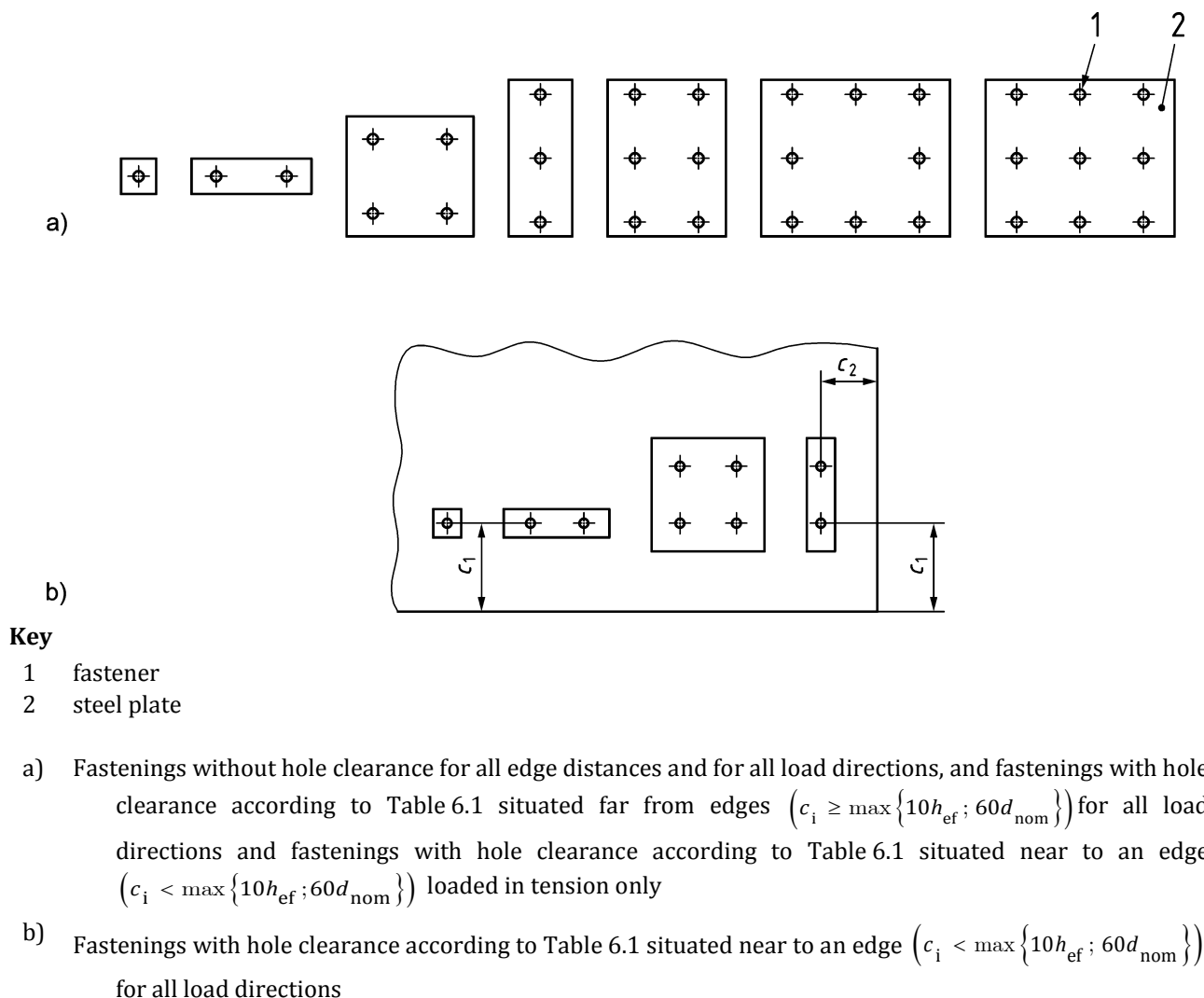


Figure 1.2 — Configuration of fastenings with headed and post-installed fasteners covered by this EN

1.3 Fastener dimensions and materials

(1) This EN applies to fasteners with a minimum diameter or a minimum thread size of 6 mm (M6) or a corresponding cross section. In case of fasteners for fastening statically indeterminate non-structural systems as addressed in 7.3, the minimum thread size is 5 mm (M5). The maximum diameter of the fastener is not limited for tension loading but is limited to 60 mm for shear loading.

(2) EN 1992-4 applies to fasteners with embedment depth $h_{ef} \geq 40$ mm. Only for fastening statically indeterminate non-structural systems as addressed in 7.3 fasteners with effective embedment depth of at least 30 mm are considered, which may be reduced to 25 mm in internal exposure conditions. For fastenings with post-installed bonded fasteners, only fasteners with an embedment depth $h_{ef} \leq 20d$ are covered. The actual value for a particular fastener may be found in the relevant European Technical Product Specification.

(3) This EN covers metal fasteners made of either carbon steel (EN ISO 898-1 and EN ISO 898-2, EN 10025-1, EN 10080), stainless steel (EN 10088-2 and EN 10088-3, EN ISO 3506-1 and EN ISO 3506-2) or malleable cast iron (ISO 5922). The surface of the steel can be coated or uncoated. This EN is valid for fasteners with a nominal steel tensile strength $f_{uk} \leq 1\,000$ N/mm². This limit does not apply to concrete screws.

1.4 Fastener loading

(1) Loading on the fastenings covered by this document can be static, quasi-static, fatigue and seismic. The suitability of the fastener to resist fatigue and seismic loadings is specifically stated in the relevant European Technical Product Specification. Anchor channels subjected to fatigue loading or seismic loading are not covered by this EN.

(2) The loading on the fastener resulting from the actions on the fixture (e.g. tension, shear, bending or torsion moments or any combination thereof) will generally be axial tension and/or shear. When the shear force is applied with a lever arm a bending moment on the fastener will arise. EN 1992-4 considers axial compression on the fixture only when it is transmitted to the concrete either directly to the concrete surface without acting on the embedded fastener load transfer mechanism or via fasteners suitable for resisting compression.

(3) In case of anchor channels, shear in the direction of the longitudinal axis of the channel is not covered by this EN.

NOTE Design rules for anchor channels with loads acting in the direction of the longitudinal axis of the anchor channel can be found in CEN/TR 17080, *Design of fastenings for use in concrete — Anchor channels — Supplementary rules*.

(4) Design of fastenings under fire exposure is covered by this EN (see informative Annex D).

1.5 Concrete strength and type

This EN is valid for fasteners installed in members made of compacted normal weight concrete without fibres with strength classes in the range C12/15 to C90/105 all in accordance with EN 206. The range of concrete strength classes in which particular fasteners may be used is given in the relevant European Technical Product Specification and may be more restrictive than stated above.

1.6 Concrete member loading

In general, fasteners are prequalified for applications in concrete members under static loading. If the concrete member is subjected to fatigue or seismic loading, prequalification of the fastener specific to this type of loading and a corresponding European Technical Product Specification are required.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

EN 1990:2002, *Eurocode - Basis of structural design*

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

EN 1992-1-1:2004, *Eurocode 2: Design of concrete structures - Part 1-1: General rules and rules for buildings*

EN 1992-1-2, *Eurocode 2: Design of concrete structures - Part 1-2: General rules - Structural fire design*

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

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1.1

anchor fastener

element made of steel or malleable iron either cast into concrete or post-installed into a hardened concrete member and used to transmit applied loads (see Figures 3.1 to 3.3)

Note 1 to entry: The term anchor is used in the context of anchor channels.

3.1.2

anchor channel

steel profile with rigidly connected anchors (see Figure 3.2) installed prior to concreting

Note 1 to entry: In the case of anchor channels, two or more steel anchors are rigidly connected to the back of the channel and embedded in concrete.

3.1.3

attached element

structural or non-structural component that is connected to the attachment

3.1.4

attachment

fixture

assembly that transmits loads to the fastener or anchor channel

3.1.5

base material

concrete member in which the fastener or anchor channel is installed

3.1.6

bending

bending effect induced by a shear load applied with a lever arm with respect to the surface of the concrete member

3.1.7

bonded expansion fastener

bonded fastener designed such that the fastener element can move relative to the hardened bonding compound resulting in follow-up expansion (see Figure 3.3 h))

3.1.8

bonded fastener

fastener placed into a hole drilled in hardened concrete, which derives its resistance from a bonding compound placed between the wall of the hole in the concrete and the embedded portion of the fastener (see Figure 3.3 g))

3.1.9

cast-in fastener

headed bolt, headed stud, internal threaded socket with head at the embedded end or anchor channel installed before placing the concrete, see also headed fastener

3.1.10

channel bolt

screw or bolt which connects the element to be fixed to the anchor channel (see Figure 3.2)

3.1.11

characteristic edge distance

edge distance required to ensure that the edge does not influence the characteristic resistance of a fastening

3.1.12

characteristic resistance

5 % fractile of the resistance (value with a 95 % probability of being exceeded, with a confidence level of 90 %)

3.1.13

characteristic spacing

spacing required to ensure the characteristic resistance of a single fastener

3.1.14

combined pull-out and concrete failure of bonded fasteners

failure mode in which failure occurs at the interface between the bonding material and the base material or between the bonding material and the fastener element (bond failure) and contains a concrete cone at the top end

3.1.15

combined tension and shear loads

oblique load

tension and shear load applied simultaneously

3.1.16

concrete blow-out failure

spalling of the concrete on the side face of the concrete element at the level of the embedded head with no major breakout at the top concrete surface

Note 1 to entry: This is usually associated with fasteners with small side cover and deep embedment.

3.1.17

concrete breakout failure

failure that corresponds to a wedge or cone of concrete surrounding the fastener, group of fasteners or anchor of an anchor channel being separated from the base material

3.1.18

concrete pry-out failure

failure that corresponds to the formation of a concrete spall opposite to the loading direction under shear loading

3.1.19**concrete related failure modes****3.1.19.1****failure modes under tension loading**

pull-out failure, combined pull-out and concrete failure (bonded fasteners), concrete cone failure, concrete blow-out failure, concrete splitting failure, anchorage failure of supplementary reinforcement

3.1.19.2**failure modes under shear loading**

concrete pry-out failure, concrete edge failure

3.1.20**concrete screw**

threaded fastener screwed into a predrilled hole where threads create a mechanical interlock with the concrete (see Figure 3.3 f))

3.1.21**concrete splitting failure**

concrete failure mode in which the concrete fractures along a plane passing through the axis of the fastener or fasteners or anchors of an anchor channel

3.1.22**deformation-controlled expansion fastener**

post-installed fastener that derives its tensile resistance by expansion against the side of the drilled hole through movement of an internal plug in the sleeve (see Figure 3.3 c)) or through movement of the sleeve over an expansion element (plug), and with which, once set, no further expansion can occur

3.1.23**displacement**

movement of the loaded end of the fastener relative to the concrete member into which it is installed in the direction of the applied load; or, in the case of anchor channels, movement of a channel bolt (see Figure 3.2) or the anchor channel relative to the concrete element

Note 1 to entry: In tension tests, displacement is measured parallel to the axis of the fastener; in shear tests, displacement is measured perpendicular to the axis of the fastener.

3.1.24**ductile steel element**

element with sufficient ductility

Note 1 to entry: The ductility conditions are given in the relevant subclauses.

3.1.25**edge distance**

distance from the edge of the concrete member to the centre of the fastener or anchor of an anchor channel

3.1.26**effective embedment depth**

overall depth through which the fastener or anchor of an anchor channel transfers force to the surrounding concrete; see Figures 3.1 to 3.3

3.1.27

European Technical Product Specification

European Standard (EN), European Technical Assessment (ETA) for fastener or anchor channel based on a European Assessment Document (EAD) or a transparent and reproducible assessment that complies with all requirements of the relevant EAD

3.1.28

fastening

assembly of fixture and fasteners or anchor channel used to transmit loads to concrete

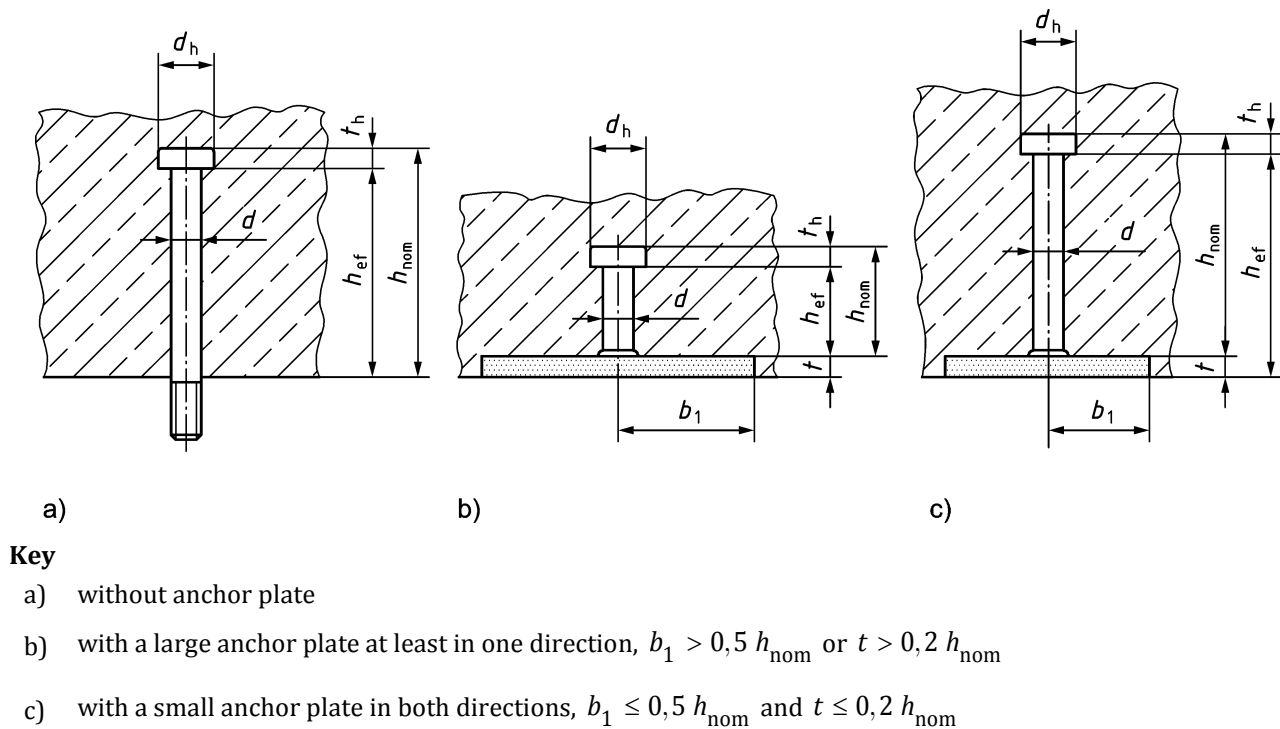
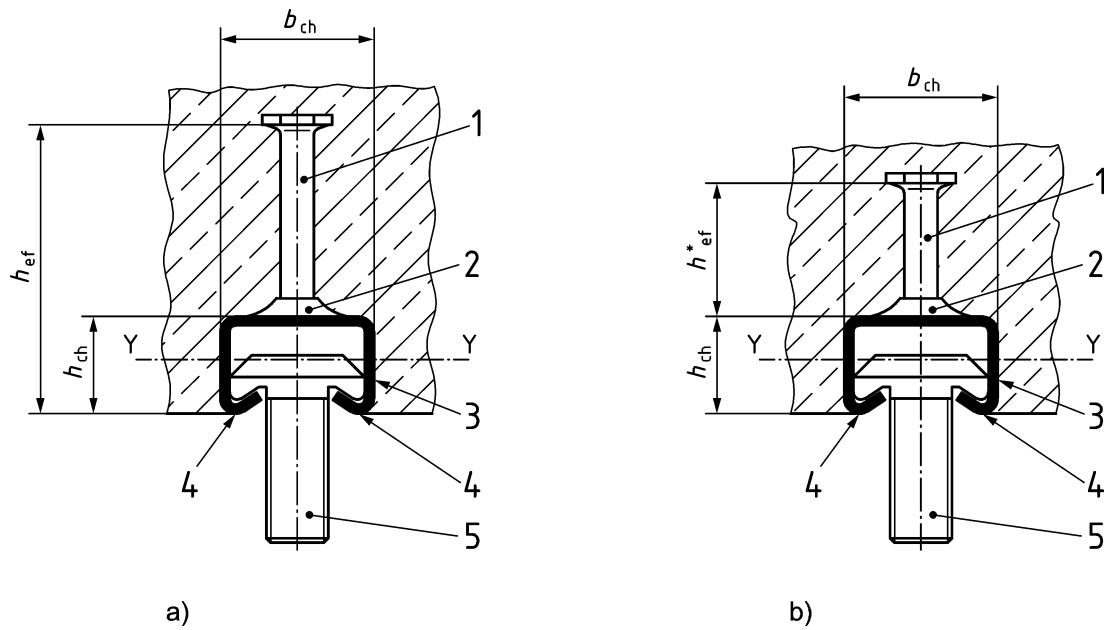


Figure 3.1 — Definition of effective embedment depth h_{ef} for headed fasteners

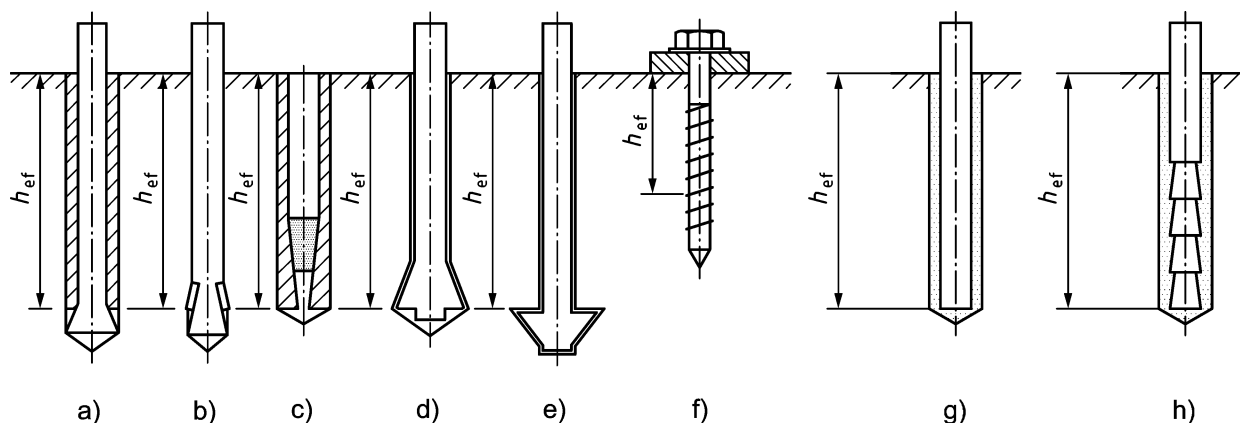
**Key**

- 1 anchor
- 2 connection between anchor and channel
- 3 channel
- 4 channel lip
- 5 channel bolt

a) h_{ef} for anchor channels (see 7.4.1.5 (1) and 7.4.1.5 (1) b))

b) h_{ef}^* for anchor channels (see 7.4.1.5 (1) a))

Figure 3.2 — Definitions for anchor channels



Key

- | | |
|--|------------------------------|
| a) torque-controlled fastener, sleeve type | e) undercut fastener, type 2 |
| b) torque-controlled fastener, wedge type | f) concrete screw |
| c) deformation-controlled fastener | g) bonded fastener |
| d) undercut fastener, type 1 | h) bonded expansion fastener |

Figure 3.3 — Definition of effective embedment depth h_{ef} for post-installed fasteners – Examples

3.1.29

flexure

bending effect in the channel of an anchor channel induced by a tension load

3.1.30

group of fasteners

number of fasteners with identical dimensions and characteristics acting together to support a common attachment, where the spacing of the fasteners does not exceed the characteristic spacing

3.1.31

headed fastener

cast-in steel fastener with a head at the embedded end (see Figure 3.1) that derives its tensile resistance from mechanical interlock at the head of the fastener

3.1.32

mechanical interlock

load transfer to a concrete member via interlocking surfaces

3.1.33

minimum edge distance

smallest allowable distance to allow adequate placing and compaction of concrete (cast-in place fasteners) and to avoid damage to the concrete during installation (post-installed fasteners), given in the European Technical Product Specification

3.1.34

minimum member thickness

smallest value for member thickness, in which a fastener or an anchor channel is allowed to be installed, given in the European Technical Product Specification

3.1.35**minimum spacing**

smallest value for distance between two fasteners to allow adequate placing and compaction of concrete (cast-in fasteners) and to avoid damage to the concrete during installation (post-installed fasteners), measured centreline to centreline, given in the European Technical Product Specification

3.1.36**post-installed fastener**

fastener installed in hardened concrete (see Figure 3.3)

3.1.37**pull-out failure**

both pull-out failure of mechanical fasteners and combined pull-out and concrete failure of bonded fasteners

3.1.38**pull-out failure of mechanical fasteners**

failure mode in which the fastener pulls out of the concrete without development of the full concrete resistance or in case of post-installed mechanical fasteners a failure mode in which the fastener body pulls through the expansion sleeve without development of the full concrete resistance

3.1.39**shear load**

load acting parallel to the concrete surface and transversely with respect to the longitudinal axis of the channel; load applied perpendicular to the longitudinal axis of a fastener

3.1.40**spacing**

distance between the centre lines of fasteners; distance between centre lines of channel bolts as well as anchors of anchor channels

3.1.41**steel failure of fastener**

failure mode characterized by fracture of the steel fastener parts

3.1.42**supplementary reinforcement****anchor reinforcement**

reinforcement tying a potential concrete breakout body to the concrete member

3.1.43**tension load**

load applied perpendicular to the surface of the base material (for anchor channels) and along the axis of a fastener

3.1.44**torque-controlled expansion fastener**

post-installed expansion fastener that derives its tensile resistance from the expansion of one or more sleeves or other components against the sides of the drilled hole through the application of torque, which pulls the cone(s) into the expansion sleeve(s) during installation

Note 1 to entry: After setting, tensile loading larger than the existing pre-stressing force causes additional expansion (follow-up expansion), see Figure 3.3 a) and b)).

3.1.45

undercut fastener

post-installed fastener that develops its tensile resistance from the mechanical interlock provided by undercutting of the concrete at the embedded end of the fastener

Note 1 to entry: The undercutting is achieved with a special drill before installing the fastener or alternatively by the fastener itself during its installation, see Figure 3.3 d) and e)).

3.2 Symbols and abbreviations

3.2.1 Indices

a	acceleration
adm	admissible
b	bond
c	concrete
ca	connection
cb	blow-out
cbo	channel bolt
ch	channel
cp	concrete pry-out
cr	cracked; characteristic
d	design value
E	action effects
Ed	design action
el	elastic
eq	seismic (earthquake)
F	action
fat	fatigue
fi	fire
fix	fixture
flex	bending
ind	indirect
k	characteristic value
L	load

l	local
M	material
max	maximum
min	minimum
N	normal force
nom	nominal
p	pull-out
pl	plastic
pr	prying
R	resistance, restraint
Rd	design resistance
re	reinforcement
s	steel
sp	splitting
u	ultimate
ucr	uncracked
v	vertical
V	shear force
y	yield

3.2.2 Superscripts

a	anchor
cb	channel bolt
ch	channel
g	load on or resistance of a group of fasteners
h	highest loaded (most stressed) fastener in a group
0	basic value

3.2.3 Actions and resistances (listing in alphabetical order)

NOTE In general, only those terms which are used in more than one section of this EN are defined. If a term is used only in one section, it may be defined in that section only.

a_g	design ground acceleration on type A ground
a_{vg}	vertical design ground acceleration on type A ground
A_a	seismic amplification factor (see Formula (C.4) and Table C.2)
A_h	load bearing area of the head of a headed fastener
A'_i	ordinate of a triangle with the height 1 at the position of the load N_{Ed} or V_{Ed} and the base length $2 l_i$ at the position of the anchor i of an anchor channel
a	ratio of the design ground acceleration on type A ground, a_g , to the acceleration of gravity g
a_{eq}	reduction factor to take into account the influence of large cracks and scatter of load displacement curves under seismic loading
a_{gap}	reduction factor to take into account inertia effects due to an annular gap between fastener and fixture in case of seismic shear loading, given in the relevant European Technical Product Specification
a_v	ratio of the vertical design ground acceleration on type A ground, a_{vg} , to the acceleration of gravity g (see Formula (C.6))
α_V	angle between design shear load V_{Ed} (single fastener) or V_{Ed}^g (group of fasteners) and a line perpendicular to the edge verified for concrete edge failure, $0^\circ \leq \alpha_V \leq 90^\circ$, see Figure 7.12 and Formula (7.48)
a_1, a_2	influencing factors according to EN 1992-1-1:2004, 8.4.4
C_d	nominal value, e.g. limiting displacement
C_{Ed}	resultant design compression force beneath the fixture (see Figure 6.2) and compression resulting from bending (see Figure 6.8)
C_{pr}	prying force
E	effect of action
E_d	design value of effect of actions
F	force in general
F_{va}	vertical effects of the seismic action for non-structural elements
g	acceleration of gravity
γ	partial factor
γ_a	importance factor of the non-structural element

γ_{inst}	factor accounting for the sensitivity to installation of post-installed fasteners
γ_{M}	partial factor for material
γ_{Mc}	partial factor for concrete cone, concrete edge, concrete blow-out and concrete pry-out failure modes
γ_{Ms}	partial factor for steel failure
H	building height, measured from the foundation or from the top of a rigid basement
M	moment
$M_{\text{Ed}}^{\text{ch}}$	design value of bending moment acting on the anchor channel due to tension loads $N_{\text{Ed}}^{\text{cb}}$ (see 6.3.2 (4))
$M_{\text{Rd,s,flex}}$	design resistance in case of steel failure in terms of flexure of channel under tension load
$M_{\text{Rk,s,flex}}$	characteristic resistance in case of steel failure in terms of flexure of channel under tension load
N	axial force (positive = tension force, negative = compression force)
N_{Ed}	resultant design tension force of the tensioned fastener
N_{Ed}^{a}	design value of tension load acting on an anchor of an anchor channel
$N_{\text{Ed}}^{\text{cb}}$	resultant design tension force acting on a channel bolt
$N_{\text{Ed}}^{\text{h}} \left(V_{\text{Ed}}^{\text{h}} \right)$	design value of tensile load (shear load) acting on the most stressed fastener of a group
$N_{\text{Ed}}^{\text{g}} \left(V_{\text{Ed}}^{\text{g}} \right)$	design value of the resultant tensile (shear) loads of the fasteners in a group effective in taking up tension (shear) loads
$N_{\text{Ed,re}}$	design value of tension load acting on the supplementary reinforcement
$N_{\text{Ed,re}}^{\text{a}}$	design value of tension load acting on the supplementary reinforcement of one anchor of the anchor channel
$N_{\text{Rd,a}}$	design resistance of supplementary reinforcement associated with anchorage failure
$N_{\text{Rd,c}}$	design resistance in case of concrete cone failure under tension load
$N_{\text{Rd,cb}}$	design resistance in case of concrete blow-out failure under tension load
$N_{\text{Rd,p}}$	design resistance in case of pull-out failure under tension load
$N_{\text{Rd,re}}$	design resistance in case of steel failure of supplementary reinforcement
$N_{\text{Rd,s}}$	design value of steel resistance of a fastener or a channel bolt under tension load
$N_{\text{Rd,s,a}}$	design value of steel resistance of one anchor of an anchor channel under tension load

$N_{Rd,s,c}$	design value of steel resistance of the connection between anchor and channel of an anchor channel under tension load
$N_{Rd,s,l}$	design resistance in case of steel failure in terms of local flexure of channel lip under tension load
$N_{Rd,sp}$	design resistance in case of concrete splitting failure under tension load
$N_{Rk,c}$	characteristic resistance in case of concrete cone failure under tension load
$N_{Rk,cb}$	characteristic resistance in case of concrete blow-out failure under tension load
$N_{Rk,p}$	characteristic resistance in case of pull-out failure under tension load
$N_{Rk,p,fi}$	characteristic tension resistance in case of pull-out failure under fire exposure
$N_{Rk,re}$	characteristic resistance in case of steel failure of supplementary reinforcement
$N_{Rk,s}$	characteristic value of steel resistance of a fastener or a channel bolt under tension load
$N_{Rk,s,a}$	characteristic value of steel resistance of one anchor of an anchor channel under tension load
$N_{Rk,s,c}$	characteristic value of steel resistance of the connection between anchor and channel of an anchor channel under tension load
$N_{Rk,s,fi}$	characteristic tension resistance in case of steel failure under fire exposure
$N_{Rk,s,l}$	characteristic resistance in case of steel failure in terms of local flexure of channel lip under tension load
$N_{Rk,sp}$	characteristic resistance in case of concrete splitting failure under tension load
ϕ_m	mandrel diameter of reinforcing bar
$\psi_{ch,c,N}$	factor taking into account the influence of a corner on the concrete cone resistance for an anchor channel
$\psi_{ch,c,Nb}$	factor taking into account the influence of a corner on the concrete blow-out resistance for an anchor channel
$\psi_{ch,c,V}$	factor taking into account the influence of a corner on the concrete edge resistance for an anchor channel
$\psi_{ch,e,N}$	factor taking into account the influence of an edge on the concrete cone resistance for an anchor channel
$\psi_{ch,h,Nb}$	factor taking into account the effect of the thickness of the concrete member on the concrete blow-out resistance for an anchor channel
$\psi_{ch,h,V}$	factor taking into account the influence of the thickness of the concrete member on the concrete edge resistance for an anchor channel
$\psi_{ch,s,N}$	factor taking into account the influence of neighbouring anchors on the concrete cone resistance for an anchor channel

$\psi_{ch,s,Nb}$	factor taking into account the influence of neighbouring anchors on the concrete blow-out resistance for an anchor channel
$\psi_{ch,s,V}$	factor taking into account the influence of neighbouring anchors on the concrete edge resistance for an anchor channel
$\psi_{ch,90^\circ,V}$	factor taking into account the influence of shear loads acting parallel to the edge on the concrete edge resistance for an anchor channel
$\psi_{ec,N}$	factor taking into account the group effect when different tension loads are acting on the individual fasteners of a group in case of concrete cone failure
$\psi_{ec,Nb}$	factor taking into account the group effect when different tension loads are acting on the individual fasteners of a group in case of concrete blow-out failure
$\psi_{ec,Np}$	factor taking into account the group effect when different tension loads are acting on the individual fasteners of a group in case of combined pull-out and concrete failure of bonded fasteners
$\psi_{ec,V}$	factor taking into account the group effect when different shear loads are acting on the individual fasteners of a group in case of concrete edge failure
$\psi_{g,Nb}$	factor taking into account a group effect of a number of fasteners in a row parallel to the edge in case of concrete blow-out failure
$\psi_{g,Np}$	factor taking into account a group effect for closely spaced bonded fasteners
$\psi_{h,sp}$	factor taking into account the influence of the actual member thickness on the splitting resistance
$\psi_{h,V}$	factor taking into account the fact that concrete edge resistance does not increase proportionally to the member thickness
$\psi_{M,N}$	factor taking into account the effect of a compression force between the fixture and concrete in case of bending moments with or without axial force
$\psi_{re,N}$	shell spalling factor
$\psi_{re,V}$	factor taking into account the effect of reinforcement located on the edge in case of concrete edge failure
$\psi_{s,N}$	factor taking into account the disturbance of the distribution of stresses in the concrete due to the proximity of an edge in the concrete member in case of concrete cone failure
$\psi_{s,Nb}$	factor taking into account the disturbance of the distribution of stresses in the concrete due to the proximity of an edge in the concrete member in case of concrete blow-out failure
$\psi_{s,Np}$	factor taking into account the disturbance of the distribution of stresses in the concrete due to the proximity of an edge in the concrete member in case of combined pull-out and concrete failure of bonded fasteners
$\psi_{s,V}$	factor taking into account the disturbance of the distribution of stresses in the concrete due to the proximity of further edges in the concrete member in case of concrete edge failure

$\psi_{\alpha,V}$	factor taking into account the influence of a shear load inclined to the edge in case of concrete edge failure
q	behaviour factor
q_a	behaviour factor for non-structural elements
Q_{ind}	indirect variable action
R	resistance
R_d	design value of resistance
R_k	characteristic value of resistance
δ	displacement of fastener
S	soil factor
S_a	horizontal seismic coefficient applicable to non-structural elements
S_{va}	vertical seismic coefficient applicable to non-structural elements
$s_{l,N}$	characteristic spacing of channel bolts for channel lip failure under tension load
$s_{l,V}$	characteristic spacing of channel bolts for channel lip failure under shear load
$\sigma_{Rk,s,fi}$	characteristic tension strength of a fastener in case of steel failure under fire exposure
T_a	fundamental period of vibration of the non-structural element
T_{Ed}	design value of applied torsional moment on fixture (see Figure 6.4 and Figure 7.11)
T_1	fundamental period of vibration of the building in the relevant direction
τ_{Rk}	characteristic bond resistance of a post-installed bonded fastener, depending on the concrete strength class, in uncracked ($\tau_{Rk,ucr}$) or cracked concrete ($\tau_{Rk,cr}$)
$\tau_{Rk,s,fi}$	characteristic shear strength of a fastener in case of steel failure under fire exposure
V	shear force
V_a	shear force on fastener (see Figure 6.4)
V_{Ed}	design shear force
$V_{Rd,c}$	design resistance in case of concrete edge failure under shear load
$V_{Rd,cp}$	design resistance in case of concrete pry-out failure under shear load
$V_{Rd,s}$	design value of steel resistance of a fastener or a channel bolt under shear load
$V_{Rd,s,a}$	design value of steel resistance of one anchor of an anchor channel under shear load
$V_{Rd,s,c}$	design value of steel resistance of the connection between anchor and channel of an anchor channel under shear load

$V_{Rd,s,M}$	design resistance in case of steel failure with lever arm under shear load
$V_{Rd,s,l}$	design resistance in case of steel failure in terms of local flexure of channel lip under shear load
$V_{Rk,c}$	characteristic resistance in case of concrete edge failure under shear load
$V_{Rk,cp}$	characteristic resistance in case of concrete pry-out failure under shear load
$V_{Rk,cp,fi}$	characteristic resistance in case of concrete pry-out failure under shear load and fire exposure
$V_{Rk,s}$	characteristic value of steel resistance of a fastener or a channel bolt under shear load
$V_{Rk,s,a}$	characteristic value of steel resistance of one anchor of an anchor channel under shear load
$V_{Rk,s,c}$	characteristic value of steel resistance of the connection between anchor and channel of an anchor channel under shear load
$V_{Rk,s,fi}$	characteristic shear resistance in case of steel failure under fire exposure
$V_{Rk,s,l}$	characteristic resistance in case of steel failure in terms of local flexure of channel lip under shear load
$V_{Rk,s,M}$	characteristic resistance in case of steel failure with lever arm under shear load
W_a	weight of the non-structural element
z	height of the non-structural element above the level of application of the seismic action

3.2.4 Concrete and steel

A_s	stressed cross section of a fastener
$A_{s,re}$	cross section of a reinforcing bar
ε	strain
f_{bd}	design bond strength of supplementary reinforcement
f_{ck}	nominal characteristic compressive cylinder strength (150 mm diameter by 300 mm height)
f_{uk}	nominal characteristic steel ultimate tensile strength
f_{yk}	nominal characteristic steel yield strength
$f_{yk,re}$	nominal characteristic steel yield strength of reinforcement
I_p	radial moment of inertia of the fastening
I_y	moment of inertia of the channel relative to the y-axis of the channel (see Figure 3.2)
σ	stress in the concrete (to determine cracked vs uncracked concrete state)
w_k	crack width
W_{el}	elastic section modulus calculated from the stressed cross section

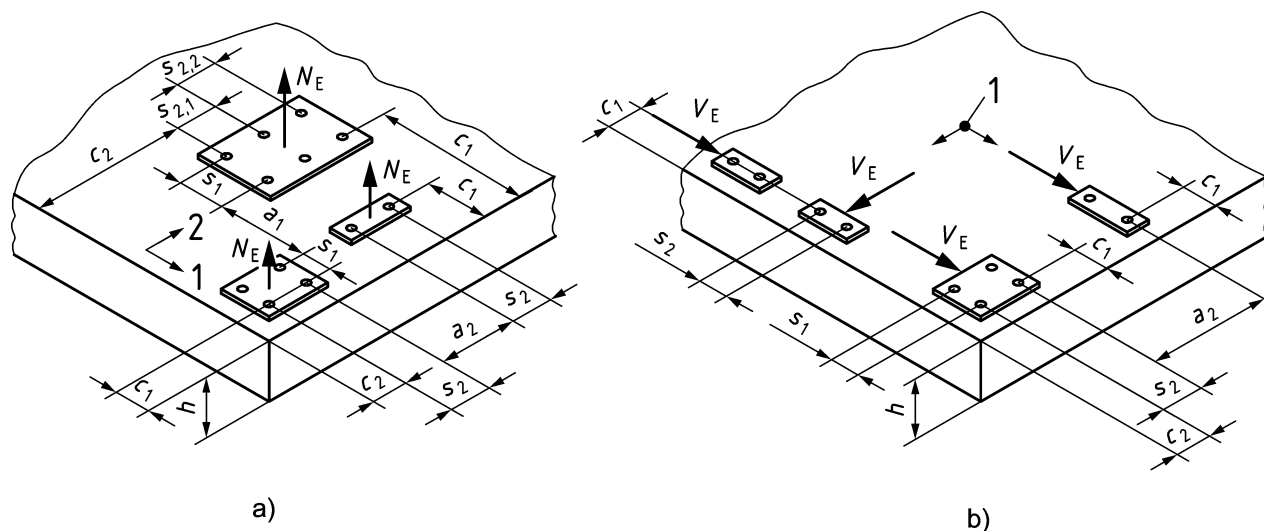
3.2.5 Fasteners and fastenings, reinforcement

a	spacing between outer fasteners in adjoining fastenings
$a_1(a_2)$	spacing between outer fasteners in adjoining fastenings in direction 1 (direction 2) (see Figure 3.4)
a_3	distance between concrete surface and point of assumed restraint of a fastener loaded by a shear force with lever arm (see Figure 6.6)
α	factor accounting for degree of restraint of the fastening
b_1	width of anchor plate (see Figure 3.1)
b_{ch}	width of the channel (see Figure 3.2)
b_{fix}	width of fixture
c	edge distance from the axis of a fastener or the axis of an anchor channel
c_1	edge distance in direction 1 (see Figure 3.4)
c_2	edge distance in direction 2 (see Figure 3.4), where direction 2 is perpendicular to direction 1
c_{cr}	characteristic edge distance to ensure the characteristic resistance of a single fastener
$c_{cr,N}$ ($c_{cr,V}$)	characteristic edge distance for ensuring the transmission of the characteristic resistance of a single fastener or anchor of an anchor channel in case of concrete break-out under tension loading (concrete edge failure under shear loading)
$c_{cr,Np}$	characteristic edge distance for ensuring the transmission of the characteristic resistance of a single bonded fastener under tension load in case of combined concrete and pull-out failure
c_{min}	minimum allowable edge distance
d	diameter of fastener bolt or thread diameter, diameter of the stud or shank of headed studs, effective depth to supplementary reinforcement (see Figure 6.8)
d_a	diameter of an anchor of an anchor channel (round anchor)
d_f	diameter of clearance hole in the fixture
d_h	diameter of the head of a headed fastener (see Figure 3.1)
d_{nom}	outside diameter of a fastener
E	modulus of elasticity
e_1	distance between shear load and concrete surface (see Figure 6.6)
e_N	eccentricity of resultant tension force of tensioned fasteners in respect to the centre of gravity of the tensioned fasteners (see Figure 6.3)
e_s	distance between the line of the shear load and the axis of the supplementary reinforcement for shear (see Figure 6.8)

e_v	eccentricity of resultant shear force of sheared fasteners in respect to the centre of gravity of the sheared fasteners (see Figure 7.15)
h	thickness of concrete member in which the fastener or anchor channel is installed (see Figure 3.4)
h_{ch}	height of the channel (see Figure 3.2)
h_{ef}	effective embedment depth (see Figures 3.1 to 3.3)
h_{min}	minimum allowed thickness of concrete member
h_{nom}	nominal length of the headed fastener welded to the anchor plate
l_1	anchorage length of the reinforcing bar in the assumed concrete break-out body (see Figures 7.2 and 7.10)
l_a	effective lever arm of the shear force acting on a fastener or on an anchor channel (see Figure 6.6) used in the calculation
l_{bd}	design anchorage length of reinforcement
l_i	influence length of an external load N_{Ed} or V_{Ed} along an anchor channel (see Figure 6.7 and Formula (6.5))
n	number of fasteners in a group
n_{re}	number of legs of the supplementary reinforcement effective for one fastener
ϕ	diameter of reinforcing bar
s	centre to centre spacing of fasteners in a group (see Figure 3.4) or anchors of an anchor channel (see Figure 6.7) or spacing of reinforcing bars
s_1 (s_2)	spacing of fasteners in a group in direction 1 (direction 2), (see Figure 3.4)
s_{cbo}	spacing of channel bolts of an anchor channel
s_{cr}	characteristic spacing for ensuring the transmission of the characteristic resistance of a single fastener or anchor of an anchor channel
$s_{cr,N}$ ($s_{cr,V}$)	characteristic spacing of fasteners or anchors of anchor channels to ensure the characteristic resistance of the individual fasteners or anchors of an anchor channel in case of concrete cone failure under tension load (concrete edge failure under shear load)
s_{min}	minimum allowable spacing
t	thickness of anchor plate (see Figure 3.1)
t_{fix}	thickness of the fixture
t_{grout}	thickness of grout layer
t_h	thickness of head of headed fastener
z	internal lever arm of a fastening calculated according to the theory of elasticity (see Figure 6.2 and Formula (7.7)); internal lever arm of concrete member (see Figure 6.8)

3.2.6 Units

In this EN SI-units are used. Unless stated otherwise in the formulae, the following units are used: dimensions are given in mm, cross sections in mm², section modulus in mm³, moment of inertia in mm⁴, forces and loads in N and stresses, strengths and moduli of elasticity in N/mm².



Key

- 1 indices 1 and 2: For fastenings close to an edge under tension loads, index 1: direction perpendicular to the edge, index 2: direction parallel to the edge. For shear loads the indices depend on the edge for which the verification of concrete edge failure is performed (index 1: direction perpendicular to the edge for which verification is made; index 2: perpendicular to direction 1)
- a) fastenings subjected to tension load
- b) fastenings subjected to shear load in the case of fastenings near an edge

Figure 3.4 — Definitions related to concrete member dimensions, fastener spacing and edge distance

4 Basis of design

4.1 General

(1) With appropriate degrees of reliability fasteners and anchor channels shall sustain all actions and influences likely to occur during execution and use (ultimate limit state). They shall not deform to an inadmissible degree (serviceability limit state) and remain fit for the use for which they are required (durability). They shall not be damaged by accidental events to an extent disproportional to the original cause.

(2) Fastening and anchor channel shall be designed according to the same principles and requirements valid for structures given in EN 1990 including load combinations and EN 1992-1-1.

NOTE A design using the partial factors given in this EN and the partial factors given in the EN 1990 Annexes is considered to lead to a structure associated with reliability class RC2, i.e. a β -value of 3,8 for a 50 year reference period. For further information, see EN 1990.

(3) The design working life of the fasteners or anchor channels shall not be less than that of the fixture. The partial factors for resistance and durability in this EN are based on a design working life of 50 years for the fastening or anchor channel.

(4) Values of actions shall be obtained from the relevant parts of the EN 1991 series and EN 1998 series in the case of seismic actions (see Annex C).

(5) If the fastening is subjected to fatigue or seismic actions, only fasteners suitable for this application shall be used (see relevant European Technical Product Specification).

(6) The design of the concrete member to which the fixture transfers loads shall comply with the EN 1992-1 series and the requirements of Annex A for safe transmission of loads to the supports of the member.

(7) For the design and execution of fastenings and anchor channels the same quality requirements are valid as for the design and execution of structures and the attachment:

- the design of the fastening and of an anchor channel shall be performed by qualified personnel;
- the execution shall comply with the requirements stated in Annex F.

4.2 Required verifications

(1) Fasteners shall be verified in accordance with EN 1992-1-1 and EN 1998-1 (where applicable).

(2) In the ultimate limit state, verifications are required for all appropriate load directions and all relevant failure modes.

(3) In the serviceability limit state, it shall be shown that the displacements occurring under the relevant actions are not larger than the admissible displacement.

(4) The material of the fastener and the corrosion protection shall be selected and demonstrated taking into account the environmental conditions at the place of installation, and whether the fasteners are inspectable, maintainable and replaceable. Information is given in informative Annex B.

(5) Where applicable the fastening shall have an adequate fire resistance. For the purpose of this EN it is assumed that the fire resistance of the fixture is adequate. Annex D describes the principles, requirements and rules for the design of fastenings exposed to fire.

4.3 Design format

(1) At the ultimate limit state it shall be shown that:

$$E_d \leq R_d \quad (4.1)$$

and at the serviceability limit state it shall be shown that

$$E_d \leq C_d \quad (4.2)$$

(2) The forces in the fasteners shall be derived using appropriate combinations of actions on the fixture in accordance with EN 1990. Forces Q_{ind} resulting from restraint to deformation, intrinsic (e.g. shrinkage) or extrinsic (e.g. temperature variations), of the attached member shall be taken into account in the design of fasteners. The design action shall be taken as $\gamma_{ind} \cdot Q_{ind}$.

(3) In general actions on the fixture may be calculated ignoring the displacement of the fasteners or of the anchor channels. However, the effect of displacement of the fasteners or of the anchor channels should be considered when a statically indeterminate stiff element is fastened.

(4) In the ultimate limit state the value of the design resistance is obtained from the characteristic resistance of the fastener, the group of fasteners or anchor channels as follows:

$$R_d = R_k / \gamma_M \quad (4.3)$$

(5) In the serviceability limit state the value E_d , which is the design value of fastener or anchor channel displacement, shall be evaluated from the information given in the relevant European Technical Product Specification. Furthermore, cracking of the concrete for fastening with supplementary reinforcement and for embedded base plates close to an edge loaded in shear shall be considered. For C_d , see Clause 11.

4.4 Verification by the partial factor method

4.4.1 Partial factors for actions

(1) Partial factors shall be in accordance with EN 1990.

(2) For the verification of indirect and fatigue actions the values of the partial factors γ_{ind} and $\gamma_{F,fat}$ shall be used.

NOTE The values of γ_{ind} and $\gamma_{F,fat}$ for use in a Country may be found in its National Annex. The recommended values for ultimate limit state are $\gamma_{ind} = 1,2$ for concrete failure and $\gamma_{ind} = 1,0$ for other modes of failure, and in case of fatigue loading $\gamma_{F,fat} = 1,0$.

4.4.2 Partial factors for resistance

4.4.2.1 General

The factor to account for the sensitivity to installation of post-installed fasteners, γ_{inst} , has been included as part of γ_{Mc} (see Table 4.1). It has its origin in the prequalification of the product. The factor γ_{inst} is product dependent and is given in the relevant European Technical Product Specification. Therefore γ_{inst} shall not be modified.

Table 4.1 — Recommended values of partial factors

Failure modes	Partial factor	
	Permanent and transient design situations	Accidental design situation
Steel failure – fasteners		
Tension	$= 1,2 \cdot f_{uk}/f_{yk} \geq 1,4$	$= 1,05 \cdot f_{uk}/f_{yk} \geq 1,25$
Shear with and without lever arm	γ_{Ms}	$= 1,0 \cdot f_{uk}/f_{yk} \geq 1,25$ when $f_{uk} \leq 800 \text{ N/mm}^2$ and $f_{yk}/f_{uk} \leq 0,8$
		$= 1,3$ when $f_{uk} > 800 \text{ N/mm}^2$ or $f_{yk}/f_{uk} > 0,8$
Steel failure – anchor channels		
Tension in anchors and channel bolts	$= 1,2 \cdot f_{uk}/f_{yk} \geq 1,4$	$= 1,05 \cdot f_{uk}/f_{yk} \geq 1,25$
Shear with and without lever arm in channel bolts	γ_{Ms}	$= 1,0 \cdot f_{uk}/f_{yk} \geq 1,25$ when $f_{uk} \leq 800 \text{ N/mm}^2$ and $f_{yk}/f_{uk} \leq 0,8$
		$= 1,3$ when $f_{uk} > 800 \text{ N/mm}^2$ or $f_{yk}/f_{uk} > 0,8$
Connection between anchor and channel in tension and shear	$\gamma_{Ms,ca} = 1,8$	$= 1,6$
Local failure of anchor channel by bending of lips in tension and shear	$\gamma_{Ms,l} = 1,8$	$= 1,6$
Bending of channel	$\gamma_{Ms,flex} = 1,15$	$= 1,0$
Steel failure – supplementary reinforcement		
Tension	$\gamma_{Ms,re} = 1,15^a$	$= 1,0$

Concrete related failure		
Concrete cone failure, concrete edge failure, concrete blow-out failure, concrete pry-out failure	γ_{Mc}	$= \gamma_c \cdot \gamma_{inst}$
	γ_c	$= 1,5^a$ for seismic repair and strengthening of existing structures see the EN 1998 series
		$= \gamma_c \cdot \gamma_{inst}$ $= 1,2^a$ for seismic repair and strengthening of existing structures see the EN 1998 series
		$= 1,0$ for headed fasteners and anchor channels satisfying the requirements of 4.6 (in tension and shear)
	γ_{inst}	$\geq 1,0$ for post-installed fasteners in tension, see relevant European Technical Product Specification
		$= 1,0$ for post-installed fasteners in shear
Concrete splitting failure	γ_{Msp}	$= \gamma_{Mc}$
Pull-out and combined pull-out and concrete failure	γ_{Mp}	$= \gamma_{Mc}$
^a The values are in accordance with EN 1992-1-1.		

4.4.2.2 Ultimate limit state (static, quasi static and seismic loading)

(1) Partial factors for fastenings under static, quasi static and seismic loading shall be applied to characteristic resistances.

(2) The recommended values for the partial factors for fastenings under seismic loading are identical to the corresponding values for quasi static loading. For accidental loads the partial factors according to Table 4.1 are recommended.

NOTE The value of a partial factor for use in a Country under static, quasi static, seismic and accidental loading may be found in its National Annex, when the partial factor is not product dependent. The recommended values are given in Table 4.1. They take into account that the characteristic resistance for steel failure is based on f_{uk} , except f_{yk} should be used for bending of the channel of anchor channels and steel failure of supplementary reinforcement.

4.4.2.3 Ultimate limit state (fatigue loading)

Partial factors for fastenings under fatigue loading $\gamma_{Ms,fat}$, $\gamma_{Mc,fat}$, $\gamma_{Msp,fat}$ and $\gamma_{Mp,fat}$ shall be applied to characteristic resistances.

NOTE The values of the partial factors for fastenings under fatigue loading for use in a Country may be found in its National Annex. For the partial factor for material, the following values are recommended: $\gamma_{Ms,fat} = 1,35$ (steel failure) and $\gamma_{Mc,fat} = \gamma_{Msp,fat} = \gamma_{Mp,fat} = 1,5 \cdot \gamma_{inst}$ (concrete related failure modes).

4.4.2.4 Serviceability limit state

The partial factor for resistance is γ_M and shall be applied to characteristic resistances.

NOTE The value of the partial factor for serviceability limit state for use in a Country may be found in its National Annex. For the partial factor γ_M the value $\gamma_M = 1,0$ is recommended.

4.5 Project specification

(1) The project specification shall typically include the following.

- a) Strength class of the concrete used in the design and indication as to whether the concrete is assumed to be cracked or not cracked. If uncracked concrete is assumed, verification is required (see 4.7).
- b) Environmental exposure assumed in design (see EN 206).
- c) A note indicating that the number, manufacturer, type and geometry of the fasteners or manufacturer, type and geometry of anchor channel or channel bolts shall not be changed unless verified and approved by the responsible designer.
- d) Construction drawings or supplementary design documents should include:
 - 1) location of the fasteners or anchor channels in the structure, including tolerances;
 - 2) number and type of fasteners (including embedment depth) or type of anchor channels and channel bolts;
 - 3) spacing and edge distance of the fastenings or anchor channels including tolerances (normally these should be specified with positive tolerances only);
 - 4) thickness of fixture and diameter of the clearance holes (if applicable);

- 5) position of the attachment on the fixture including tolerances;
 - 6) maximum thickness of a possible intervening layer e.g. grout or insulation between the fixture and surface of the concrete;
 - 7) (special) installation instructions (if applicable). These shall not contradict the manufacturer's installation instructions.
- e) Reference to the manufacturer's installation instructions.
- f) A note that the fasteners shall be installed ensuring the specified embedment depth.
- (2) For additional quality assurance of the installation project specification may call for proof loading of installation on site.

4.6 Installation of fasteners

The resistance and reliability of fastenings are significantly influenced by the manner in which the fasteners are installed. The partial factors given in 4.4 are valid only when the conditions and the assumptions given in Annex F are fulfilled.

4.7 Determination of concrete condition

(1) In the region of the fastening the concrete may be cracked or uncracked. The condition of the concrete for the service life of the fastening shall be determined by the designer.

NOTE In general, it is conservative to assume that the concrete is cracked over its service life.

(2) Uncracked concrete may be assumed if it is proven that under the characteristic combination of loading at serviceability limit state the fastener with its entire embedment depth is located in uncracked concrete. This will be satisfied if Formula (4.4) is observed (compressive stresses are negative):

$$\sigma_L + \sigma_R \leq \sigma_{adm} \quad (4.4)$$

where

- σ_L is the stress in the concrete induced by external loads including fastener loads
- σ_R is the stress in the concrete due to restraint of intrinsic imposed deformations (e.g. shrinkage of concrete) or extrinsic imposed deformations (e.g. due to displacement of support or temperature variations). If no detailed analysis is conducted, then $\sigma_R = 3 \text{ N/mm}^2$ should be assumed;
- σ_{adm} is the admissible tensile stress for the definition of uncracked concrete.

The stresses σ_L and σ_R should be calculated assuming that the concrete is uncracked. For concrete members which transmit loads in two directions (e.g. slabs, walls and shells) Formula (4.4) should be fulfilled for both directions.

NOTE The value of σ_{adm} may be found in a Country's National Annex. The recommended value is $\sigma_{adm} = 0$ and is based on the characteristic combination of loading at the serviceability limit state.

5 Durability

Fasteners and fixtures shall be chosen to have adequate durability taking into account the environmental conditions for the structure (such as exposure classes) as given in EN 1992-1-1.

NOTE 1 Product specific information might be stated in the relevant European Technical Product Specification.

NOTE 2 Further information is given in informative Annex B.

6 Derivation of forces acting on fasteners – analysis

6.1 General

(1) Clause 6 applies to static and quasi static loading. The requirements for fatigue and seismic loading are given in Clauses 8 and 9, respectively.

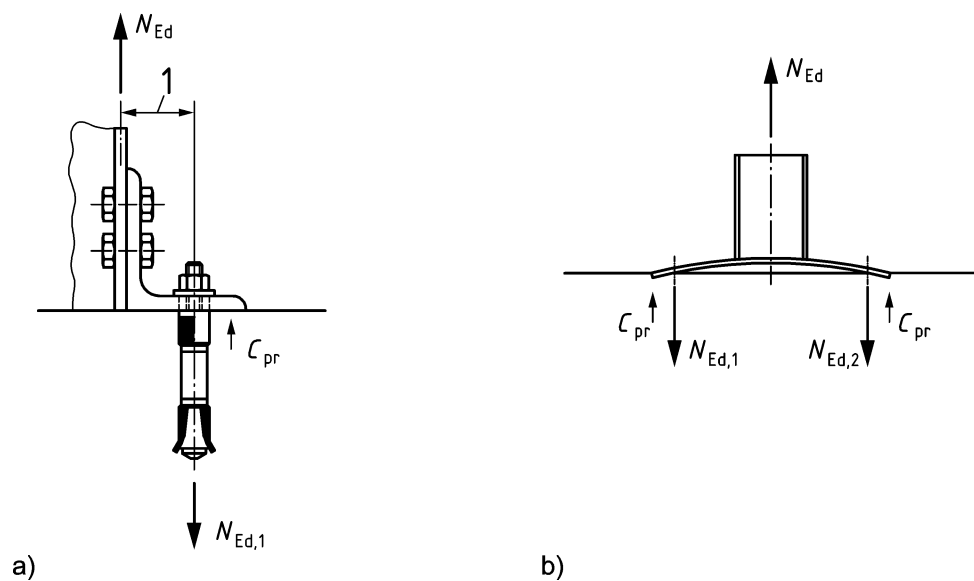
(2) The actions acting on a fixture shall be transferred to the fasteners as statically equivalent tension and shear forces.

(3) When a bending moment and/or a compression force act on a fixture, which is in contact with concrete or mortar, a friction force will develop. If a shear force is also acting on a fixture, this friction will reduce the shear force on the fastener. However, in this EN friction forces are neglected in the design of the fastenings.

(4) Eccentricities and prying effects shall be explicitly considered in the design of the fastening (see Figure 6.1). Prying forces C_{pr} arise with deformation of the fixture and displacement of the fasteners.

(5) In general, elastic analysis may be used for establishing the loads on individual fasteners both at ultimate and serviceability limit states.

For ultimate limit states plastic analysis for headed and post-installed fasteners may be used, if the conditions of CEN/TR 17081, *Design of fastenings for use in concrete — Plastic design of fastenings with headed and post-installed fasteners*, are observed.

**Key**

1 eccentricity

 C_{pr} prying force

a) $N_{Ed,1} = N_{Ed} + C_{pr}$

b) $N_{Ed,1} = N_{Ed,2} = 0,5N_{Ed} + C_{pr}$

Figure 6.1 — Eccentricity and prying action – Examples for amplification of tension forces acting on fastener a) due to eccentricity and b) due to prying action

6.2 Headed fasteners and post-installed fasteners

6.2.1 Tension loads

(1) The design value of tension loads acting on each fastener due to the design values of normal forces and bending moments acting on a rigid fixture may be calculated assuming a linear distribution of strains as shown in Figure 6.2 and a linear relationship between strains and stresses. If the fixture bears on the concrete with or without a grout layer, the compression forces are transmitted to the concrete by the fixture. The load distribution to the fasteners may be calculated analogous to the elastic analysis of reinforced concrete using the following assumptions (see Figure 6.2).

- The fixture is sufficiently rigid such that linear strain distribution will be valid (analogous to Bernoulli hypothesis).
- The axial stiffness of all fasteners is equal. The stiffness should be determined on the basis of the elastic steel strains in the fastener.
- The modulus of elasticity of the concrete is taken from EN 1992-1-1. As a simplification, the modulus of elasticity of concrete may be assumed as $E_c = 30\,000\text{ N/mm}^2$. If no specific information is available in the relevant European Technical Product Specification, the modulus of elasticity of steel of the fastener may, as a simplification, be assumed as $E_s = 210\,000\text{ N/mm}^2$.
- In the zone of compression under the fixture the fasteners do not take up normal forces.