SLOVENSKI STANDARD
SIST-TS CEN/TS 1992-4-2:2009

01-oktober-2009

Projektiranje pritrjevanja za uporabo v betonu - 4-2. del: Glavna pritrjevala

Design of fastenings for use in concrete - Part 4-2: Headed Fasteners

Bemessung von Befestigungen in Beton - Teil 4-2: Kopfbolzen

Conception-calcul des éléments de fixation pour béton - Partie 4-2 : Eléments de fixation à tête

Ta slovenski standard je istoveten z: CEN/TS 1992-4-2:2009

ICS:

21.060.01	Vezni elementi na splošno	Fasteners in general
91.080.40	Betonske konstrukcije	Concrete structures

SIST-TS CEN/TS 1992-4-2:2009 en,fr,de

TECHNICAL SPECIFICATION

SPÉCIFICATION TECHNIQUE

TECHNISCHE SPEZIFIKATION

CEN/TS 1992-4-2

May 2009

ICS 21.060.10; 91.080.40

English Version

Design of fastenings for use in concrete - Part 4-2: Headed Fasteners

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This Technical Specification (CEN/TS) was approved by CEN on 20 October 2008 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

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Ref. No. CEN/TS 1992-4-2:2009: E

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Foreword

This Technical Specification (CEN/TS 1992-4-2:2009) has been prepared by Technical Committee CEN/TC 250 “Structural Eurocodes”, the secretariat of which is held by BSI.

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

The Technical Specification CEN/TS 1992-4–2 — Headed fasteners, describes the principles and requirements for safety, serviceability and durability of headed fasteners for use in concrete. It is based on the limit state concept used in conjunction with a partial factor method.

This Technical Specification does not provide information about the use of National Determined Parameters (NDP).

CEN/TS 1992-4 'Design of fastenings for use in concrete' is subdivided into the following parts:

— *Part 1: General*

— *Part 2: Headed fasteners*

— *Part 3: Anchor channels*

— *Part 4: Post-installed fasteners — Mechanical systems*

— *Part 5: Post-installed fasteners — Chemical systems*

Relation to Part 1 of this Technical Specification TS

The principles and requirements of Part 2 of this CEN/TS are additional to those in Part 1, all the clauses and subclauses of which also apply to Part 2 unless varied in this Part. Additional information is presented under the relevant clauses/subclauses of Part 1 of the CEN/TS. The numbers for the clauses/sub-clauses of Part 2 continue from the number of the last relevant clauses/sub-clauses of Part 1.

The above principles also apply to Figures and Tables in Part 2.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: 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 the United Kingdom.

1 Scope

1.1 General

1.1.6 This document relies on characteristic resistances and distances which are stated in a European Technical Specification. In minimum the following characteristics should be given in a European Technical Specification as base for the design methods of this CEN/TS:

— $N_{Rk,p}$, $N_{Rk,s}$, $V_{Rk,s}$

— $M^{0}_{Rk,s}$

— $c_{cr,N}$, $s_{cr,N}$

— $c_{cr,sp}$, $s_{cr,sp}$

— c_{min}, s_{min}, h_{min}

— limitations on concrete strength classes of base material

— k_{cr}, k_{ucr}, k_2, k_4, k_6, k_7

— d_h, d_{nom}, h_{ef}, l_f

— γ_{Mi} partial factors for material see also CEN/TS 1992-4-1:2009, clause 4.

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.

NOTE The following references to Eurocodes are references to European Standards and European Prestandards. These are the only European documents available at the time of publication of this TS. National documents take precedence until Eurocodes are published as European Standards.

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

CEN/TS 1992-4-1:2009, *Design of fastenings for use in concrete — Part 4-1: General*

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

EN ISO 13918, *Welding — Studs and ceramic ferrules for arc stud welding (ISO 13918:2008)*

3 Definitions and symbols

Definitions and symbols are given in CEN/TS 1992-4-1.

4 Basis of design

4.5.4 Design of welding should be in accordance with EN 1993-1.

4.5.5 The following assumptions in respect to installation have been made in this CEN/TS. The installation instructions should reflect them:

1) The fastener should be fixed to the formwork or auxiliary constructions in a way that no movement of the fastener will occur during placing of reinforcement or during pouring and compacting of the concrete.

2) Requirements for

   — adequate compaction particularly under the head of the stud or fastener and under the fixture,

   — provisions for vent openings in fixtures larger than 400 mm × 400 mm.

3) Requirement for inspection and approval of the correct installation of the fasteners by qualified personnel.

4) The following conditions should be observed if the fasteners are vibrated (not just punched) into the wet concrete immediately after pouring:

   — The size of the fixture does not exceed 200 mm × 200 mm and the number of fastenings is limited to 4 fasteners, so that it can be placed simultaneously during vibrating by the available personnel.

   — The installation is done according to a quality system.

   — The fastenings should not be moved after vibrating has been finished.

   — The concrete under the head of the headed stud or anchor as well as under the base plate should be properly compacted.

5) The welding procedure for studs should be done in accordance with the provisions given in the relevant European Technical Specification.

6) Inspection and approval of the correct installation of the fasteners is carried out by appropriately qualified personnel.

5 Determination of action effects

5.3 Tension forces in a supplementary reinforcement

5.3.1 General

Where supplementary reinforcement is provided, the design tension forces in the supplementary reinforcement should be established using an appropriate strut and tie model. The supplementary reinforcement should be designed to resist the total external load on the fastening.

5.3.2 Fasteners loaded in tension

The design tension forces $N_{\mathrm{Ed,re}}$ in the supplementary reinforcement should be calculated using the design load on the fastener.

5.3.3 Fixtures loaded in shear

The design tension force $N_{\mathrm{Ed,re}}$ in the supplementary reinforcement caused by the design shear force V_{Ed} acting on a fixture is given by Equation (1).

$$N_{\mathrm{Ed,re}} = \left(\frac{e_{\mathrm{s}}}{z} + 1\right) \cdot V_{\mathrm{ed}} \tag{1}$$

with (see Figure 1):

e_s = distance between reinforcement and shear force acting on a fixture

z = internal lever arm of the concrete member

$\approx 0{,}85d$

$$d \leq \min \begin{cases} 2\, h_{ef} \\ 2\, c_1 \end{cases}$$

If the supplementary reinforcement is not arranged in the direction of the shear force (see Figure 10c)) then this must be taken into account in the calculation of the design tension force of the reinforcement.

In the case of different shear forces on the fasteners of a fixture, Equation (1) should be solved for the shear load V_{Ed}^{h} of the most loaded fastener resulting in $N_{Ed,re}^{h}$.

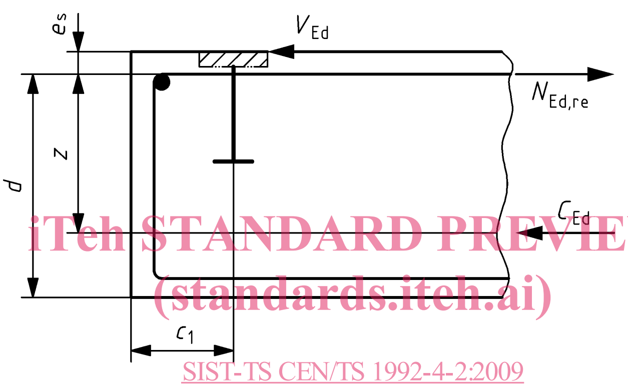


Figure 1 — Detailing of reinforcement to take up shear forces

6 Verification of ultimate limit state by elastic analysis

6.1 General

6.1.5 This section applies when forces on the fasteners have been calculated using elastic analysis. Annex B of Part 1 should be used for plastic analysis.

6.1.6 The spacing between outer headed fasteners of adjoining groups or the distance to single fasteners shall be $a > s_{cr,N}$.

6.2 Tension load

6.2.1 Required verifications

The required verifications are given in Table 1.

6.2.1.1 For fasteners without supplementary reinforcement the verifications of Table 1, lines 1 to 5 apply.

6.2.1.2 For fasteners with supplementary reinforcement the verifications of Table 1, lines 1, 2 and 4 to 7 apply.

6.2.2 Detailing of supplementary reinforcement

When the design relies on supplementary reinforcement, concrete cone failure according to Equation (4) needs not to be verified but the supplementary reinforcement should be designed to resist the total load.

The supplementary reinforcement to take up tension loads should comply with the following requirements (see also Figure 2):

a) In general, the same diameter of the reinforcement should be provided for all fasteners of a group. The reinforcement should consist of ribbed reinforcing bars ($f_{yk} \leq 500$ N/mm²) with a diameter d_s not larger than 16 mm and should be detailed in form of stirrups or loops with a mandrel diameter according to EN 1992-1-1.

Table 1 — Required verifications for headed fasteners loaded in tension

		Single fastener	Fastener group	
			most loaded fastener	fastener group
1	**Steel failure of fastener**	$N_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$	$N_{Ed}^{h} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$	
2	**Pull-out failure of fastener**	$N_{Ed} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	$N_{Ed}^{h} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	
3	**Concrete cone failure**	$N_{Ed} \leq N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$		$N_{Ed}^{g} \leq N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$
4	**Splitting failure**	$N_{Ed} \leq N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$		$N_{Ed}^{g} \leq N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$
5	**Blow-out failure**[a]	$N_{Ed} \leq N_{Rd,cb} = \frac{N_{Rk,cb}}{\gamma_{Mc}}$		$N_{Ed}^{g} \leq N_{Rd,cb} = \frac{N_{Rk,cb}}{\gamma_{Ms}}$
6	**Steel failure of reinforcement**	$N_{Ed,re} \leq N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$	$N_{Ed,re}^{h} \leq N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$	
7	**Anchorage failure of reinforcement**	$N_{Ed,re} \leq N_{Rd,a}$	$N_{Ed,re}^{h} \leq N_{Rd,a}$	

[a] Not required for fasteners with $c > 0{,}5\, h_{ef}$

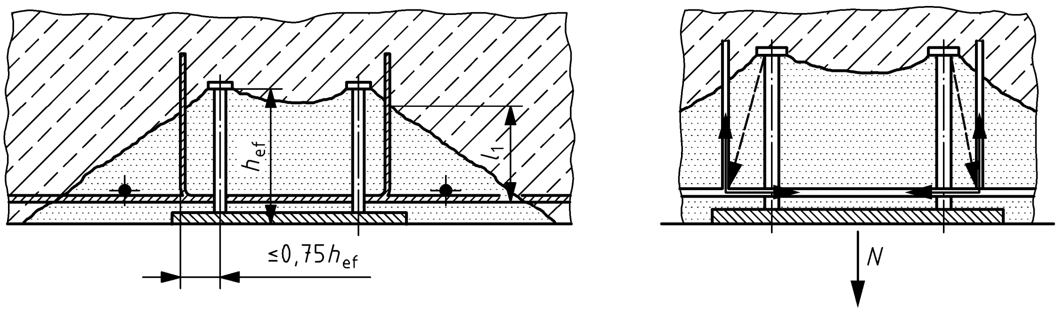


Figure 2 — Example for a multiple fastening with supplementary reinforcement to take up tension loads and corresponding strut and tie model

b) The supplementary reinforcement should be placed as close to the fasteners as practicable to minimize the effect of eccentricity associated with the angle of the failure cone. Preferably, the supplementary reinforcement should enclose the surface reinforcement. Only these reinforcement bars with a distance $\leq 0{,}75\ h_{ef,}$ from the fastener should be assumed as effective.

c) The minimum anchorage length of supplementary reinforcement in the concrete failure cone is $\min l_1 = 4d_s$ (anchorage with bends, hooks or loops) or $\min l_1 = 10d_s$ (anchorage with straight bars with or without welded transverse bars).

d) The supplementary reinforcement should be anchored outside the assumed failure cone with an anchorage length l_{bd} according to EN 1992-1-1.

e) A surface reinforcement should be provided as shown in Figure 2 designed to resist the forces arising from the assumed strut and tie model, taking into account the splitting forces according to 6.2.6.

6.2.3 Steel failure of fastener

The characteristic resistance of a fastener in case of steel failure $N_{Rk,s}$ is given in the relevant European Technical Specification. The strength calculation is based on f_{uk}.

6.2.4 Pull-out failure of fastener

The characteristic resistance in case of pull-out failure $N_{Rk,p}$ is given in the relevant European Technical Specification.

NOTE The characteristic resistance $N_{Rk,p}$ is limited by the concrete pressure under the head of the fastener according to Equation (2):

$$N_{Rk,\,p} = 6 \cdot A_h \cdot f_{ck,\,cube} \cdot \psi_{ucr,\,N} \qquad (2)$$

with

A_h = load bearing area of the head of the fastener

$$= \frac{\pi}{4}\left(d_h^2 - d^2\right) \qquad (3)$$

$f_{ck,cube,}$ characteristic cube strength of the concrete strength class but noting the limitations given in the relevant European Technical Specification

$\psi_{ucr,\,N}$ = 1,0 for fasteners in cracked concrete
= 1,4 for fasteners in non-cracked concrete

6.2.5 Concrete cone failure

The characteristic resistance of a fastener, a group of fasteners and the tensioned fasteners of a group of fasteners in case of concrete cone failure may be obtained by Equation (4).

$$N_{Rk,\,c} = N^{o}_{Rk,\,c} \cdot \frac{A_{c,\,N}}{A^{0}_{c,\,N}} \cdot \psi_{s,\,N} \cdot \psi_{re,\,N} \cdot \psi_{ec,\,N} \qquad [N] \qquad (4)$$

The different factors of Equation (4) are given below.

6.2.5.1 Characteristic resistance of a single fastener

— **Cracked concrete:**

The characteristic resistance of a single fastener placed in cracked concrete and not influenced by adjacent fasteners or edges of the concrete member is obtained by:

$$N^{0}_{\mathrm{Rk,c}} = k_{\mathrm{cr}} \cdot \sqrt{f_{\mathrm{ck,cube}}} \cdot h_{\mathrm{ef}}^{1,5} \quad \text{[N]} \qquad (5)$$

with k_{cr} factor to take into account the influence of load transfer mechanisms for applications in cracked concrete, the actual value is given in the corresponding European Technical Specification.

$f_{\mathrm{ck,cube}}$ [N/mm^2], characteristic cube strength of the concrete strength class but noting the limitations given in the relevant European Technical Specification.

h_{ef} [mm], see CEN/TS 1992-4-1:2009, Figure 5, the actual value is given in the corresponding European Technical Specification.

NOTE For headed fasteners according to current experience the value is 8,5. The actual value for a particular fastener may be taken from the relevant European Technical Specification.

— **Non-cracked concrete:**

The characteristic resistance of a single fastener placed in non-cracked concrete and not influenced by adjacent fasteners or edges of the concrete member is obtained by:

$$N^{0}_{\mathrm{Rk,c}} = k_{\mathrm{ucr}} \cdot \sqrt{f_{\mathrm{ck,cube}}} \cdot h_{\mathrm{ef}}^{1,5} \quad \text{[N]} \qquad (6)$$

with k_{ucr} factor to take into account the influence of load transfer mechanisms for applications in non-cracked concrete, the actual value is given in the corresponding European Technical Specification.

NOTE For headed fasteners according to current experience the value is 11,9. The actual value for a particular fastener may be taken from the relevant European Technical Specification.

6.2.5.2 Effect of axial spacing and edge distance

The geometric effect of axial spacing and edge distance on the characteristic resistance is taken into account by the value $A_{\mathrm{c,N}}/A^{0}_{\mathrm{c,N}}$, where

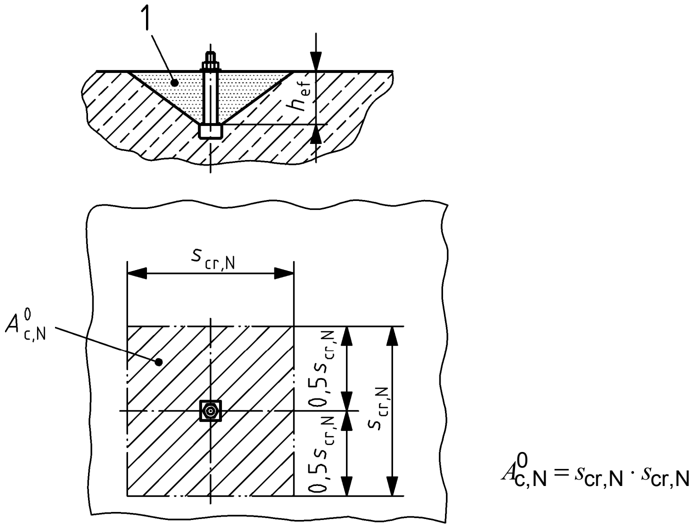
$A^{0}_{\mathrm{c,N}}$ = reference projected area, see Figure 3

$$= s_{\mathrm{cr,N}} \cdot s_{\mathrm{cr,N}} \qquad (7)$$

$A_{\mathrm{c,N}}$ = actual projected area, limited by overlapping concrete cones of adjacent fasteners ($s \leq s_{\mathrm{cr,N}}$) as well as by edges of the concrete member ($c \leq c_{\mathrm{cr,N}}$). Examples for the calculation of $A_{\mathrm{c,N}}$ are given in Figure 4

$s_{\mathrm{cr,N}}$, $c_{\mathrm{cr,N}}$ given in the corresponding European Technical Specification

NOTE For headed fasteners according to current experience $s_{\mathrm{cr,N}} = 2\, c_{\mathrm{cr,N}} = 3\, h_{\mathrm{ef}}$.



Key

1 Concrete cone

Figure 3 — Idealized concrete cone and area $A^0_{c,N}$ of concrete cone of an individual fastener