DRAFT FOR DEVELOPMENT

DD CEN/TS 1992-4-2:2009

Design of fastenings for use in concrete

Part 4-2: Headed Fasteners

ICS 21.060.10; 91.080.40

British Standards

National foreword

This Draft for Development is the UK implementation of CEN/TS 1992-4-2:2009.

This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature. It should be applied on this provisional basis, so that information and experience of its practical application can be obtained.

Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the international organization responsible for its conversion to an international standard. A review of this publication will be initiated not later than 3 years after its publication by the international organization so that a decision can be taken on its status. Notification of the start of the review period will be made in an announcement in the appropriate issue of Update Standards.

According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into an international Standard, to extend the life of the Technical Specification or to withdraw it. Comments should be sent to the Secretary of the responsible BSI Technical Committee at British Standards House, 389 Chiswick High Road, London W4 4AL.

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.

Compliance with a British Standard cannot confer immunity from legal obligations.

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

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

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

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.

CEN members are required to announce the existence of this CEN/TS in the same way as for an EN and to make the CEN/TS available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the CEN/TS) until the final decision about the possible conversion of the CEN/TS into an EN is reached.

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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:

— $N_{\mathrm{Rk,p}}$, $N_{\mathrm{Rk,s}}$, $V_{\mathrm{Rk,s}}$

— $M^{0}_{\mathrm{Rk,s}}$

— $c_{\mathrm{cr,N}}$, $s_{\mathrm{cr,N}}$

— $c_{\mathrm{cr,sp}}$, $s_{\mathrm{cr,sp}}$

— 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).

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

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 $N_{Ed,re}^{h}$.

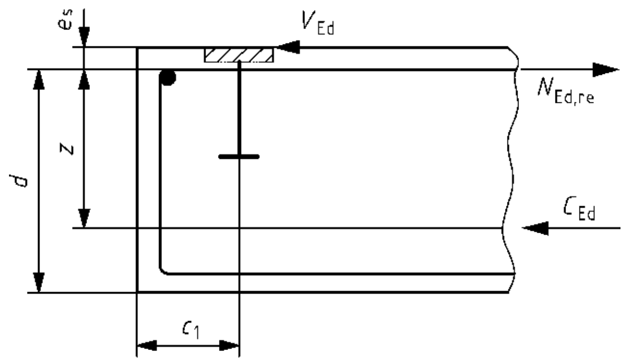


Figure 1— Detailing of reinforcement to take up shear forces

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/mm^2) 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**	$N_{Ed} \leq N_{Rd,s} = \dfrac{N_{Rk,s}}{\gamma_{Ms}}$	$N_{Ed}^{h} \leq N_{Rd,s} = \dfrac{N_{Rk,s}}{\gamma_{Ms}}$	
2	**Pull-out failure of fastener**	$N_{Ed} \leq N_{Rd,p} = \dfrac{N_{Rk,p}}{\gamma_{Mp}}$	$N_{Ed}^{h} \leq N_{Rd,p} = \dfrac{N_{Rk,p}}{\gamma_{Mp}}$	
3	**Concrete cone failure**	$N_{Ed} \leq N_{Rd,c} = \dfrac{N_{Rk,c}}{\gamma_{Mc}}$		$N_{Ed}^{g} \leq N_{Rd,c} = \dfrac{N_{Rk,c}}{\gamma_{Mc}}$
4	**Splitting failure**	$N_{Ed} \leq N_{Rd,sp} = \dfrac{N_{Rk,sp}}{\gamma_{Msp}}$		$N_{Ed}^{g} \leq N_{Rd,sp} = \dfrac{N_{Rk,sp}}{\gamma_{Msp}}$
5	**Blow-out failure**[a]	$N_{Ed} \leq N_{Rd,cb} = \dfrac{N_{Rk,cb}}{\gamma_{Mc}}$		$N_{Ed}^{g} \leq N_{Rd,cb} = \dfrac{N_{Rk,cb}}{\gamma_{Ms}}$
6	**Steel failure of reinforcement**	$N_{Ed,re} \leq N_{Rd,re} = \dfrac{N_{Rk,re}}{\gamma_{Ms,re}}$	$N_{Ed,re}^{h} \leq N_{Rd,re} = \dfrac{N_{Rk,re}}{\gamma_{Ms,re}}$	
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 $c > 0,5\ h_{ef}$

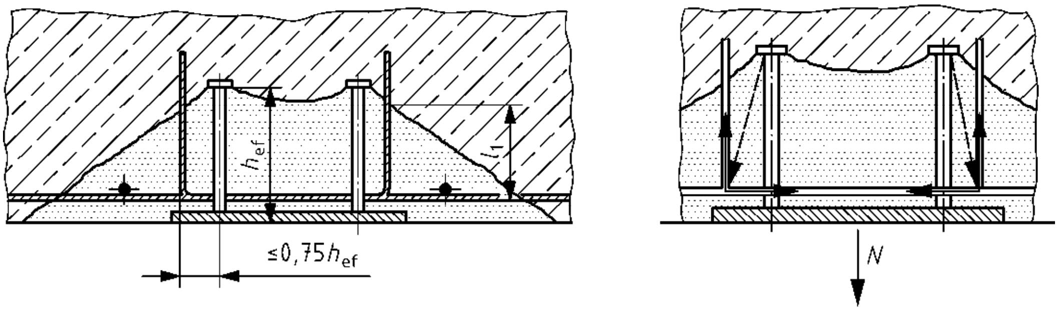


Figure 2 — Example for a multiple fastening with supplementary reinforcement to take up tension loads and corresponding strut and tie model

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 ≤ 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):

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

with

A_h = load bearing area of the head of the fastener

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

$f_{ck,cube,}$ 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).

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

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:

$$N^{o}_{Rk,c} = k_{cr} \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1,5} \quad [N] \tag{5}$$

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.

$f_{ck,cube}$ [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:

$$N^{o}_{Rk,c} = k_{ucr} \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1,5} \quad [N] \tag{6}$$

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 $A_{c,N}/A^0_{c,N}$, where

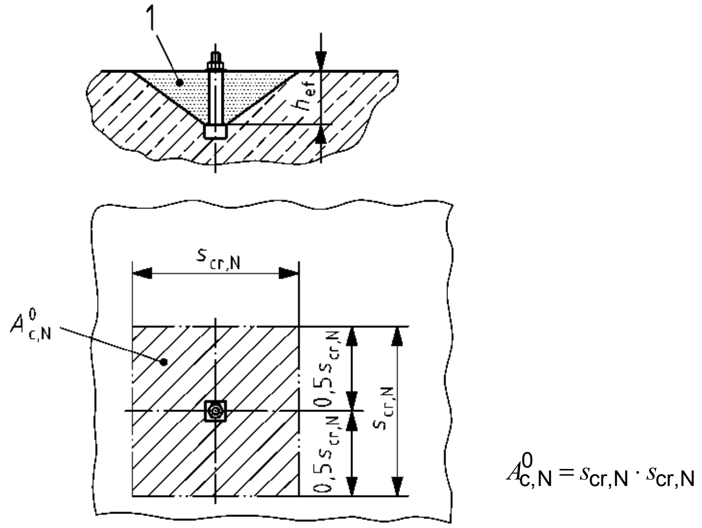
$A^0_{c,N}$ = reference projected area, see Figure 3

$$= s_{cr,N} \cdot s_{cr,N} \tag{7}$$

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

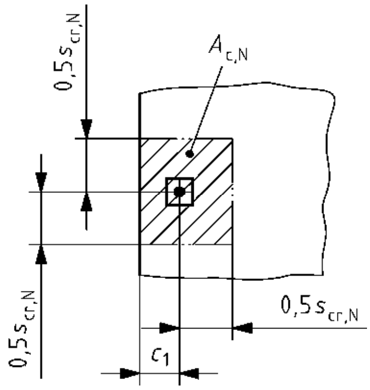
$s_{cr,N}$, $c_{cr,N}$ given in the corresponding European Technical Specification

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



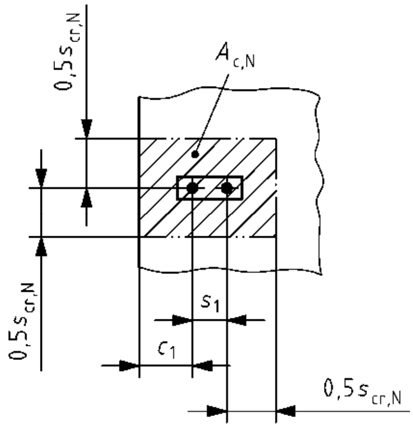
Key
1 Concrete cone

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

a) 

$A_{c,\,N} = (c_1 + 0{,}5\ s_{cr,\,N}) \cdot s_{cr,\,N}$

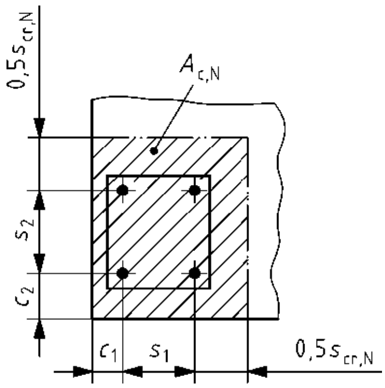
if: $c_1 \leq c_{cr,\,N}$

b) 

$A_{c,\,N} = (c_1 + s_1 + 0{,}5\ s_{cr,\,N}) \cdot s_{cr,\,N}$

if: $c_1 \leq c_{cr,\,N}$

$s_1 \leq s_{cr,\,N}$

c) 

$A_{c,\,N} = (c_1 + s_1 + 0{,}5\ s_{cr,\,N}) \cdot (c_2 + s_2 + 0{,}5\ s_{cr,\,N})$

if: $c_1;\ c_2 \leq c_{cr,\,N}$

$s_1\ ;\ s_2 \leq s_{cr,\,N}$

Key
a) Individual fastener at the edge of a concrete member
b) Group of two fasteners at the edge of a concrete member
c) Group of four fasteners at a corner of a concrete member

Figure 4 — Examples of actual areas $A_{c,\,N}$ of the idealised concrete cones for different arrangements of fasteners in case of axial tension load

6.2.5.3 Effect of the disturbance of the distribution of stresses in the concrete due to edges

The factor $\psi_{s,\,N}$ takes account of the disturbance of the distribution of stresses in the concrete due to edges of the concrete member. For fastenings with several edge distances (e.g. fastening in a corner of the concrete member or in a narrow member), the smallest edge distance c should be inserted in Equation (8).

$$\psi_{s,N} = 0{,}7 + 0{,}3 \cdot \frac{c}{c_{cr,N}} \leq 1 \qquad [-] \qquad (8)$$

6.2.5.4 Effect of shell spalling

The shell spalling factor $\psi_{re,N}$ takes account of the effect of a dense reinforcement for embedment depths h_{ef} < 100 mm:

$$\psi_{re,N} = 0{,}5 + \frac{h_{ef}}{200} \leq 1 \qquad [-] \qquad (9)$$

with: h_{ef} [mm]

Irrespective of the embedment depth of the fastener, $\psi_{re,N}$ may be taken as 1,0 in the following cases:

a) Reinforcement (any diameter) is provided at a spacing ≥ 150mm, or

b) Reinforcement with a diameter of 10 mm or less is provided at a spacing ≥ 100 mm.

6.2.5.5 Effect of the eccentricity of the load

The factor $\psi_{ec,N}$ takes account of a group effect when different tension loads are acting on the individual fasteners of a group.

$$\psi_{ec,N} = \frac{1}{1 + 2 \cdot e_N / s_{cr,N}} \leq 1 \qquad [-] \qquad (10)$$

with

e_N eccentricity of the resulting tensile load acting on the tensioned fasteners (see CEN/TS 1992-4-1:2009, 5.2).

Where there is an eccentricity in two directions, $\psi_{ec,N}$ should be determined separately for each direction and the product of both factors should be inserted in Equation (4).

6.2.5.6 Effect of the position of the fastening

The factor $\psi_{ucr,N}$ takes account of the position of the fastening in cracked or non-cracked concrete.

$\psi_{ucr,N}$ = 1,0 for fasteners in cracked concrete (11)

= 1,4 for fasteners in non-cracked concrete (12)

6.2.5.7 Effect of a narrow member

For the case of fasteners in an application with three or more edges distances less than $c_{cr,N}$ from the fasteners (see Figure 5) the calculation according to Equation (4) leads to conservative results. More precise results are obtained if in the case of single fasteners the value h_{ef} is substituted by

$$h'_{ef} = \frac{c_{max}}{c_{cr,N}} \cdot h_{ef} \qquad (13)$$

or in the case of groups h_{ef} is substituted by the larger value of

$$h'_{ef} = \frac{c_{max}}{c_{cr,N}} \cdot h_{ef} \text{ or } h'_{ef} = \frac{s_{max}}{s_{cr,N}} \cdot h_{ef} \quad (14)$$

with c_{max} = maximum distance from centre of a fastener to the edge of concrete member $\le c_{cr,N}$

s_{max} = maximum centre to centre spacing of fasteners $\le s_{cr,N}$

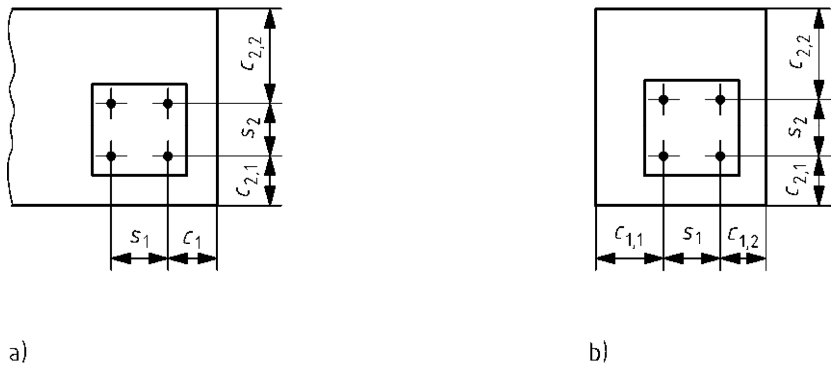
The value h'_{ef} is inserted in Equation (5) or Equation (6) and used for the determination of $A^0_{c,N}$ and $A_{c,N}$ according to Figures 3 and 4 as well as in Equations (7), (8) and (9), where the values

$$s'_{cr,N} = s_{cr,N} \cdot \frac{h'_{ef}}{h_{ef}} \quad (15)$$

$$c'_{cr,N} = c_{cr,N} \cdot \frac{h'_{ef}}{h_{ef}} \quad (16)$$

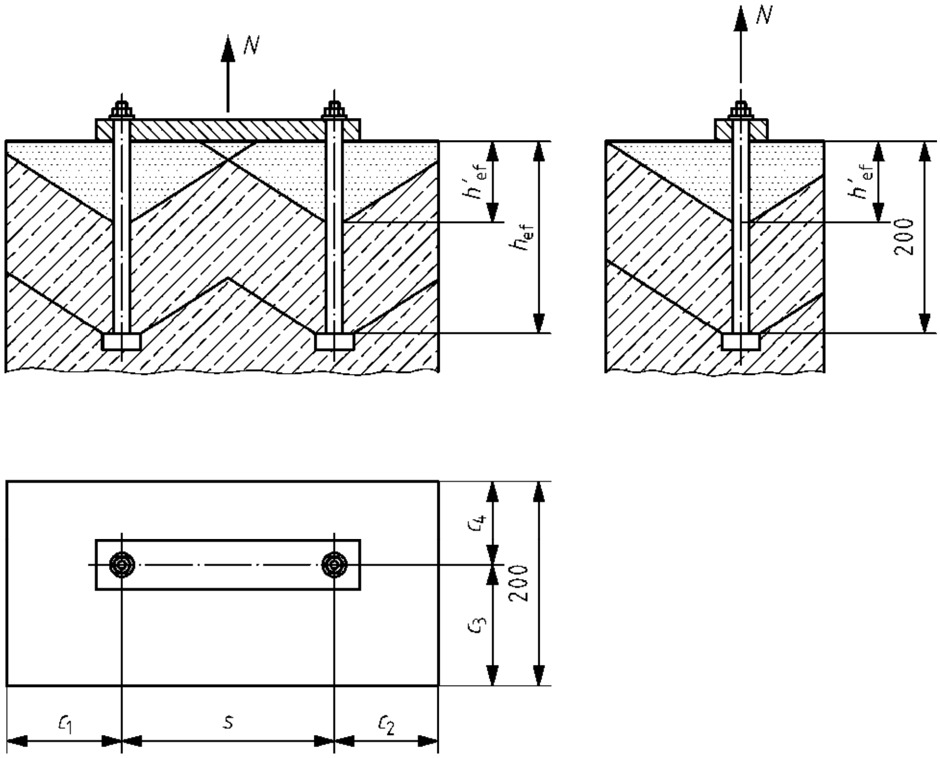
are inserted for $s_{cr,N}$ or $c_{cr,N}$, respectively.

NOTE An example for the calculation of h'_{ef} is illustrated in Figure 6.



Key
a) $(c_1;\ c_{2,1};\ c_{2,2}) \le c_{cr,N}$
b) $(c_{1,1};\ c_{1,2};\ c_{2,1};\ c_{2,2}) \le c_{cr,N}$

Figure 5 — Examples for fastenings in concrete members where h'_{ef} , $s'_{cr,N}$ and $c'_{cr,N}$ may be used



c_1 = 110 mm
c_2 = 100 mm
c_3 = 120 mm = c_{max}
c_4 = 80 mm
s = 210 mm
h_{ef} = 200 mm
h'_{ef} = 120/1,5 = 80 mm > 210/3 = 70mm

Figure 6 — Illustration of the calculation of h'_{ef} for a double fastening influenced by 4 edges

6.2.6 Splitting failure

6.2.6.1 Splitting failure due to installation

Splitting failure during installation e.g. by torquing of fasteners (see CEN/TS 1992-4-1:2009, Figure 3) is avoided by complying with minimum values for edge distances c_{min}, spacing s_{min}, and member thickness h_{min} and requirements for reinforcement as given in the relevant European Technical Specification.

NOTE Minimum values for edge distance, spacing and member thickness should also be observed for headed fasteners not torqued to allow adequate placing and compaction of the concrete.

6.2.6.2 Splitting failure due to loading

No verification of splitting failure is required if one of the following conditions is fulfilled:

a) The edge distance in all directions is $c \geq 1{,}0\ c_{cr,sp}$ for fastenings with one anchor and $c \geq 1{,}2\ c_{cr,sp}$ for fastenings with more than one anchor.

   The characteristic values $c_{cr,sp}$ and $s_{cr,sp}$ are given in the relevant European Technical Specification.

b) The characteristic resistance for concrete cone failure and pull-out failure is calculated for cracked concrete and reinforcement resists the splitting forces and limits the crack width to $w_k \leq 0{,}3$ mm.

   The required cross-section A_s of the splitting reinforcement may be determined as follows:

$$A_s = 0{,}5 \frac{\Sigma N_{Ed}}{f_{yk}/\gamma_{Ms,re}} \quad [mm^2] \tag{17}$$

with

ΣN_{Ed} = sum of the design tensile force of the fasteners in tension under the design value of the actions [N]

f_{yk} = nominal yield strength of the reinforcing steel ≤ 500 N/mm²

If the conditions a) and b) of 6.2.6.2 are not fulfilled, then the characteristic resistance of one fastener or a group of fasteners should be calculated according to Equation (18).

$$N_{Rk,sp} = N^0_{Rk} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{ec,N} \cdot \psi_{re,N} \cdot \psi_{h,sp} \quad [N] \tag{18}$$

with $N^0_{Rk} = \min(N_{Rk,p}, N^0_{Rk,c})$

$N_{Rk,p}$ according to Section 6.2.4

$N^0_{Rk,c}, \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{ucr,N}$ according to 6.2.5, however the values $c_{cr,N}$ and $s_{cr,N}$ should be replaced by $c_{cr,sp}$ and $s_{cr,sp}$. The values $c_{cr,sp}$ and $s_{cr,sp}$ are based on a member thickness h_{min}

The factor $\psi_{h,sp}$ takes into account the influence of the actual member depth h on the splitting resistance. For fasteners according to current experience it is given by Equation (19).

$$\psi_{h,sp} = \left(\frac{h}{h_{min}}\right)^{2/3} \leq \left(\frac{2\,h_{ef}}{h_{min}}\right)^{2/3} \tag{19}$$

For fastenings with several edge distances (e.g. fastening in a corner of the concrete member or in a narrow member), the smallest edge distance c shall be inserted in Equation (18).

NOTE If in the European Technical Specification $c_{cr,sp}$ for more than one member depth h is given, then the member depth valid for the used $c_{cr,sp}$ shall be inserted in Equation (4).

If the edge distance is smaller than the value $c_{cr,sp}$ then a longitudinal reinforcement should be provided along the edge of the member.

6.2.7 Blow-out failure

Verification of blow-out failure is not required if the edge distance in all directions exceeds $c = 0{,}5\ h_{ef}$. If a verification is required, the characteristic resistance in case of blow-out failure is:

$$N_{Rk,cb} = N^0_{Rk,cb} \cdot \frac{A_{c,Nb}}{A^0_{c,Nb}} \cdot \psi_{s,Nb} \cdot \psi_{g,Nb} \cdot \psi_{ec,Nb} \cdot \psi_{ucr,N} \quad [N] \tag{20}$$

The different factors of Equation (20) are given below:

NOTE For groups of fasteners perpendicular to the edge, which are loaded uniformly, verification is only required for the fasteners closest to the edge.

6.2.7.1 Characteristic resistance of a single anchor

The characteristic resistance of a single anchor, not influenced by adjacent fasteners or free structural component edges placed in cracked concrete, is obtained by:

$$N^0_{Rk,cb} = 8 \cdot c_1 \cdot \sqrt{A_h} \cdot \sqrt{f_{ck,cube}} \quad [N] \tag{21}$$

with

$f_{ck,cube}$ [N/mm²], characteristic cube strength of the concrete strength class but noting the limitations given in the relevant European Technical Specification

A_h [mm²], see Equation (3)

c_1 [mm], edge distance, see Figure 7

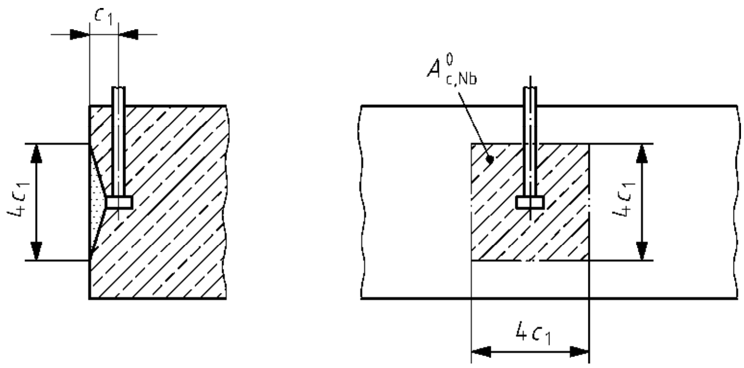


Figure 7 — Idealized concrete break-out body and area $A^0_{c,Nb}$ of an individual fastener in case of blow-out failure

6.2.7.2 Geometric 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

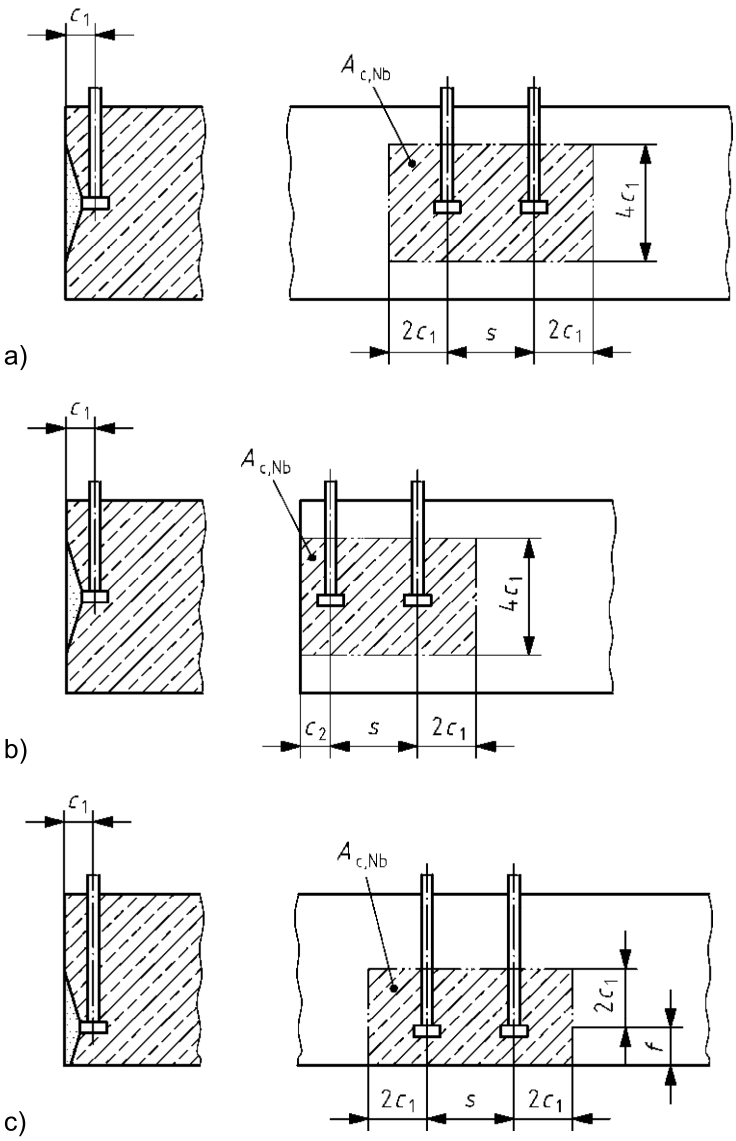
$A_{c,Nb}/A^0_{c,Nb}$

where

$A^0_{c,Nb}$ = reference projected area, see Figure 7

$= (4\ c_1)^2$ (22)

$A_{c,Nb}$ = actual projected area, limited by overlapping concrete break-out bodies of adjacent fasteners ($s \leq 4\ c_1$) as well as by edges of the concrete member ($c_2 \leq 2 \cdot c_1$) or the member depth. Examples for the calculation of $A_{c,Nb}$ are given in Figure 8.



a) $A_{c,\,Nb} = 4\,c_1\,(4\,c_1 + s)$

$s \leq 4\,c_1$

b) $A_{c,\,Nb} = 4\,c_1\,(c_2 + s + 2\,c_1)$

$c_2 \leq 2\,c_1$

$s \leq 4\,c_1$

c) $A_{c,\,Nb} = (2\,c_1 + f)\,(4\,c_1 + s)$

$f \leq 2\,c_1$

$s \leq 4\,c_1$

Figure 8 — Examples of actual areas Ac, Nb of the idealised concrete break-out bodies for different arrangements of fasteners in case of blow-out

6.2.7.3 Effect of the disturbance of the distribution of stresses in the concrete due to a corner

The factor $\psi_{s,\,Nb}$ takes account of the disturbance of the distribution of stresses in the concrete due to a corner of the concrete member. For fastenings with several edge distances (e.g. fastening in a corner of the concrete member), the smallest edge distance, c_2, should be inserted in Equation (23).

$$\psi_{s,\,Nb} = 0{,}7 + 0{,}3 \cdot \frac{c_2}{c_1} \leq 1 \tag{23}$$

6.2.7.4 Effect of the bearing area on the behaviour of groups

The factor $\psi_{g,\,Nb}$ takes account of the bearing areas of the individual fasteners of a group.

$$\psi_{g,\,Nb} = \sqrt{n} + (1 - \sqrt{n}) \cdot \frac{s_1}{4\,c_1} \geq 1 \tag{24}$$

with n = number of tensioned fasteners in a row parallel to the edge

$s_1 \leq 4c_1$

6.2.7.5 Effect of the eccentricity of the load

The factor $\psi_{ec,\,Nb}$ takes account of a group effect, when different loads are acting on the individual fasteners of a group.

$$\psi_{ec,\,Nb} = \frac{1}{1 + 2 \cdot e_N/(4\,c_1)} \tag{25}$$

with

e_N = eccentricity of the resulting tensile load in respect of the centre of gravity of the tensioned fasteners

6.2.7.6 Effect of the position of the fastening

The factor $\psi_{ucr,\,N}$ takes into account of the position of the fastening in cracked or non-cracked concrete.

$\psi_{ucr,\,N}$ = 1,0 for fastenings in cracked concrete (26)

= 1,4 for fastenings in non-cracked concrete (27)

6.2.8 Steel failure of the supplementary reinforcement

The characteristic resistance the supplementary reinforcement $N_{Rk,,re}$ of one fastener is

$$N_{Rk,\,re} = n \cdot A_s \cdot f_{yk} \tag{28}$$

with

A_s = cross section of one leg of the supplementary reinforcement

f_{yk} = nominal yield strength of the supplementary reinforcement ≤ 500 N/mm²

n = number of legs of the supplementary reinforcement effective for one fastener

6.2.9 Anchorage failure of the supplementary reinforcement in the concrete cone

The design resistance $N_{Rd,a}$ of the supplementary reinforcement of one fastener is given by

$$N_{Rd,\,a} = \sum_n \frac{l_1 \cdot \pi \cdot d_s \cdot f_{bd}}{\alpha} \tag{29}$$

with

l_1 = anchorage length of the supplementary reinforcement in the assumed failure cone (see Figure 2)

≥ $l_{b,min}$ = $4 \cdot d_s$ (anchorage with bends, hooks or loops)

≥ $10 \cdot d_s$ (anchorage with straight bars with or without welded transverse bars)

$l_{b,min}$ = minimum anchorage length

d_s = diameter of the reinforcement bar

f_{bd} = design bond strength according to EN 1992-1-1, taking into account the concrete cover of the supplementary reinforcement

α = influencing factor, according to EN 1992-1-1
= 0,7 for hooked bars

n = number of legs of the supplementary reinforcement effective for one fastener

6.3 Shear load

6.3.1 Required verifications

The required verifications are given in Table 2.

6.3.1.1 For fasteners without supplementary reinforcement the verifications of Table 2, lines 1 to 4 apply.

6.3.1.2 For fasteners with supplementary reinforcement the verifications of Table 2, lines 1, 2 and 4 to 6 apply.

Table 2 — Verification for headed fasteners loaded in shear

		Single fastener	Fastener groups	
			most loaded fastener	fastener group
1	**Steel failure of fastener without lever arm**	$V_{Ed} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	$V_{Ed}^{h} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	
2	**Steel failure of fastener with lever arm**	$V_{Ed} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	$V_{Ed}^{h} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	
3	**Concrete edge failure**	$V_{Ed} \leq V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$		$V_{Ed}^{g} \leq V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$
4	**Concrete pry-out failure**	$V_{Ed} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$		$V_{Ed}^{g} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$
5	**Steel failure of supplementary reinforcement**	$V_{Ed,re} \leq V_{Rd,re} = \frac{V_{Rk,re}}{\gamma_{Ms,re}}$	$V_{Ed,re}^{h} \leq V_{Rd,re} = \frac{V_{Rk,re}}{\gamma_{Ms,re}}$	
6	**Anchorage failure of supplementary reinforcement**	$V_{Ed,re} \leq N_{Rd,a}$	$V_{Ed,re}^{h} \leq N_{Rd,a}$	

6.3.2 Detailing of supplementary reinforcement

When the design relies on supplementary reinforcement, concrete cone failure according to Equation (32) needs not to be verified but the supplementary reinforcement should be designed to resist the total load. The supplementary reinforcement may be in the form of a surface reinforcement (Figure 9) or in the shape of stirrups or loops (Figure 10).

The supplementary reinforcement should be anchored outside the assumed failure cone with an anchorage length $l_{b,net}$ according to EN 1992-1-1.

In general, for all fasteners of a group the same diameter of reinforcement should be provided. It should consist of ribbed bars with f_{yk} ≤ 500 N/mm² and a diameter not larger than 16 mm. The mandrel diameter, d_b, should comply with EN 1992-1-1.

If the shear force is taken up by a surface reinforcement according to Figure 9, the following additional requirements should be met:

a) Only bars with a distance ≤ $0{,}75c_1$ from the fastener should be assumed as effective.

b) The anchorage length l_1 (see Figure 9) in the concrete breakout body is at least

min l_1 = 10 d_s, straight bars with or without welded transverse bars
= 4 d_s bars with a hook, bend or loop

c) Reinforcement along the edge of the member should be provided and be designed for the forces according to an appropriate strut and tie model (see Figure 9). As a simplification an angle of the compression struts of 45° may be assumed.

If the shear forces are taken up by a supplementary reinforcement is detailed according to Figure 10, it should enclose and contact the shaft of the fastener and be positioned as closely as possible to the fixture.

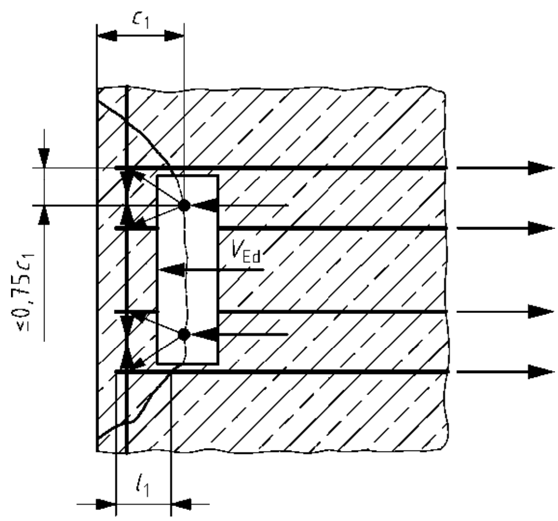


Figure 9 — Surface reinforcement to take up shear forces with simplified strut and tie model to design edge reinforcement

6.3.3 Steel failure of fastener

6.3.3.1 Shear load without lever arm

For headed fasteners welded or not welded to a steel fixture the characteristic resistance of a fastener in case of steel failure $V_{Rk,s}$ is given in the relevant European Technical Specification. The strength calculations are based on f_{uk}. In case of groups with fasteners with a hole clearance d_f given in CEN/TS 1992-4-1:2009, Table 1 and made of non-ductile steel, this characteristic shear resistance should be multiplied with the factor k_2. The factor k_2 is given in the relevant European Technical Specification.

NOTE According to current experience the factor k_2 for non-ductile steel is k_2 = 0,8.

6.3.3.2 Shear load with lever arm

For headed fastener the characteristic resistance in case of steel failure $V_{Rk,s}$ may be obtained from Equation (30).

$$V_{Rk,s} = \frac{\alpha_M \cdot M_{Rk,s}}{l} \quad [N] \tag{30}$$

with

α_M, l see CEN/TS 1992-4-1:2009, Section 5.2.3.3

$$M_{Rk,s} = M^0_{Rk,s} \cdot (1 - N_{Sd}/N_{Rd,s}) \tag{31}$$

$N_{Rd,s} = N_{Rk,s}/\gamma_{Ms}$

The characteristic resistance under tension load in case of steel failure $N_{Rk,s}$ the partial safety factor γ_{Ms} and the characteristic bending resistance of a single headed fastener $M^0_{Rk,s}$, are given in the relevant European Technical Specification.

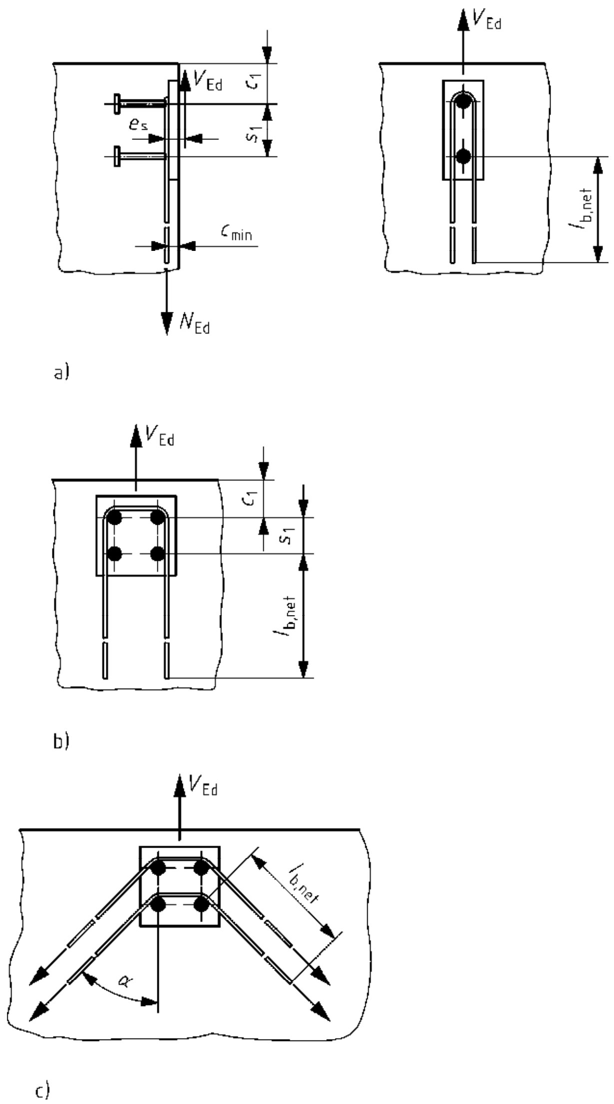


Figure 10 — Illustration of detailing of the supplementary reinforcement in form of loops, examples

NOTE The reinforcement in form of stirrups or loops should be detailed with a mandrel diameter according to EN 1992-1-1.

6.3.4 Concrete pry-out failure

Fastenings may fail due to a concrete pry-out failure at the side opposite to load direction. The corresponding characteristic resistance $V_{Rk,cp}$ may be calculated from Equation (32).

$$V_{Rk,\,cp} = k_3 \cdot N_{Rk,c} \qquad \text{[N]} \qquad (32)$$

with

k_3 factor to be taken from the relevant European Technical Specification, valid for applications without supplementary reinforcement. In case of supplementary reinforcement the factor k_3 should be multiplied with 0,75

$N_{Rk,c}$ according to 6.2.5, determined for a single fastener or all fasteners in a group loaded in shear

NOTE In cases where a fastener group is loaded by shear loads and/or external torsion moments, the direction of the individual shear loads may alter. In the example of Figure 11 the shear loads acting on the individual anchors neutralise each other and the shear load acting on the entire group is V_{Ed} = 0. Then verification of pry-out failure for the entire group according to Equation (32) is substituted by the verification of the most unfavourable anchor.

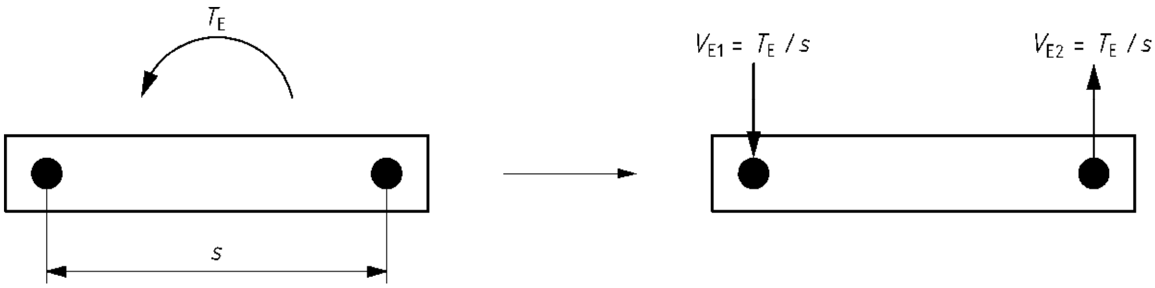
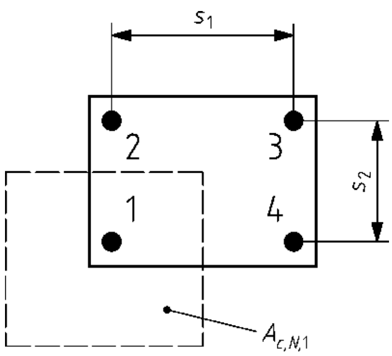


Figure 11 — Group of two fasteners loaded by a torsion moment; shear loads acting on the individual anchors of the group alter their directions, example

When calculating the resistance of the most unfavourable anchor the influences of both edge distances as well as anchor spacing have to be considered. Examples for the calculation of $A_{c,N}$ are given in Figure 12 and Figure 13.



$$A_{c,N,1} = (0.5) \cdot s_{cr,N} + s_1 / 2) \cdot (0.5 \cdot s_{cr,N} + s_2 / 2)$$
$$A_{c,N,2} = A_{c,N,1}$$
$$A_{c,N,3} = A_{c,N,1}$$
$$A_{c,N,4} = A_{c,N,1}$$
$$(s_1; s_2) \leq s_{cr,N}$$

Figure 12 — Group of four fasteners without edge influence, if the most unfavourable fastener shall be verified, example for the calculation of the area Ac,N

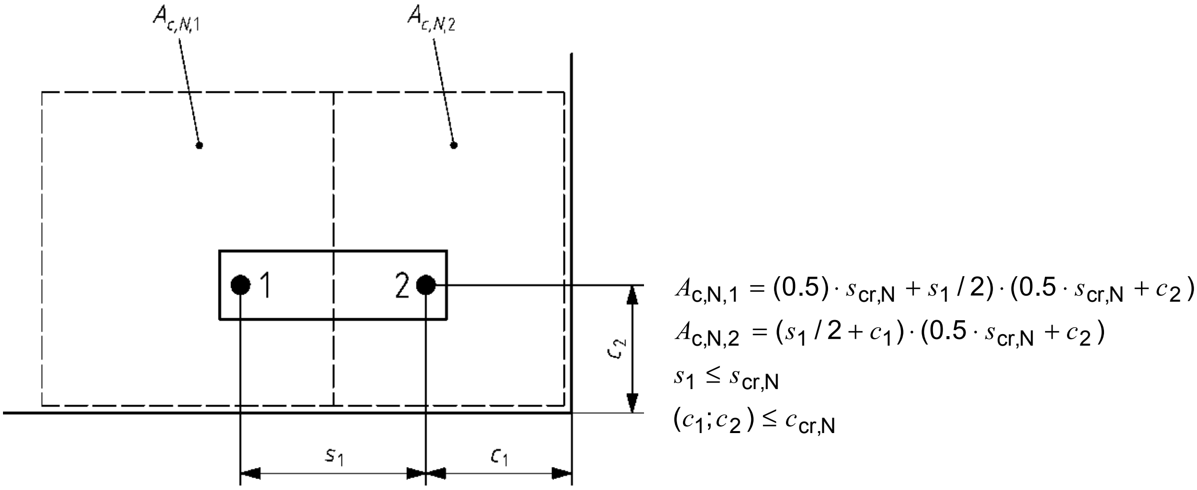


Figure 13 — Group of two fasteners located in a corner, if the most unfavourable fastener shall be verified, example for the calculation of the area Ac,N

6.3.5 Concrete edge failure

6.3.5.1 General

The following conditions shall be observed:

— For single fasteners and groups with not more than 4 fasteners and with an edge distance in all directions $c \geq 10\ h_{ef}$ or $c \geq 60\ d$, a check of the characteristic concrete edge failure resistance may be omitted. The smaller value is decisive.

— For fastenings with more than one edge (see Figure 14), the resistances for all edges shall be calculated. The smaller value is decisive.

— For groups with fasteners arranged perpendicular to the edge and loaded parallel to the edge or by a torsion moment the verification for concrete edge failure is valid for $s_1 \geq c_1$ or $c_1 \geq 150$ mm.

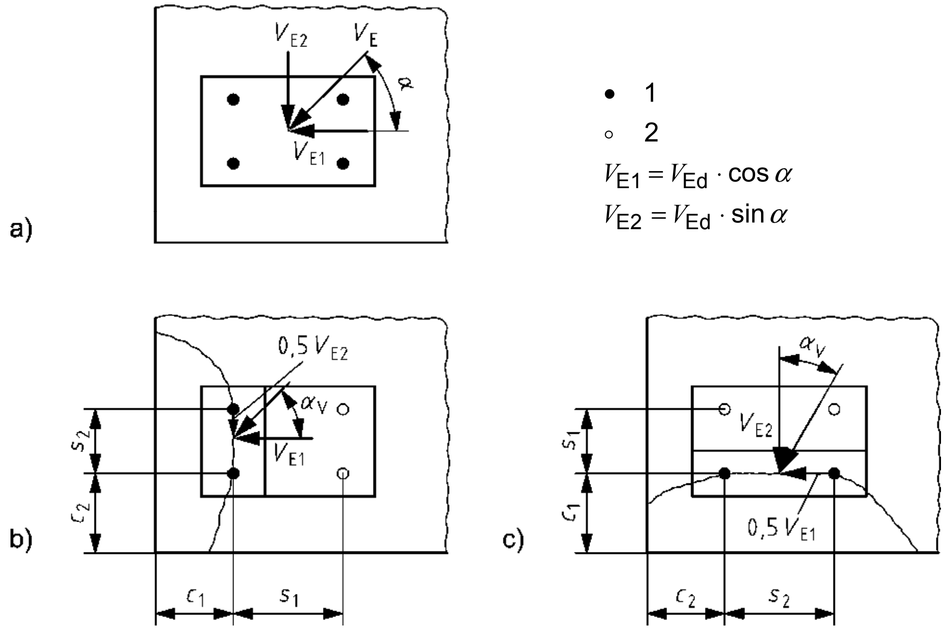
NOTE In cases of groups with fasteners arranged perpendicular to the edge and loaded parallel to the edge or by a torsion moment where $s_1 < c_1$ and $c_1 < 150$ mm the design method for concrete edge failure may yield unconservative results.

6.3.5.2 Characteristic shear resistance $V_{Rk,c}$

The characteristic resistance of a fastener or a fastener group (Figure 15) corresponds to:

$$V_{Rk,c} = V^0_{Rk,c} \cdot \frac{A_{c,V}}{A^0_{c,V}} \cdot \psi_{s,V} \cdot \psi_{h,V} \cdot \psi_{ec,V} \cdot \psi_{\alpha,V} \cdot \psi_{re,V} \quad [N] \tag{33}$$

The different factors of Equation (33) are given below.



Key
1 loaded fastener
2 unloaded fastener
a) situation
b) verification for the left edge
c) verification for the bottom edge

Figure 14 — Verification for a quadruple fasting with hole clearance at a corner, example

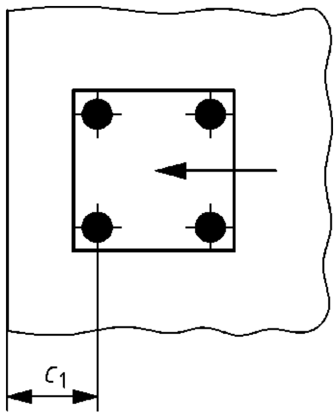


Figure 15 — Example of a fastener group loaded perpendicular to the edge

6.3.5.2.1 Characteristic resistance of a single anchor

The initial value of the characteristic resistance of a headed fastener loaded perpendicular to the edge in cracked concrete corresponds to:

$$V_{Rk,c} = 1{,}6 \cdot d_{nom}^{\alpha} \cdot l_f^{\beta} \cdot \sqrt{f_{ck,\,cube}} \cdot c_1^{1{,}5} \qquad [N] \qquad (34)$$

with

$$\alpha = 0{,}1 \cdot \left(\frac{l_{\mathrm{f}}}{c_1}\right)^{0{,}5} \qquad [-] \qquad (35)$$

$$\beta = 0{,}1 \cdot \left(\frac{d_{\mathrm{nom}}}{c_1}\right)^{0{,}2} \qquad [-] \qquad (36)$$

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

c_1 edge distance in the direction of the shear load [mm]

l_{f} = h_{ef} in case of a uniform diameter of the shank of the headed fastener [mm]

≤ 8 d_{nom}

d_{nom} ≤ 60 mm, [mm]

The values d_{nom} and l_{f} are given in the relevant European Technical Specification.

6.3.5.2.2 Geometric effect of axial spacing, edge distance and member thickness

The geometrical effect of spacing as well as of further edge distances and the effect of thickness of the concrete member on the characteristic resistance is taken into account by the ratio $A_{\mathrm{c,V}}/A^0_{\mathrm{c,V}}$, where:

$A^0_{\mathrm{c,V}}$ = reference projected area, see Figure 16

$$= 4{,}5\ c_1^2 \qquad (37)$$

$A_{\mathrm{c,V}}$ area of the idealized concrete break-out, limited by the overlapping concrete cones of adjacent fasteners ($s \leq 3\ c_1$) as well as by edges parallel to the assumed loading direction ($c_2 \leq 1{,}5\ c_1$) and by member thickness ($h \leq 1{,}5\ c_1$). Examples for calculation of $A_{\mathrm{c,V}}$ are given in Figure 17.

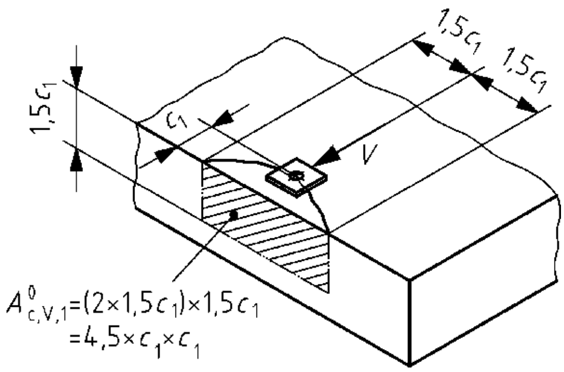
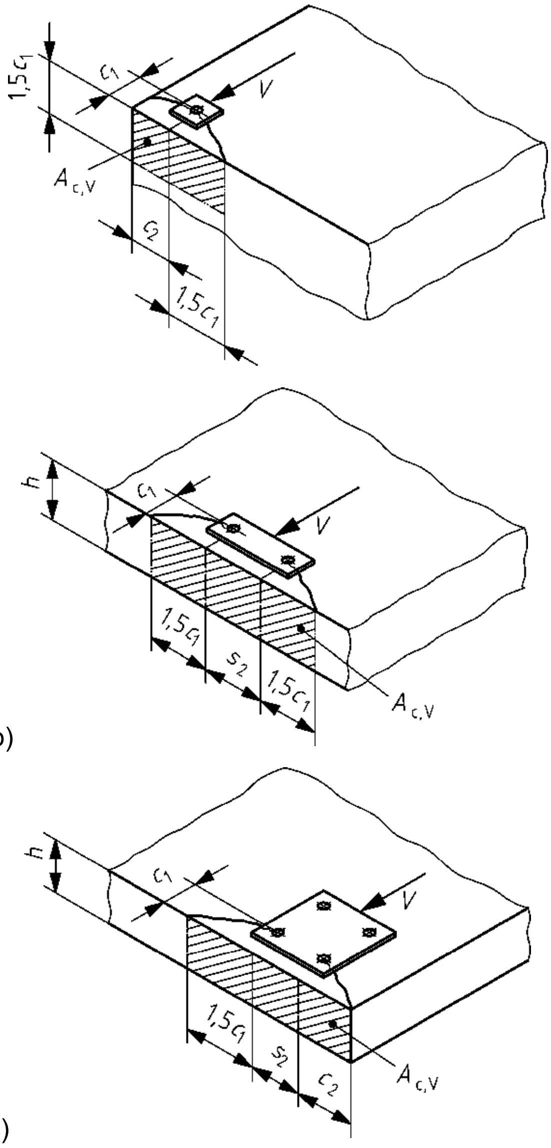


Figure 16 — Idealized concrete break-out body and area $A^0_{\mathrm{c,V}}$ for a single fastener



a)

$A_{c,V} = 1{,}5\ c_1\ (1{,}5\ c_1 + c_2)$
$h \geq 1{,}5\ c_1$
$c_2 \leq 1{,}5\ c_1$

b)

$A_{c,V} = (2 \cdot 1{,}5\ c_1 + s_2) \cdot h$
$h < 1{,}5\ c_1$
$s_2 \leq 3\ c_1$

c)

$A_{c,V} = (1{,}5\ c_1 + s_2 + \cdot c_2) \cdot h$
$h < 1{,}5\ c_1$
$s_2 \leq 3\ c_1$
$c_2 \leq 1{,}5\ c_1$

Key
a) single anchor at a corner
b) group of anchors at an edge in a thin concrete member
c) group of anchors at a corner in a thin concrete member

Figure 17 — Examples of actual projected areas $A_{c,V}$ of the idealized concrete break-out bodies for different fastener arrangements under shear loading

6.3.5.2.3 Effect of the disturbance of the distribution of stresses in the concrete due to further edges

The factor $\psi_{s,V}$ takes account of the disturbance of the distribution of stresses in the concrete due to further edges of the concrete member on the shear resistance. For fastenings with two edges parallel to the direction of loading (e.g. in a narrow concrete member) the smaller edge distance should be inserted in Equation (38).

$$\psi_{s,V} = 0{,}7 + 0{,}3 \cdot \frac{c_2}{1{,}5\ c_1} \leq 1 \qquad (38)$$

6.3.5.2.4 Effect of the thickness of the structural component

The factor $\psi_{h,V}$ takes account of the fact that the concrete edge resistance does not decrease proportionally to the member thickness as assumed by the ratio $A_{c,V}/A^0_{c,V}$ (Figures 17b) and 17c)).

$$\psi_{h,V} = \left(\frac{1{,}5\, c_1}{h}\right)^{0{,}5} \geq 1 \tag{39}$$

6.3.5.2.5 Effect of the eccentricity of the load

The factor $\psi_{ec,V}$ takes account into a group effect when different shear loads are acting on the individual fasteners of a group (see Figure 18).

$$\psi_{ec,V} = \frac{1}{1 + 2 \cdot e_V / (3 \cdot c_1)} \leq 1 \tag{40}$$

e_V eccentricity of the resulting shear load acting on the fasteners relative to the centre of gravity of the fasteners loaded in shear

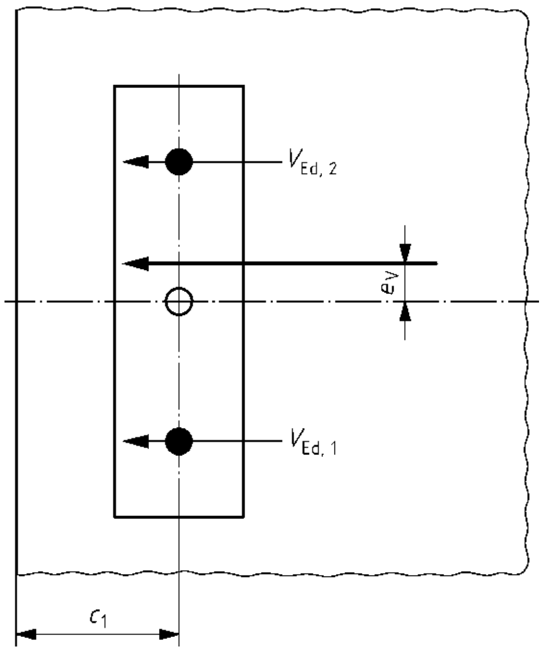


Figure 18 — Resolving unequal shear components into an eccentric shear load resultant, example

6.3.5.2.6 Effect of load direction

The factor $\psi_{\alpha,V}$ takes into account the angle α_V between the load applied V_{Sd} and the direction perpendicular to the free edge under consideration for the calculation of the concrete edge resistance (see Figure 14).

$$\psi_{\alpha,V} = \sqrt{\frac{1}{(\cos\alpha_V)2 + (0.4 \cdot \sin\alpha_V)^2}} \geq 1 \tag{41}$$

α_V = angle between design shear load V_{Sd} and a line perpendicular to the edge, $0° \leq \alpha_V \leq 90°$, see Figure 14

6.3.5.2.7 Effect of the position of the fastening

The factor $\psi_{re,V}$ takes account of the effect of the position of the fastening in cracked or non-cracked concrete or of the type of reinforcement on the edge.

$\psi_{re,V}$ = 1,0 fastening in cracked concrete without edge reinforcement or stirrups

$\psi_{re,V}$ = 1,2 fastening in cracked concrete with straight edge reinforcement ($\geq$ Ø 12 mm)

$\psi_{re,V}$ = 1,4 fastening in cracked concrete with edge reinforcement and closely spaced stirrups or wire mesh with a spacing $a \leq 100$ mm and $a \leq 2\,c_1$, or
fastening in non-cracked concrete (verification according to Part 1, Section 5)

A factor $\psi_{re,V} > 1$ for applications in cracked concrete should only be applied, if the embedment depth h_{ef} of the fastener is $h_{ef} \geq 2{,}5$ times the concrete cover of the edge reinforcement.

6.3.5.2.8 Effect of a narrow thin member

For fastenings in a narrow, thin member with $c_{2,max} \leq 1{,}5\,c_1$ and $h \leq 1{,}5\,c_1$ (see Figure 19) the calculation according to Equation (33) leads to conservative results. More precise results are achieved if c_1 is limited in case of single fasteners to the larger value of

$$c_1' = \max \begin{cases} c_{2,max}/1{,}5 \\ h/1{,}5 \end{cases} \tag{42}$$

with

$c_{2,max}$ = largest of the two edge distances parallel to the direction of loading

or in case of groups c_1 is limited to the largest value of

$$c_1' = \max \begin{cases} c_{2,max}/1{,}5 \\ h/1{,}5 \\ s_{max}/3 \end{cases} \tag{43}$$

with

s_{max} = maximum spacing between fasteners within the group

The value c_1' is inserted in Equations (34) to (40) as well as in the determination of the areas $A^0_{c,V}$ and $A_{c,V}$ according to Figures 16 and 17.

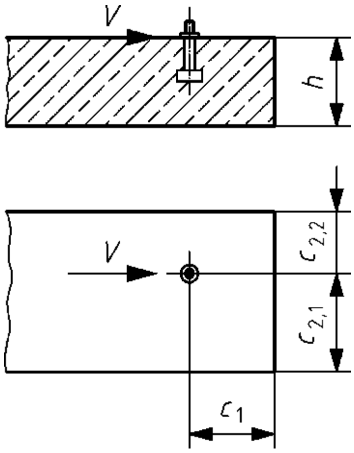
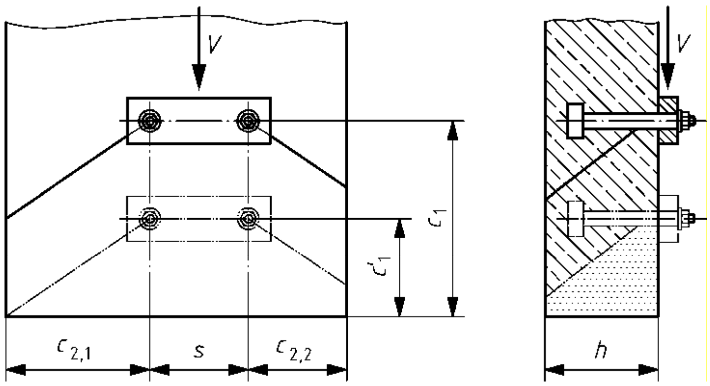


Figure 19 — Example of a fastener in a thin, narrow member where the value c_1' may be used

NOTE An example for the calculation of c_1' is illustrated in Figure 20.



s = 100 mm c_1 = 200 mm, h = 120 mm < 1,5 · 200 mm,

$c_{2,1}$ = 150 mm ≤ 1,5 · 200 mm, $c_{2,2}$ = 100 mm < 1,5 · 200 mm, c_1' = 150/1,5 = 100 mm

Figure 20 — Illustration of the calculation of the value c_1', example

6.3.5.3 Steel failure of supplementary reinforcement

The characteristic resistance of one fastener in case of steel failure of the supplementary reinforcement may be calculated according to Equation (44).

$$N_{Rk,re} = k_6 \cdot n \cdot A_s \cdot f_{yk} \tag{44}$$

with

k_6 = efficiency factor

= 1,0 surface reinforcement according to Figure 9

= 0,5 supplementary reinforcement according to Figure 10

n = number of bars of the supplementary reinforcement of one fastener

A_s = cross section of one bar of the supplementary reinforcement

f_{yk} = nominal yield strength of the supplementary reinforcement ≤ 500 N/mm²

NOTE The factor k_6 = 0,5 for supplementary reinforcement according to Figure 10 takes account of unavoidable tolerances in workmanship.

6.3.5.4 Anchorage failure of supplementary reinforcement in the concrete breakout body

For applications according to Figure 10 no proof of the anchorage capacity is necessary.

For applications according to Figure 9 the design resistance $V_{Rd,,a}$ of the supplementary reinforcement of one fastener in case of an anchorage failure is given by Equation (45).

$$N_{Rd,\alpha} = \sum_{n} \frac{l_1 \cdot \pi\, d_s \cdot f_{bd}}{\alpha} \tag{45}$$

with

l_1 = anchorage length of the supplementary reinforcement in the assumed failure cone see Figure 9)

≥ $l_{b,min}$ = $4 \cdot d_s$ (anchorage with bends, hooks or loops)

≥ $10 \cdot d_s$ (anchorage with straight bars with or without welded transverse bars)

$l_{b,min}$ = minimum anchorage length

d_s = diameter of the reinforcement bar

f_{bd} = design bond strength according to EN 1992-1-1, taking into account the concrete cover of the supplementary reinforcement

α = influencing factor, according to EN 1992-1-1

= 0,7 for hooked bars

n = number of legs of the supplementary reinforcement effective for one fastener

6.4 Combined tension and shear load

6.4.1 Fastenings without supplementary reinforcement

6.4.1.1 Steel failure decisive for tension and shear load

For combined tension and shear loads the following equations should be satisfied:

$$\beta_N^2 + \beta_V^2 \leq 1 \tag{46}$$

where

$\beta_N = N_{Ed}/N_{Rd} \leq 1$ and $\beta_V = V_{Ed}/V_{Rd} \leq 1$

6.4.1.2 Other modes of failure decisive

For combined tension and shear loads either of the following Equations (47) (see Figure 21) or Equation (48) should be satisfied:

$$\beta_N + \beta_V \leq 1,2 \tag{47}$$

$$\beta_N^{1,5} + \beta_V^{1,5} \leq 1 \quad (48)$$

where

$\beta_N = N_{Ed}/N_{Rd} \leq 1$ and $\beta_V = V_{Ed}/V_{Rd} \leq 1$

In Equations (47) and (48) the largest value of β_N and β_V for the different failure modes should be taken.

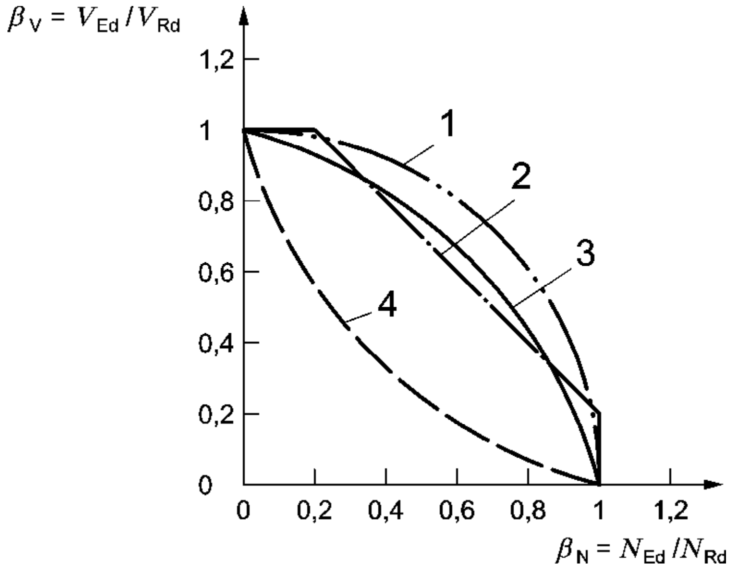
6.4.1.3 Fastenings with supplementary reinforcement

For fastenings with a supplementary reinforcement for tension and shear loads 6.4.1.1 and 6.4.1.2 apply. For fastenings with a supplementary reinforcement to take up tension or shear loads only, Equation (49) should be used with the largest value of β_N and β_V for the different failure modes.

$$\beta_N^{k_7} + \beta_V^{k_7} \leq 1 \quad (49)$$

The value k_7 is given in the relevant European Technical Specification.

NOTE According to current experience k_7 = 2/3



Key
1) according equation (46)
2) according equation (47)
3) according equation (48)
4) according equation (49) (by applying k_7 =2/3)

Figure 21 — Interaction diagram for combined tension and shear loads

7 Fatigue

Part 1 'General' of this Technical Specification applies.

8 Seismic

Part 1 'General' of this Technical Specification applies.

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