POST-INSTALLED CONSTRUCTION FIXINGS

EN1992-4 (Eurocode 2): **Design of concrete structures - Part 4 : Design of fastenings for use in concrete**

HISTORICAL OVERVIEW

EOTA: ETAG001 - ANNEX C
Design method for anchorages.
June 1997

EOTA: TR 020
Resistance to fire.
May 2004

EOTA: TR029
Design of bonded anchors.
June 2007

ACI: 318 APP D
Anchoring to concrete.
September 2008

EOTA: TR 045
Design under seismic actions.
February 2013

ACI: 318 CHAPT 17
Anchoring to concrete.
September 2014

SA: TS 101
Design of post-installed and cast-in fastenings for use in concrete.
2015

SA: AS5216
Design of post-installed and cast-in fastenings for use in concrete.
2018

CEN: EN1992-4
Design of Fastenings for use in concrete.
July 2018

NEW
CEN: TR 082
Design of bonded fasteners in concrete under fire conditions
April 2023

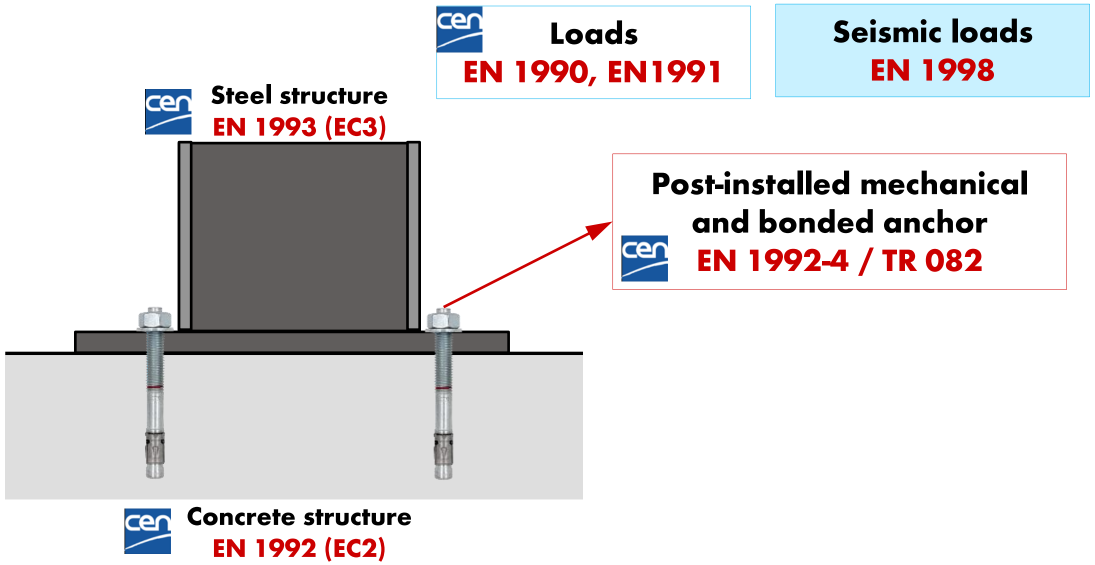
EOTA ... European Organisation for Technical Assessment, ACI ... American Concrete Institute, SA ... Standards Australia, CEN ... European Committee for Standardization
ETAG ... European Technical Approval Guideline, TR ... Technical Report, TS ... Technical Specification, AS ... Australian Standard

STANDARDS AND LAWS

STANDARDS AND LAWS

Construction law → Structural safety → No risk to public and nature

Contract law → Execution of construction works: accepted **engineering standards**

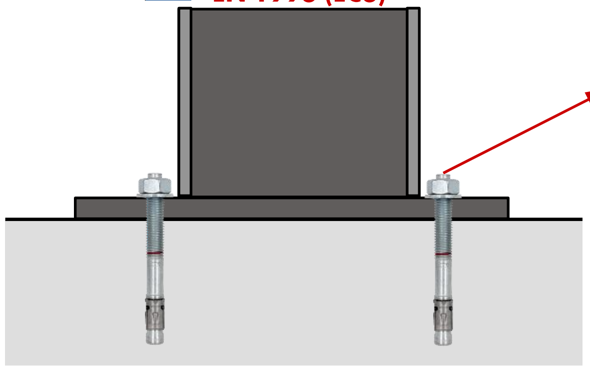


STANDARDS AND LAWS

Construction law → Structural safety → No risk to public and nature

Contract law → Execution of construction works: accepted engineering standards

Construction Product Regulation → **Assessment of the fitness for their intended use:**
- economically reasonable working life,
- mechanical strength and stability,
- safety in the event of fire
- ....



FROM THE ASSESSMENT TO THE DESIGN

ASSESSMENT


EUROPEAN ASSESSMENT DOCUMENT

EAD 330499-01-0601

December 2018

BONDED FASTENERS FOR USE IN CONCRETE

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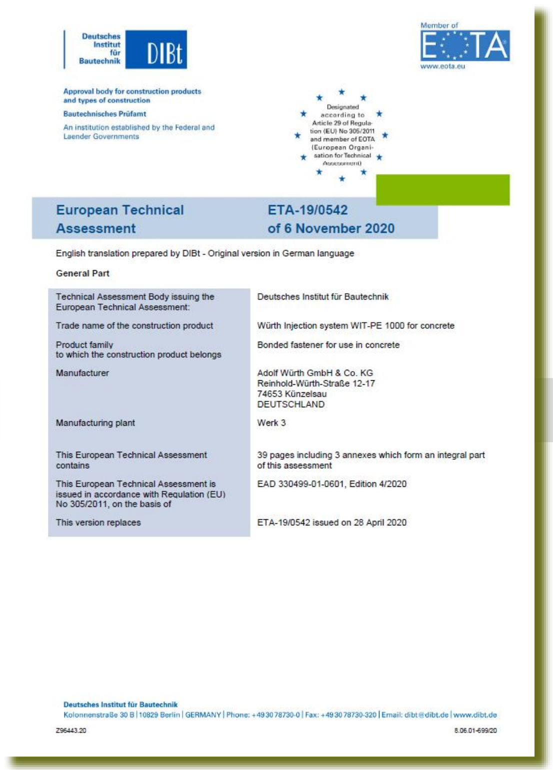
TECHNICAL PRODUCTS SPECIFICATION


Deutsches Institut für Bautechnik

Approval body for construction products and types of construction

Bautechnisches Prüfamt

An institution established by the Federal and Laender Governments

Member of EOTA
www.eota.eu

Designated according to Article 29 of Regulation (EU) No 305/2011 and member of EOTA (European Organisation for Technical Assessment)

European Technical Assessment | ETA-19/0542 of 6 November 2020

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	Würth Injection system WIT-PE 1000 for concrete
Product family to which the construction product belongs	Bonded fastener for use in concrete
Manufacturer	Adolf Würth GmbH & Co. KG Reinhold-Würth-Straße 12-17 74653 Künzelsau DEUTSCHLAND
Manufacturing plant	Werk 3
This European Technical Assessment contains	39 pages including 3 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	EAD 330499-01-0601, Edition 4/2020
This version replaces	ETA-19/0542 issued on 28 April 2020

DESIGN / VERIFICATION


EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 1992-4

July 2018

ICS 91.010.30; 91.080.40

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, CEN/TS 1992-4-5:2009

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.

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

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

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Ref. No. EN 1992-4:2018 E

EAD ... European Assessment Doument; ETA ... European Technical Assessment; EN ... European Standard

STANDARDS AND LAW

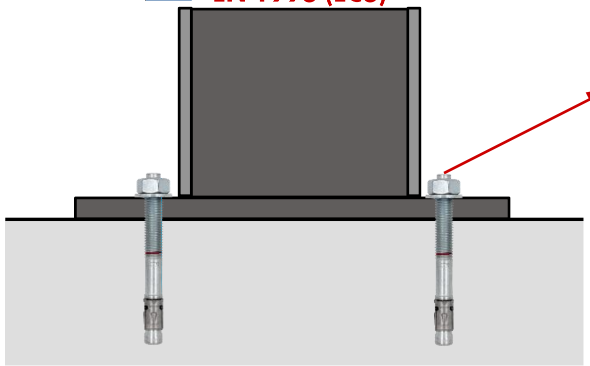
Construction law → Structural safety → No risk to public and nature

Contract law → Execution of construction works: accepted engineering standards

Loads
EN 1990, EN1991

Seismic loads
EN 1998

Steel structure
EN 1993 (EC3)



Post-installed mechanical and bonded anchor
EN 1992-4 / TR 082

Concrete structure
EN 1992 (EC2)

Construction Product Regulation →

Fitness for their intended use:
- economically reasonable working life,
- mechanical strength and stability,
- safety in the event of fire
- ....

Suitability tests

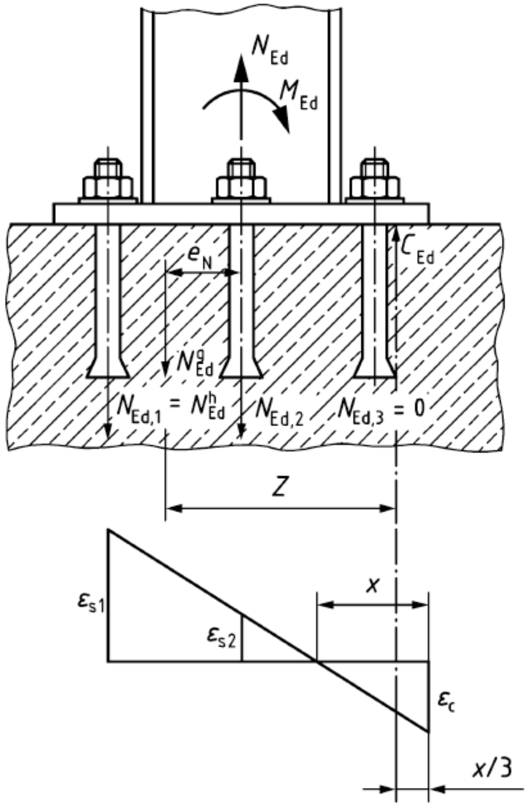
Test: admissible service conditions

ETA
(Techn. Product specification)

RIGID ANCHOR PLATE - TENSION

EN1992-4

- **6.1 (5):**
  In general, **elastic analysis** may be used for establishing the loads on individual fasteners both at ultimate and serviceability limit states.
- **6.2.1 (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**.
- **6.2.1 (2):**
  The assumption in 6.2.1 (1) may be considered to be satisfied if the base plate remains **elastic under design actions** ($\sigma_{Ed} \leq \sigma_{Rd}$) and its **deformation remains negligible** in comparison with the axial displacement of the fasteners.



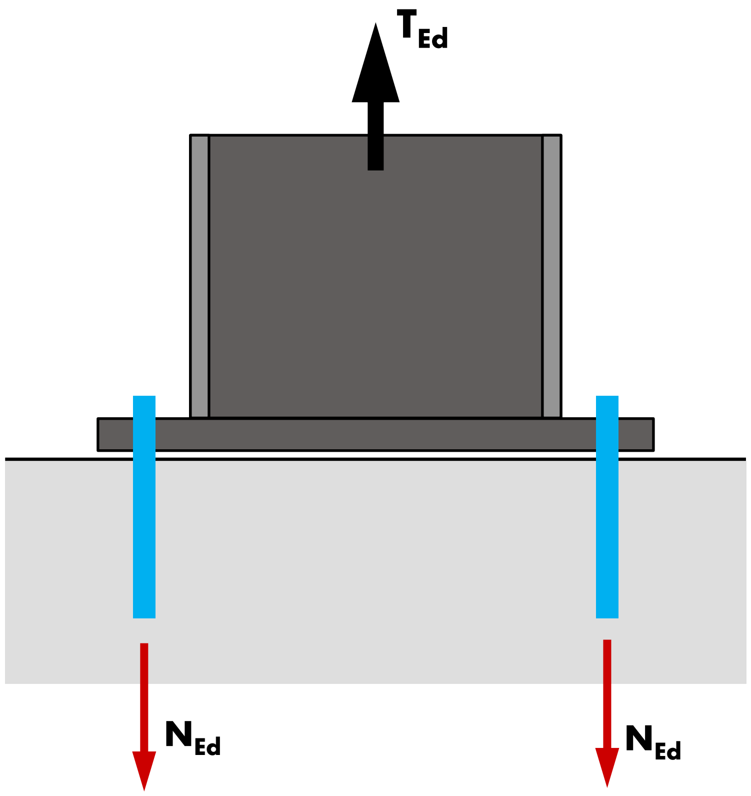
FORCES ACTING ON FASTENERS

Tension Load

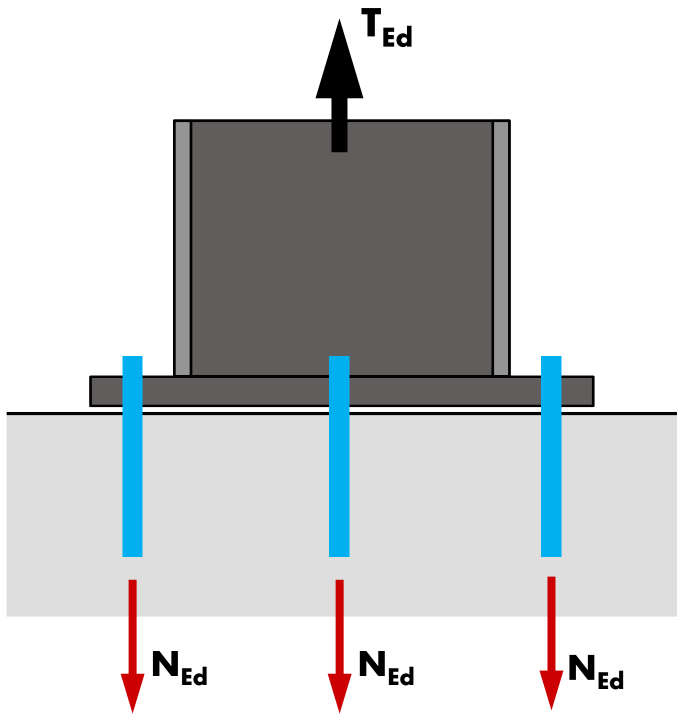
Base plate is sufficiently rigid such that linear strain distribution will be valid.

Rigid Base Plate

Rigid



Rigid



FORCES ACTING ON FASTENERS

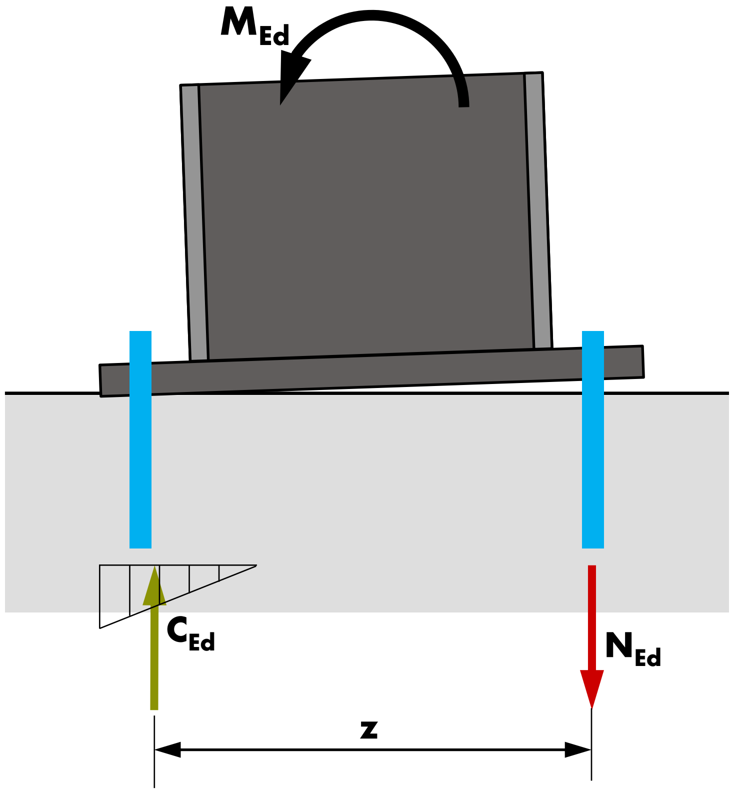
Tension Load

Base plate is sufficiently rigid such that linear strain distribution will be valid.

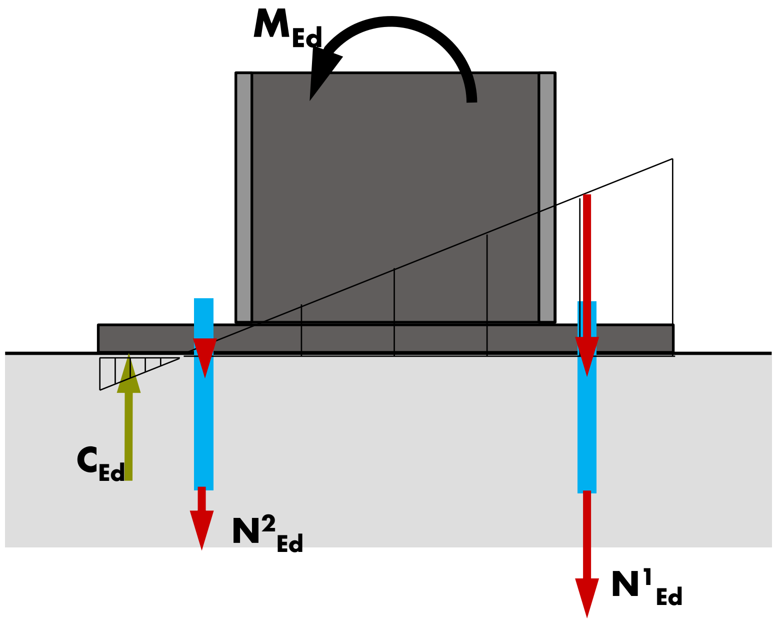
Rigid Base Plate

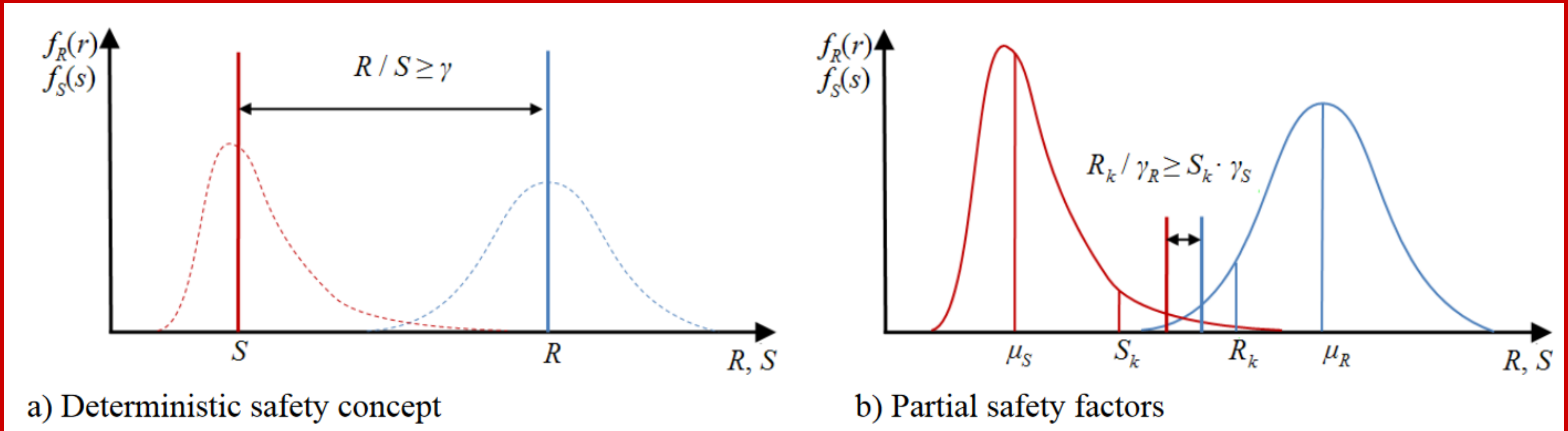
Rigid

Acting Tension on fasteners is calculated from a linear correlation



- **anchor forces (linear)**





DESIGN FORMAT AND SAFETY CONCEPT

DESIGN FORMAT
Ultimate Limit State

Verification by the partial factor method

The limit states that concern

- ✓ **the safety of people, and/or**
- ✓ **the safety of the structure**

shall be classified as **ultimate limit states**.

Design value of effect of actions	$E_d \leq R_d$	Design value of resistances	(4.1)

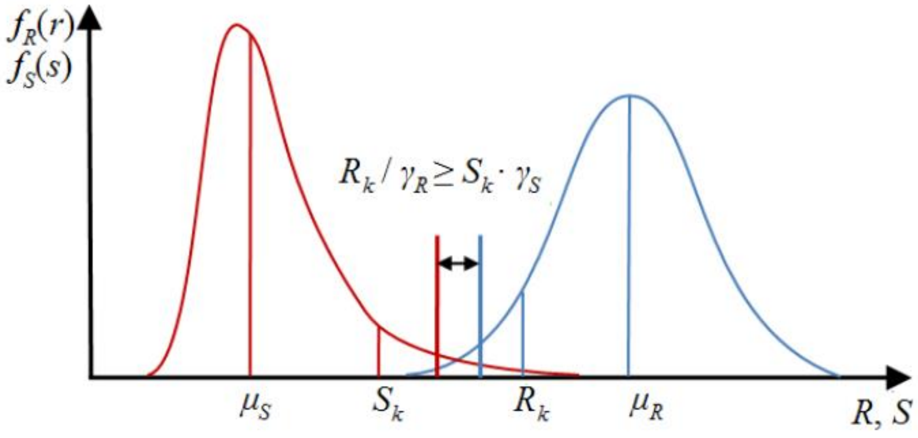
DESIGN FORMAT
Ultimate Limit State

Verification by the partial factor method

The limit states that concern

- ✓ **the safety of people, and/or**
- ✓ **the safety of the structure**

shall be classified as **ultimate limit states**.



b) Partial safety factors

Design value of effect of actions	$E_d \leq R_d$	Design value of resistances	(4.1)
Design value of effect of actions	$E_d \leq \dfrac{R_k}{\gamma_M}$	Characteristic value of resistances **Partial safety factor** for the resistances	(4.3)

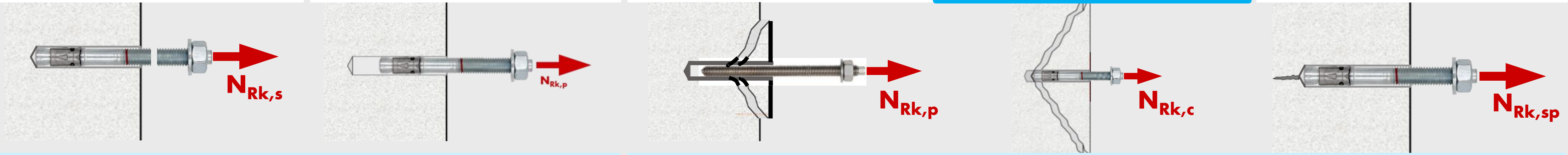
- ✓ Structural and non-structural elements are covered.
- ✓ The support of the fixture can be either statically determinate or statically indeterminate.

REQUIRED VERIFICATIONS TENSION

VERIFICATION OF ULTIMATE LIMIT STATE
Tension Loads

Overview of the required verifications / Verification by the partial factor method (Table 7.1)

FAILURE MODES		**Steel failure of fastener**	**Pull-out failure of fastener**	**Combined pull-out and concrete failure**	**Concrete cone failure**	**Concrete splitting failure**
SINGLE ANCHOR		$N_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$	Mechanical anchor only $N_{Ed} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	Bonded anchor only $N_{Ed} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	$N_{Ed} \leq N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$	$N_{Ed} \leq N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$
GROUP	Most loaded anchor	$N_{Ed}^{h} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$	$N_{Ed}^{h} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$			
	Group			$N_{Ed}^{g} \leq N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	$N_{Ed}^{g} \leq N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$	$N_{Ed}^{g} \leq N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$
		Verifications for the most loaded anchors		**Verifications for the concrete failures**		



VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

WÜRTH GROUP

7.2.1.4 Concrete cone failure

$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N}$		(7.1)
$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1.5}$	**Characteristic resistance of a single fastener** placed in concrete and not influenced by adjacent fasteners or edges of the concrete member.	(7.2)
$\frac{A_{c,N}}{A^0_{c,N}}$	**Geometric effect of axial spacing and edge distance.**	
$\psi_{s,N} = 0.7 + 0.3 \frac{c}{c_{cr,N}} \leq 1.0$	**Disturbance of the distribution of stresses** in the concrete due to the proximity of an edge of the concrete member.	(7.4)
$\psi_{re,N} = 0.5 + \frac{h_{ef}}{200} \leq 1.0$	**Shell spalling factor.**	(7.5)
$\psi_{ec,N} = \frac{1}{1 + 2\left(e_N / s_{cr,N}\right)} \leq 1.0$	**Group effect** when different tension loads are acting on the individual fasteners of a group.	(7.6)
$\psi_{M,N}$	**Effect of a compression force between fixture and concrete** in cases of bending moments with or without axial force.	

VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

7.2.1.4 **Concrete cone failure**

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N} \qquad (7.1)$$

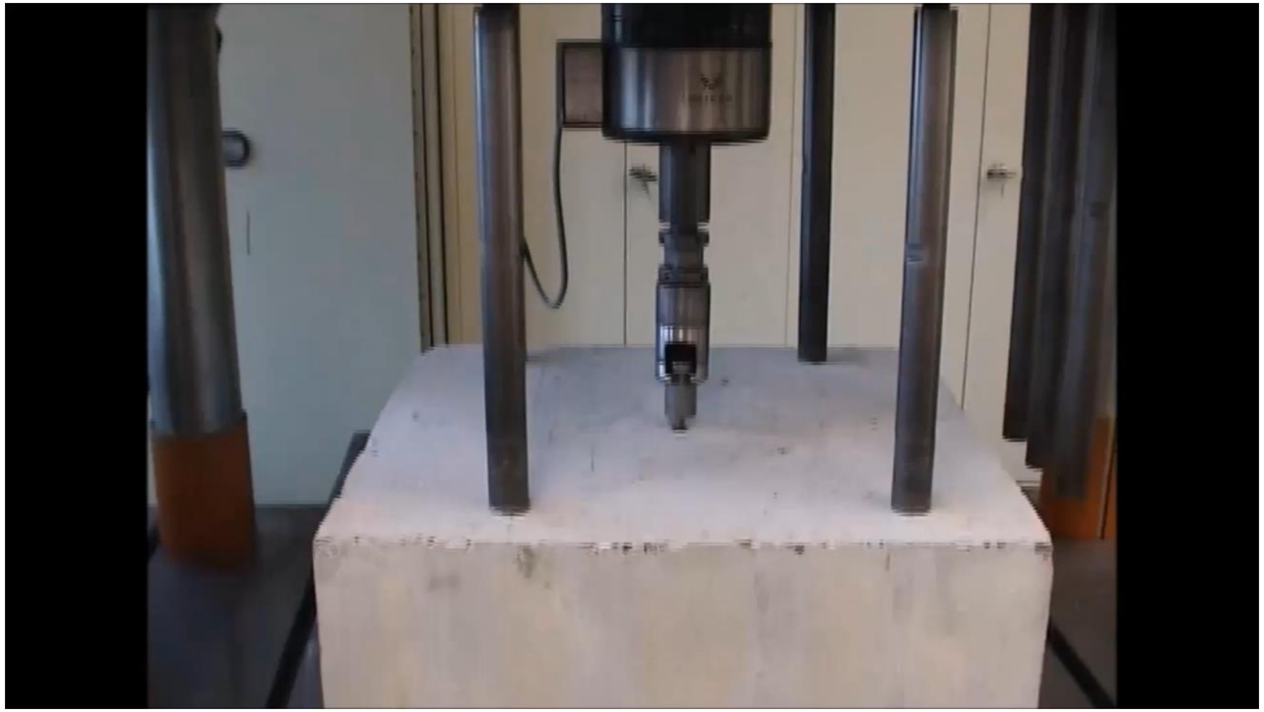
$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1.5} \qquad (7.2)$$

Characteristic resistance of a single fastener
placed in concrete and not influenced by adjacent fasteners or edges of the concrete member.

VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

WÜRTH GROUP

(7.2) Characteristic resistance of a single fastener



The characteristic resistance for the concrete cone failure does not depend on anchor diameter and anchor type!

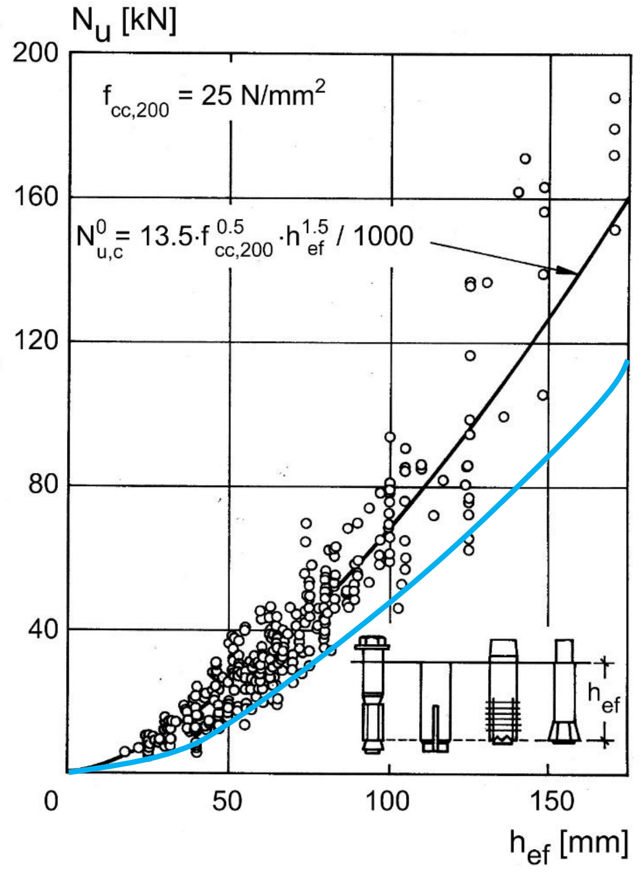
Test results after Fuchs/Eligehausen/Breen (1995)
519 test series.

Mean failure load

$$N^0_{u,c} = 13.5 \cdot \sqrt{f_{cc,200}} \cdot h_{ef}^{1.5}$$

5%-fractile of the failure load

$$N^0_{5\%} = k \cdot \sqrt{f_{cc,200}} \cdot h_{ef}^{1.5}$$



VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

WÜRTH GROUP

7.2.1.4 **Concrete cone failure**

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N} \qquad (7.1)$$

$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1.5} \qquad (7.2)$$

Characteristic resistance of a single fastener
placed in concrete and not influenced by adjacent fasteners or edges of the concrete member.

$$k_1 = \begin{cases} k_{cr,N} = 7.7 \ \ldots \text{cracked concrete} \\ k_{ucr,N} = 11.0 \ \ldots \text{uncracked concrete} \end{cases}$$

The factor $\mathbf{k_{cr,N}}$ only for anchors with ETA for cracked concrete.

ETA CE

VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

WÜRTH GROUP

7.2.1.4 Concrete cone failure

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N} \qquad (7.1)$$

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The factor $\mathbf{k_{cr,N}}$ only for anchors with ETA for cracked concrete.

CRACKED concrete C20/25

h_{ef}	mm	40	50	60	70	80	100	125	170
f_{ck}	N/mm²	20							
$N^0_{Rk,c}$	kN	8.7	12.1	16.0	20.1	24.6	34.4	48.1	76.3

VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

WÜRTH GROUP

Concrete failure and its partial safety factors

$$N_{Ed} \leq N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$$

$$\gamma_{M,c} = \gamma_c \cdot \gamma_{inst}$$

$$\gamma_c = 1.5$$

Permanent and transient design situations

$$\gamma_{inst} \geq 1.0$$

No	Essential characteristic	Assessment method	Type of expression of product performance
Basic Works Requirement 1: Mechanical resistance and stability			
5	Robustness	2.2.5	γ_{inst} [-]

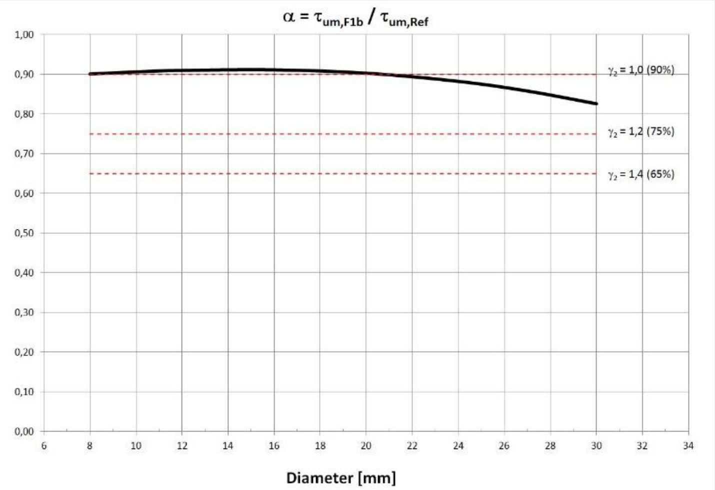
GOOD TO KNOW
Installation safety / Robustness

WÜRTH GROUP

Concrete failure and its partial safety factors

$\gamma_{inst} \geq 1.0$

(Table 4.1)



N°	Purpose of test	concrete	crack width [mm]	size 2)	h_{ef}	n_{min}	rqd. α	Section
R5	Reference for sensitivity to reduced cleaning effort	C20/25	0	s/m/l	max	5	-	2.2.5
B6	Robustness in dry concrete	C20/25	0	s/m/l	max2)	5	see Table 2.4	2.2.5.2
B7	Robustness in water saturated concrete	C20/25	0	s/m/l	max2)	5		2.2.5.3
B8	Robustness in water filled holes (clean water)	C20/25	0	s/m/l	max2)	5		2.2.5.4
B9	Robustness to mixing technique	C20/25	0	m	max2)	5		2.2.5.5

EAD

Table 2.4 Values of rqd. α in the sensitivity to robustness tests for bonded fasteners

factor γ_{inst}	rqd. α for tests according to Table A.1, respectively	
1,0	≥ 0,95	≥ 0,90
1,2	≥ 0,80	≥ 0,75
1,4	≥ 0,70	≥ 0,65

The robustness factor depends on the anchor diameter and anchor type.

VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

WÜRTH GROUP

Concrete failure and its partial safety factors

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N} \quad (7.1)$$

$\gamma_{M,c} = \gamma_c \cdot \gamma_{inst}$ $\boldsymbol{\gamma_c = 1.5}$	**Permanent and transient design situations**	$\gamma_{M,c} = \gamma_c \cdot \gamma_{inst}$ $\boldsymbol{\gamma_c = 1.2}$	**Accidential design situations**
		γ_c	**Seismic design situations EN1998**

$\gamma_{inst} \geq 1.0$ (Table 4.1)

γ_{inst}	1.0	1.2	1.4
$\gamma_{M,c}$	**1.5**	**1.8**	**2.1**

VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

WÜRTH GROUP

7.2.1.4 Concrete cone failure

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N} \quad (7.1)$$

$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1.5} \quad (7.2)$$

Characteristic resistance of a single fastener
placed in concrete and not influenced by adjacent fasteners or edges of the concrete member.

$$k_1 = \begin{cases} k_{cr,N} = 7.7 \text{ ... cracked concrete} \\ k_{ucr,N} = 11.0 \text{ ... uncracked concrete} \end{cases}$$

Cracked concrete C20/25

h_{ef}	mm	40	50	60	70	80	100	125	170
f_{ck}	N/mm²	20							
$N^0_{Rk,c}$	kN	8.7	12.1	16.0	20.1	24.6	34.4	48.1	76.3
$\gamma_{M,c}$		1.5							
$N^0_{Rd,c}$	kN	5.8	8.1	10.6	13.4	16.4	22.9	32.0	50.8

VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

WÜRTH GROUP

7.2.1.4 Concrete cone failure

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N} \quad (7.1)$$

$$N^0_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1.5} \quad (7.2)$$

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ETA CE

Cracked concrete C20/25

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f_{ck}	N/mm²	20							
$N^0_{Rk,c}$	kN	8.7	12.1	16.0	20.1	24.6	34.4	48.1	76.3
$\gamma_{M,c}$		1.5							
$N^0_{Rd,c}$	kN	5.8	8.1	10.6	13.4	16.4	22.9	32.0	50.8

CRACKED AND NON-CRACKED CONCRETE

REQUIREMENTS FOR ANCHOR DESIGN

- **EN 1992-4**
  - **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.

REQUIREMENTS FOR ANCHOR DESIGN

- **EN 1992-4**
  - **4.7 Determination of concrete condition**

(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

$$\sigma_L + \sigma_R \leq \sigma_{adm}$$

is observed (compressive stresses are negative).

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 σ_R = 3N/mm^2 should be assumed;

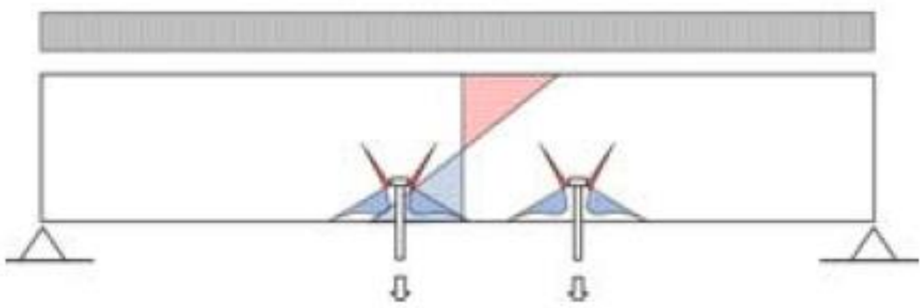
σ_{adm} ... is the admissible tensile stress for the definition of uncracked concrete.

NOTE The recommended value is $\sigma_{adm} = 0$ and is based on the characteristic combination of loading at the serviceability limit state.

ANCHORS IN CONCRETE

- ... including fastener loads.

Any tensile stresses already present due to structure loading, restraint of thermal movement, etc., will be superimposed on the anchor-induced stress state, thus leading to a loss of capacity.



Eligehausen et al.: Anchorage in Concrete Construction. Ernst & Sohn Verlag, 2006.

REINFORCED CONCRETE DESIGN

- **EN 1992-1-1**
  - **7.3 Crack control**

7.3.1 General considerations

(1) Cracking shall be **limited** to an extent that will not impair the proper functioning or durability of the structure or cause its appearance to be unacceptable.

(2) Cracking is **normal** in reinforced concrete structures subject to bending, shear, torsion or tension resulting from either direct loading or restraint or imposed deformations.

(3) Cracks may also arise from other causes such as plastic shrinkage or expansive chemical reactions within the hardened concrete. Such cracks may be unacceptably large but their avoidance and control lie outside the scope of this Section.

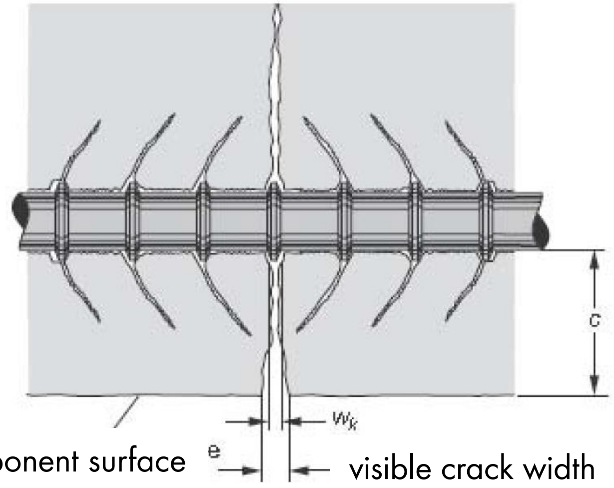
REINFORCED CONCRETE DESIGN

- **EN 1992-1-1**
  - **7.3 Crack control**

7.3.1 General considerations

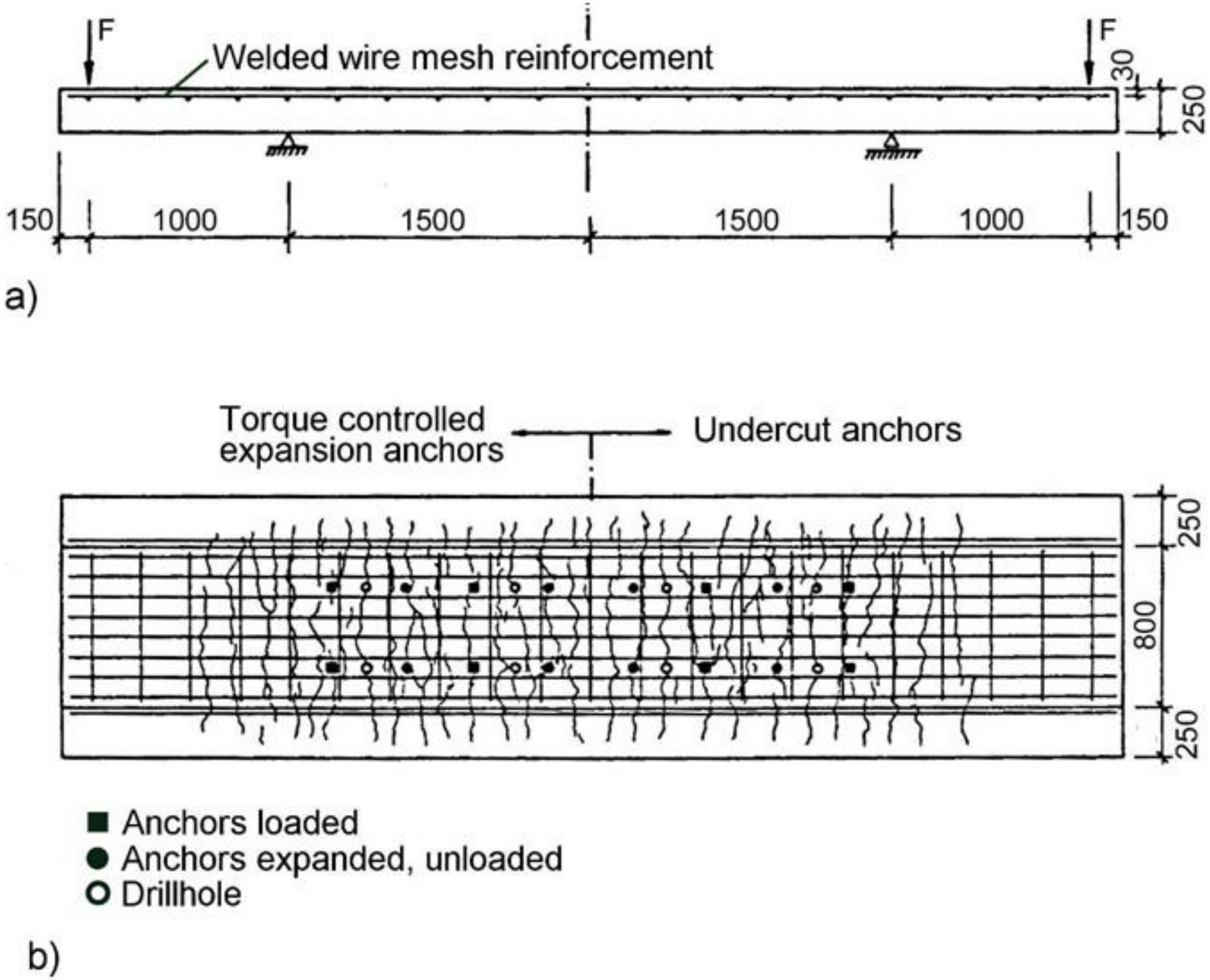
(4) Cracks may be permitted to form without any attempt to **control their width**, provided they do not impair the functioning of the structure.

(5) A limiting value, $\mathbf{w_{max} = 0.3mm}$, for the calculated crack width, w_k, taking into account the proposed function and nature of the structure and the costs of limiting cracking, should be established.



ANCHORS IN CONCRETE

- There is a relatively high probability that cracks will intersect the anchor location.



Eligehausen et al.: Anchorage in Concrete Construction. Ernst & Sohn Verlag, 2006.

PERFORMANCE OF ANCHORS IN CONCRETE - TENSION TESTS

N°	Purpose of test	concrete	crack width [mm]	size 2)	h_{ef}	n_{min}	rqd. α	Section
Reference tests (confined test setup)								
R1	Bond strength with confined test setup	C20/25	0	All	7d 1)	5	-	2.2.2.1
R2		C50/60	0	s/m/l	7d 1)	5	-	
R3		C20/25	0,3	s/m/l	7d 1)	5	-	
R4		C50/60	0,3	s/m/l	7d 1)	5	-	
Basic tension tests with unconfined test setup								
A1	Characteristic resistance for tension loading not influenced by edge and spacing effects	C20/25	0	s/m/l	min	5	-	2.2.2.2
A2		C50/60	0	s/m/l	min	5	-	
A3		C20/25	0,3	s/m/l	min	5	-	
A4		C50/60	0,3	s/m/l	min	5	-	
Resistance to pull-out failure								
B10	Increased crack width	C20/25	0,5	s/m/l	7d 1)	5	0,80	2.2.2.3
B11	Increased crack width	C50/60	0,5	s/m/l	7d 1)	5	0,80	2.2.2.3
B12	Repeated loads	C20/25	0	m	7d 1)	5	1,00	2.2.2.4
B13	Crack cycling under load	C20/25	0,1 - 0,3	All	7d 1)	5	0,90	2.2.2.5

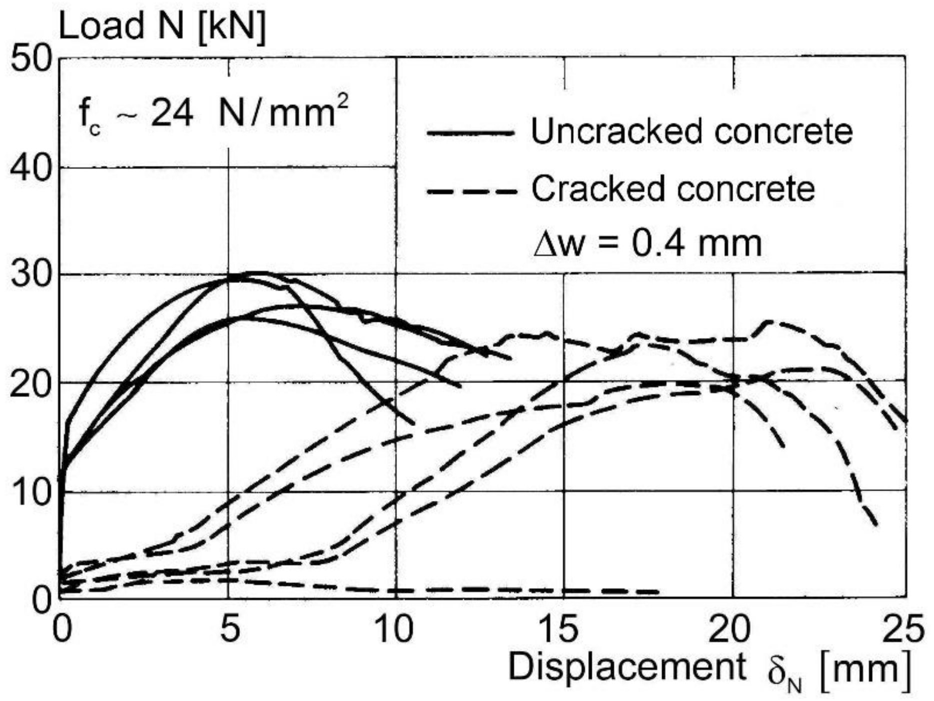
EAD 330499-01-0601: BONDED FASTENERS FOR USE IN CONCRETE

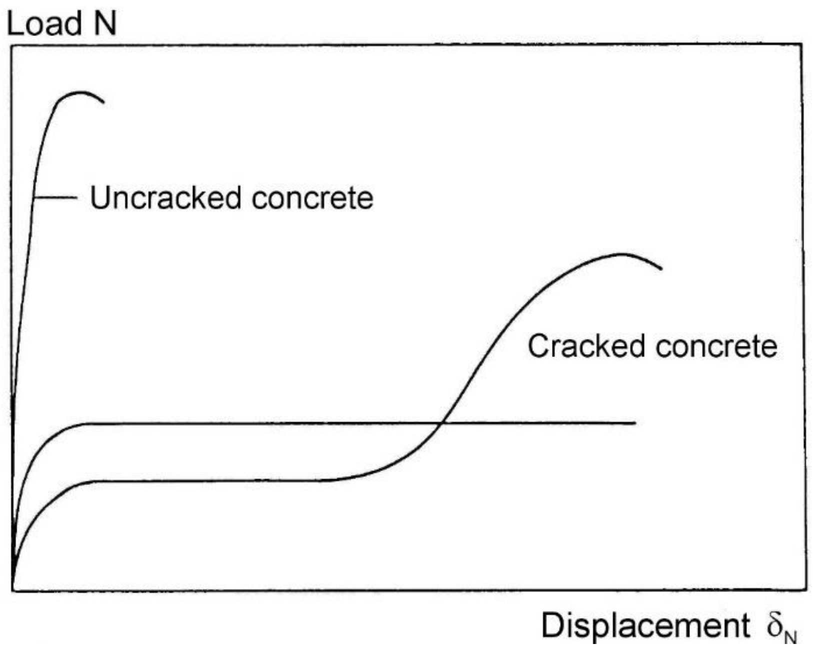
Consequences for the anchor testing:

- Permanent loads are causing static cracks.
- Slowly varying live loads are causing the crack opening and closing.

PERFORMANCE OF ANCHORS IN CONCRETE - TENSION TESTS

- on **torque-controlled expansion anchors** developed for **uncracked** concrete.

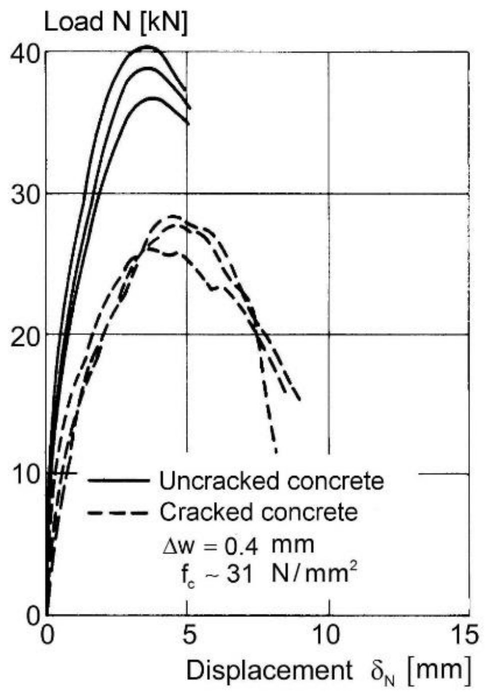


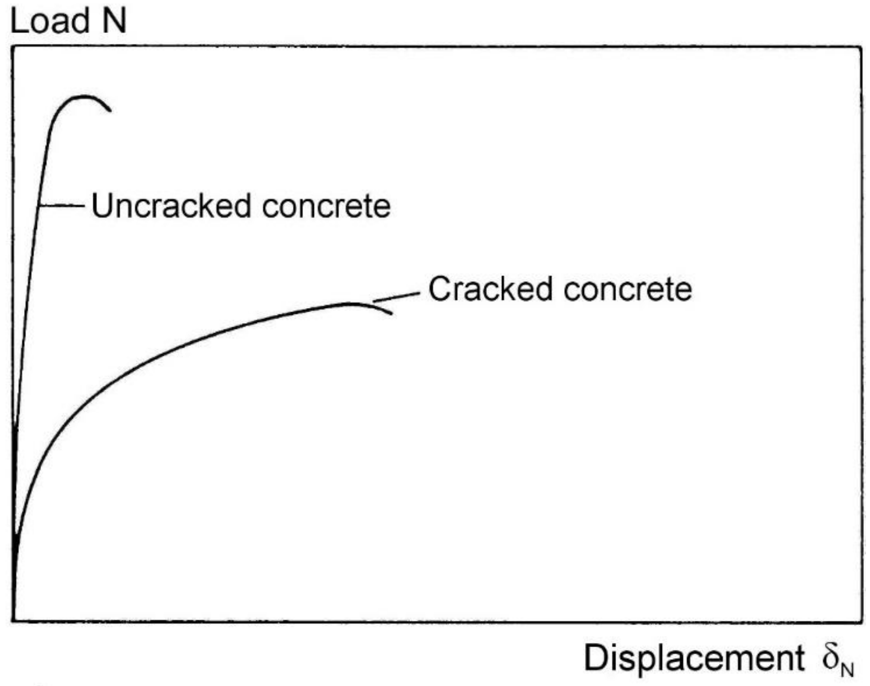


Eligehausen et al.: Anchorage in Concrete Construction. Ernst & Sohn Verlag, 2006.

PERFORMANCE OF ANCHORS IN CONCRETE - TENSION TESTS

- on **torque-controlled expansion anchors** developed for **cracked** concrete.

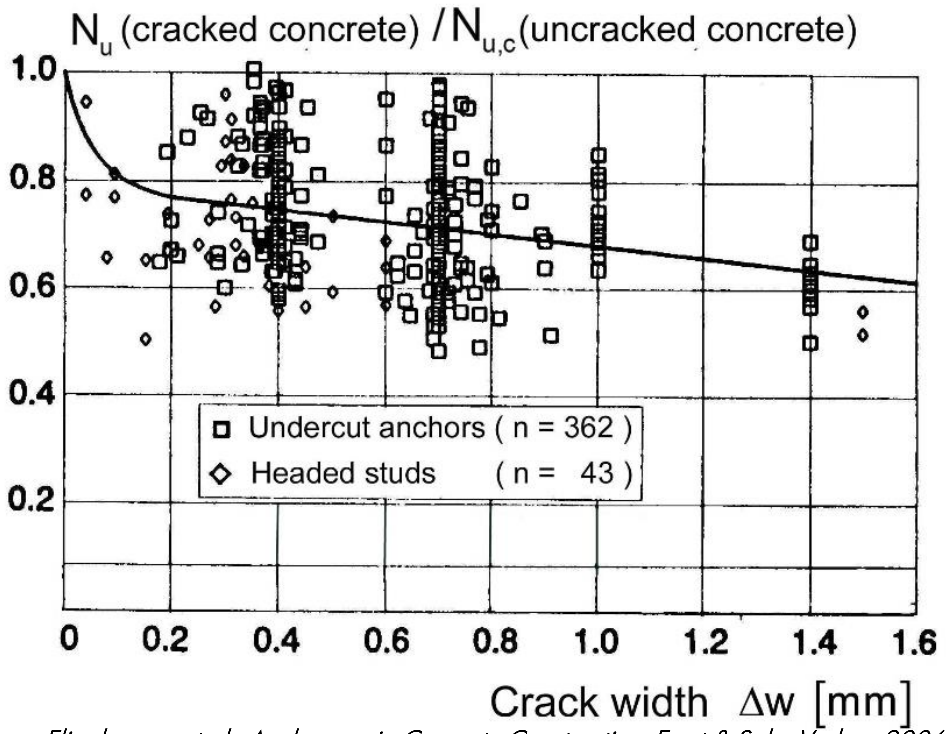




Eligehausen et al.: Anchorage in Concrete Construction. Ernst & Sohn Verlag, 2006.

PERFORMANCE OF ANCHORS IN CONCRETE - TENSION TESTS

- Summary



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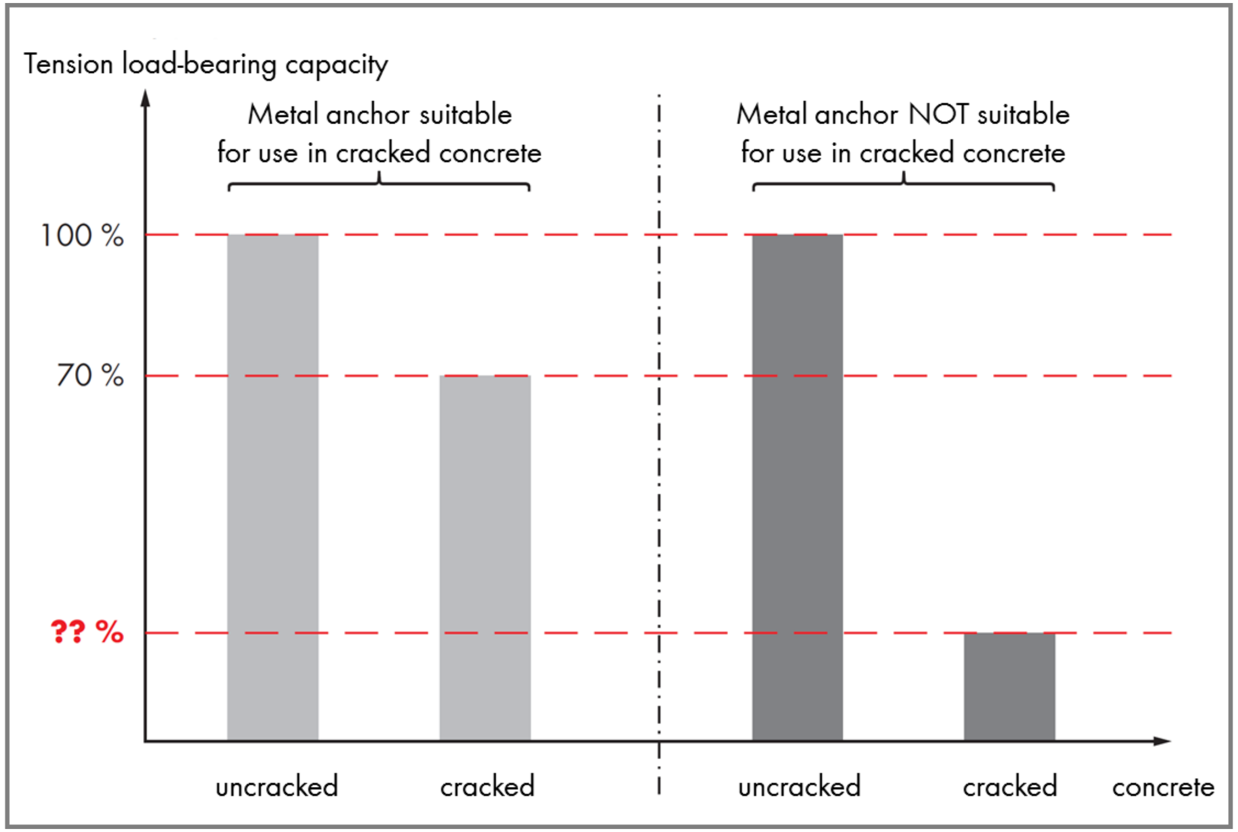
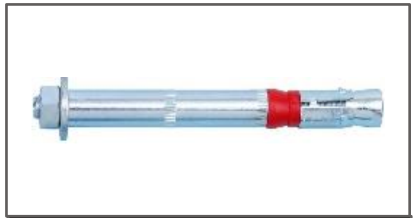


ANCHORS SUITABLE FOR CRACKED CONCRETE

W-BS

W-FAZ PRO

W-FAZ



W-HAZ

WIT-UH 300

WIT-VM 250

WIT-PE 500

WIT-PE 1000

WIT-VIZ

VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

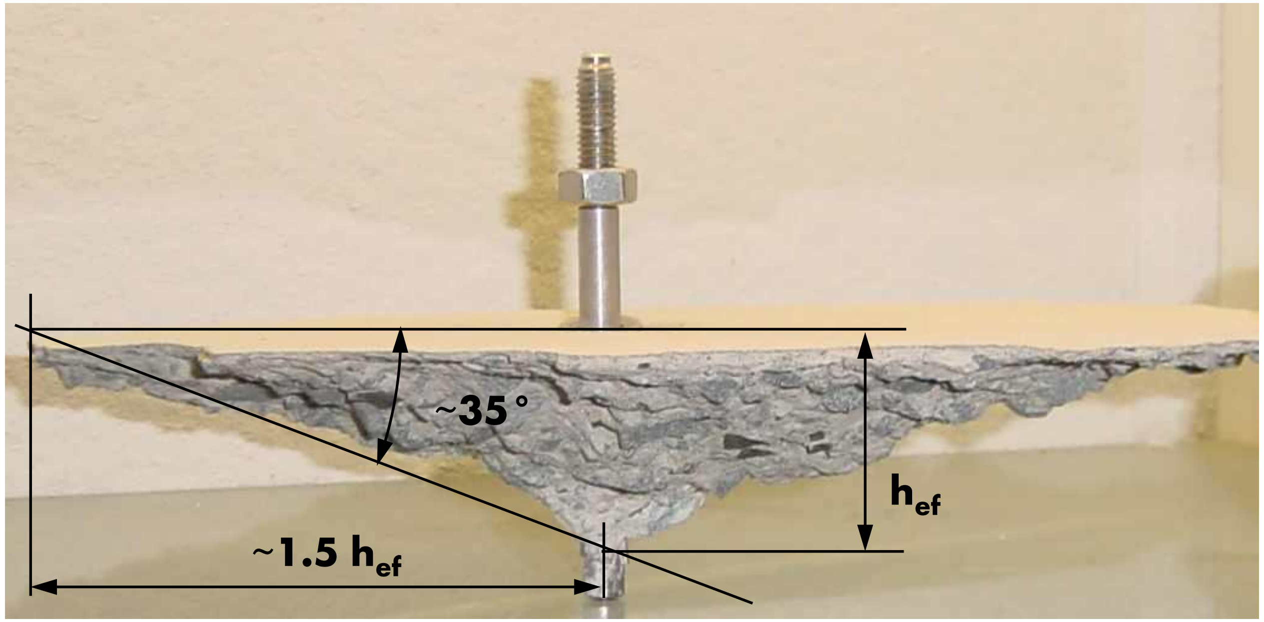
WÜRTH GROUP

Geometric effect of axial spacing and edge distance.

$N_{Rk,c} = N_{Rk,c}^0 \cdot \frac{A_{c,N}}{A_{c,N}^0} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N}$	(7.1)
$\frac{A_{c,N}}{A_{c,N}^0}$ **Geometric effect of axial spacing and edge distance.**	

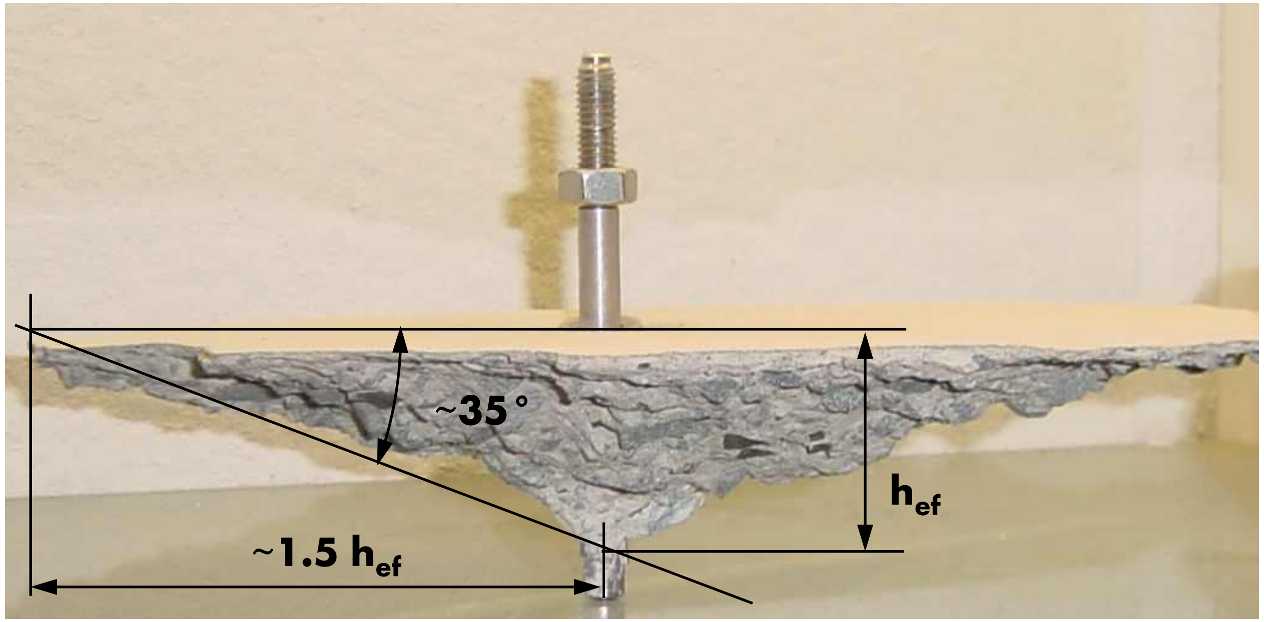
VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

Good to know **Idealized concrete cone and area $A^0_{c,N}$ of concrete cone of an individual fastener**

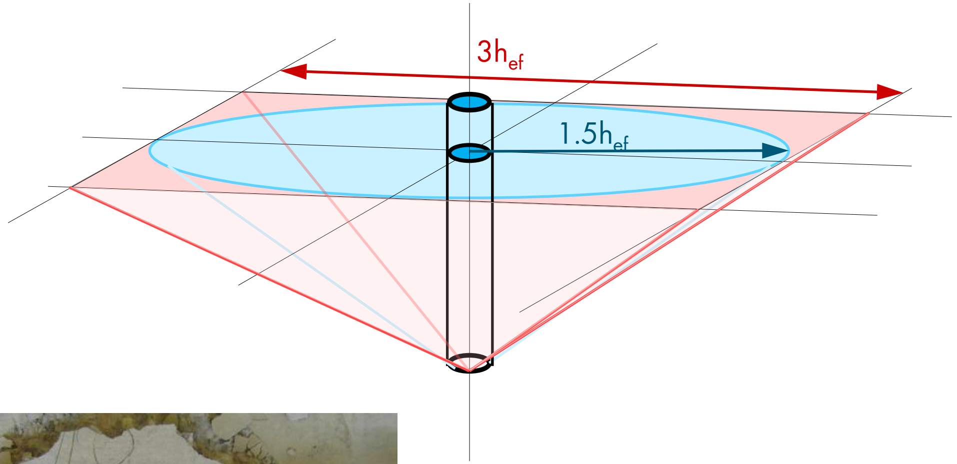


VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

Good to know **Idealized concrete cone and area $A^0_{c,N}$ of concrete cone of an individual fastener**



From cone to pyramid

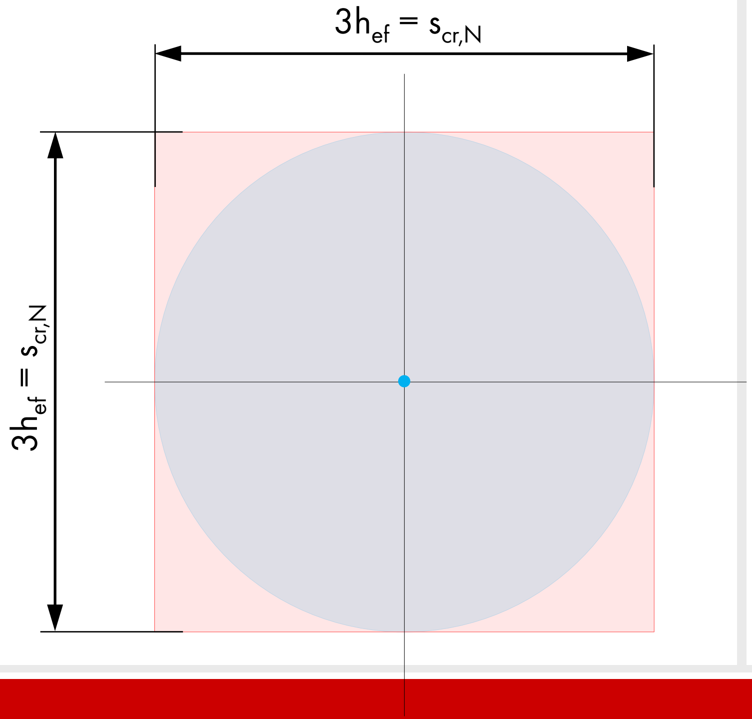


VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

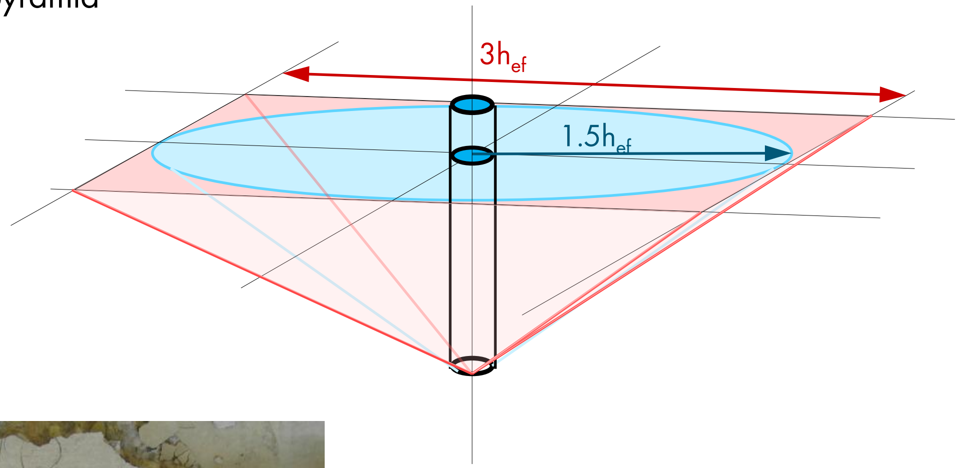
Good to know **Idealized concrete cone and area $A^0_{c,N}$ of concrete cone of an individual fastener**

Characteristic spacing $s_{cr,N} = 3h_{ef}$

Reference projected area $$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$$



From cone to pyramid

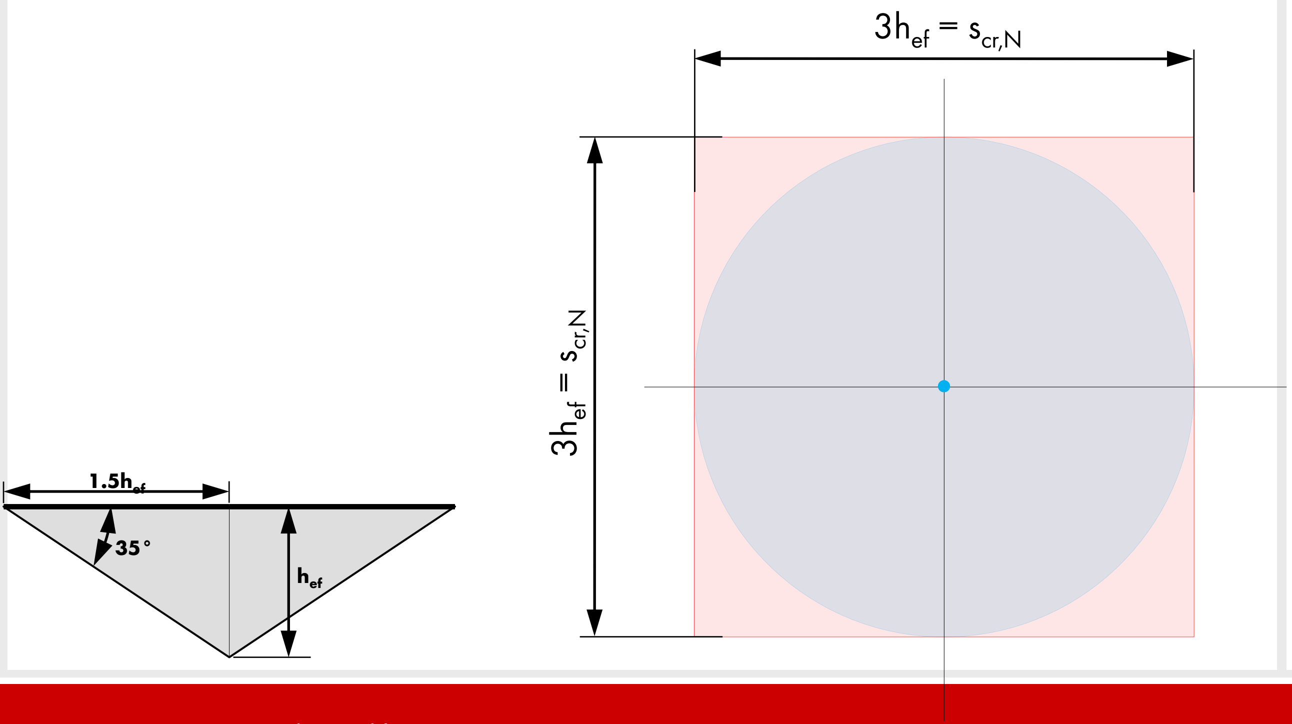


VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

Good to know **Actual area $A_{c,N}$ of the idealized concrete cone for a group of fasteners**

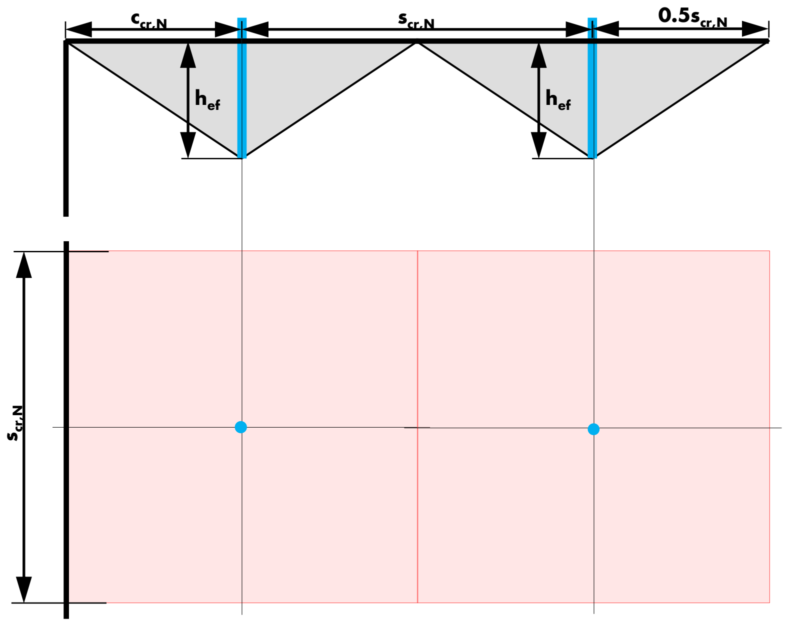
Characteristic spacing $s_{cr,N} = 3h_{ef}$

Reference projected area $$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N}$$



Characteristic spacing $s_{cr,N}$ and characteristic edge distance $c_{cr,N} = 0.5s_{cr,N}$

Actual projected area $$A_{c,N} = s_{cr,N}(c_{cr,N} + s_{cr,N} + 0.5s_{cr,N}) = 2 \cdot s_{cr,N} \cdot s_{cr,N}$$

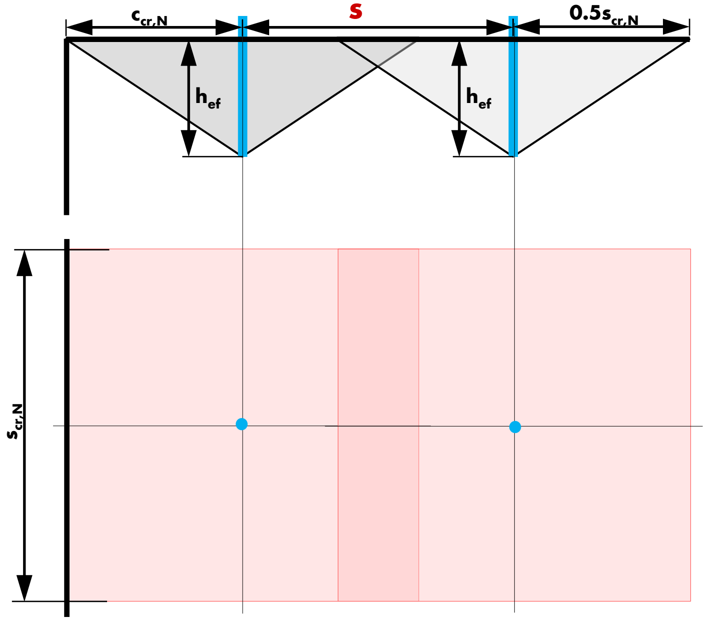


VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

Good to know **Actual area $A_{c,N}$ of the idealized concrete cone for a group of fasteners**

Actual projected area $A_{c,N} = s_{cr,N}(c_{cr,N} + s + 0.5s_{cr,N})$

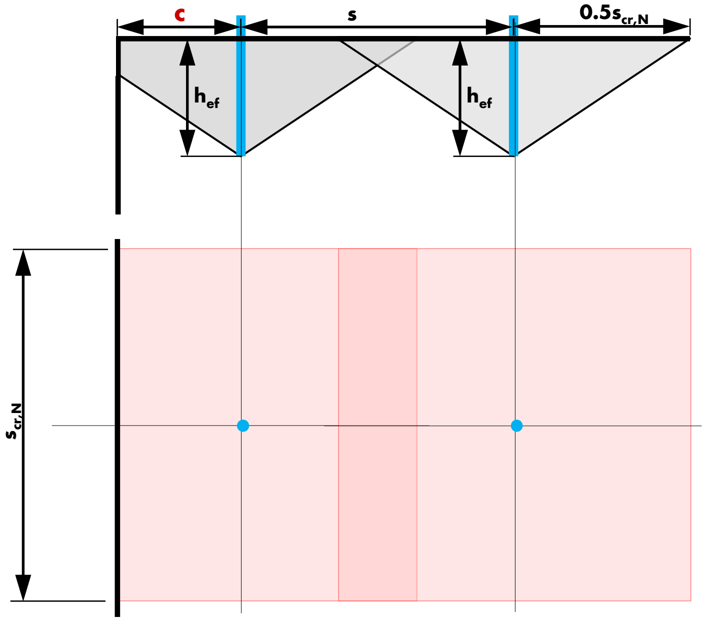
$s \leq s_{cr,N}$



Actual projected area $A_{c,N} = s_{cr,N}(c + s + 0.5s_{cr,N})$

$s \leq s_{cr,N}$

$c \leq c_{cr,N}$



VERIFICATION OF ULTIMATE LIMIT STATE
Tension Load

Good to know **Actual area $A_{c,N}$ of the idealized concrete cone for a group of four fasteners**

Actual projected area $A_{c,N} = (0.5s_{cr,N} + s_1 + c_1)(c_2 + s_2 + 0.5s_{cr,N})$

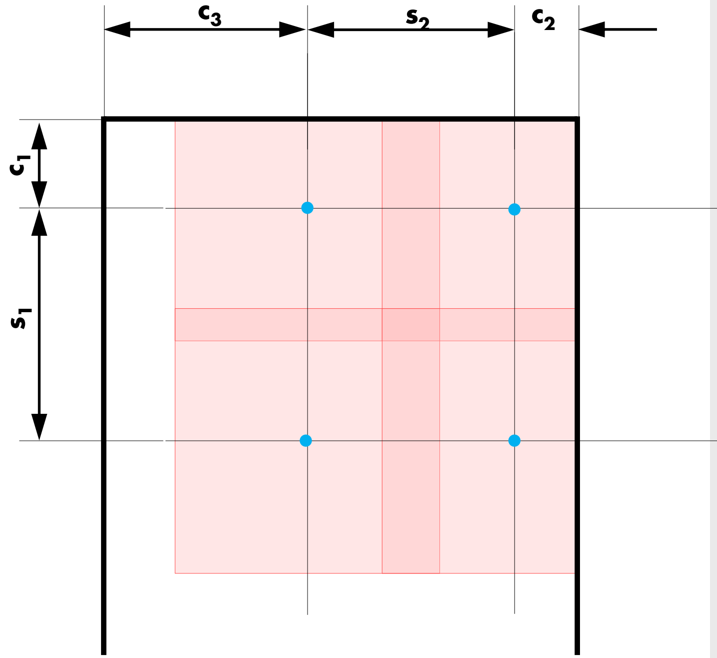
$s_1 \leq s_{cr,N}$

$s_2 \leq s_{cr,N}$

$c_1 \leq c_{cr,N} = 0.5s_{cr,N}$

$c_2 \leq c_{cr,N} = 0.5s_{cr,N}$

$c_3 \geq c_{cr,N} = 0.5s_{cr,N}$



Concrete splitting during installation
is avoided by complying with minimum values for **edge distances c_{min}, spacing s_{min}, member thickness h_{min}** and requirements for reinforcement as given in the relevant European Technical Product Specification.

CONCRETE SPLITTING DURING INSTALLATION