Hilti Anchor Channel

Fastening Technology Manual

Dear customer,

As it is our ambition to be the worldwide leader in fastening technology, we are continuously striving to provide you with state-of-the-art technical information reflecting the latest developments in codes, regulations and approvals and technical information for our products.

The Fastening Technology Manual for anchor channel reflects our ongoing investment into long term research, and development of leading fastening products.

This Fastening Technology Manual for Anchor Channel should be a valuable support tool for you when solving fastening tasks with cast-in fastening technology. It should provide you with profound technical know-how, and help you to be more productive in your daily work without any compromise regarding reliability and safety.

We will expand its scope further, along with more cast-in products we will develop in the future. As we strive to be a reliable partner for you, we would very much appreciate your feedback for improvements. We are available at any time to answer additional questions that even go beyond this content.

Raimund Zaggl
Business Unit Anchor

Important notice

1. The information and recommendations given herein are based on the principles, formulae and safety factors set out in the Hilti technical instructions, the operating manuals, the setting instructions, the installation manuals and other data sheets that are believed to be correct at the time of writing. The data and values are based on the respective characteristic data obtained from tests under laboratory or other controlled conditions. It is the user's responsibility to use the data given in the light of conditions on site and taking into account the intended use of the products concerned. The user has to check the listed prerequisites and criteria conform to the conditions actually existing on the job-site. Whilst Hilti can give general guidance and advice, the nature of Hilti products means that the ultimate responsibility for selecting the right product for a particular application must lie with the customer.
2. All products must be used, handled and applied strictly in accordance with all current instructions for use published by Hilti, i.e. technical instructions, operating manuals, setting instructions, installation manuals and others.
3. All products are supplied and advice is given subject to the Hilti terms of business.
4. Hilti's policy is one of continuous development. We therefore reserve the right to alter specifications, etc. without notice.
5. The given characteristic data in the Anchor Channel Fastening Technology Manual reflect actual test results and are thus valid only for the indicated test conditions.
6. Hilti is not obligated for direct, indirect, incidental or consequential damages, losses or expenses in connection with, or by reason of, the use of, or inability to use the products for any purpose. Implied warranties of merchantability or fitness for a particular purpose are specially excluded.

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Content

1 Introduction

In over 60 years Hilti has acquired tremendous know-how and gained worldwide acceptance as a reliable partner in the field of fastening systems. Being an innovative company, our foremost goal is to provide innovative, well-engineered products. Accordingly, we now offer an extensive cast-in anchor channel portfolio for a wide range of applications.

Anchor channel systems have been awarded approvals by Germany's DIBt (Deutsches Institut für Bautechnik) since the 1970s. Based on the state of the art at that time, these approvals represented a great step forward toward use of approved and reliable systems. But over the past few years the approach to the use of cast-in parts in the construction industry has changed significantly.

Up to now, the design of these systems has been based on tables. The load values given in these tables represent steel failure. This often results in systems being massively over-designed and boundary conditions are chosen to ensure that concrete failure cannot be expected. Today, in a world where cost-efficient design is absolutely crucial and natural resources such as the iron that goes into making steel are considered increasingly precious, the demand for better material utilization has grown. In recent years, a better understanding of various anchor channel failure modes has also been gained. Intensive research and testing has now yielded a new design method that elevates anchor channel design to the level of anchor design. A side effect of this new design method is the requirement for a complex calculation and verification model. All possible failure modes are taken into consideration during the verification process. This new design method thus fits perfectly in today's new generation of building codes utilizing the partial safety factor concept.

CEN-TS 1992-4 in combination with an European Technical Approval forms the basis for safe and economical as well as detailed anchor channel design.

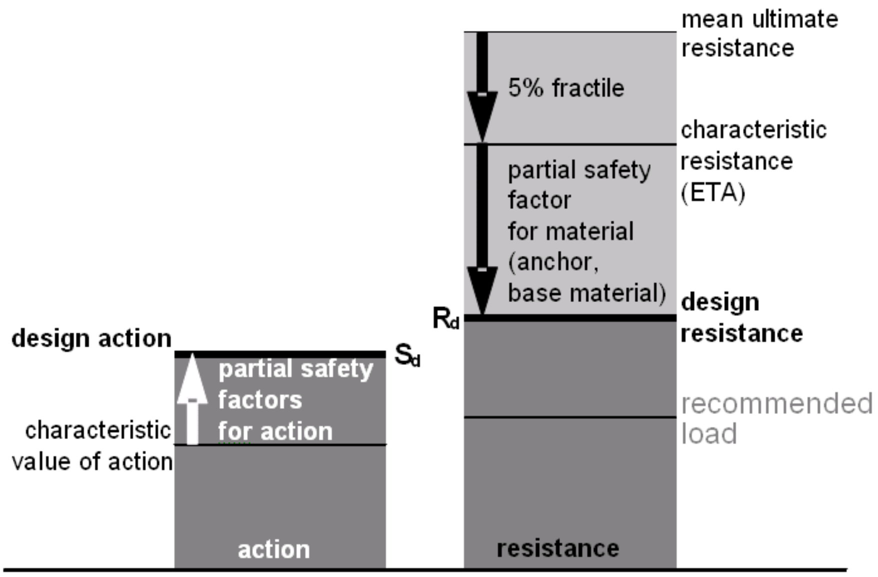
This manual refers to

- Static tensile loads as well as lateral shear loads in both cracked and un-cracked concrete from C12/15 through C90/105
- Load values in the event of fire for cracked concrete grade C20/25

The specification of anchor channels in accordance with CEN demands use of flexible, up-to-date software that allows engineers work efficiently. PROFIS Anchor Channel, the new PC application from Hilti, meets these requirements admirably.

1.1 Safety concept

Partial safety factor concept



For anchor channels for use in concrete with European Technical Approval (ETA) the partial safety factor concept according to the Common Understanding of Assessment Procedure, CUAP 06.01/01:2010 and CEN/TS 1992-4:2009 for static loads shall be applied. It must be shown that the value of design actions does not exceed the value of the design resistance:

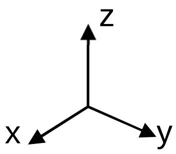
$S_d \leq R_d$.

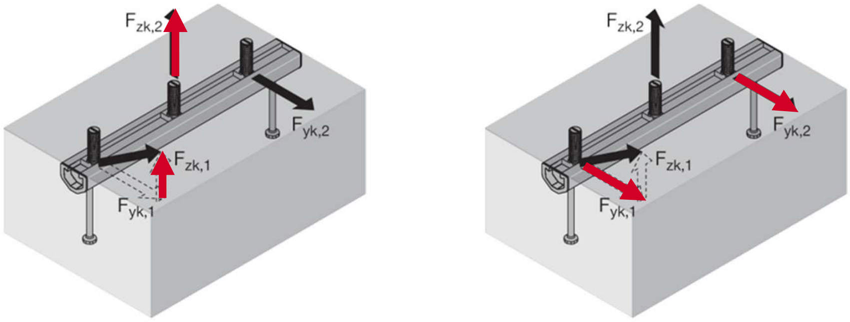
As for the characteristic resistance given in the respective ETA, reduction factors due to e.g. application conditions are already considered.

2 Required verifications

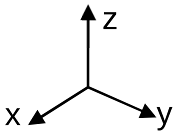
2.1 CEN design method

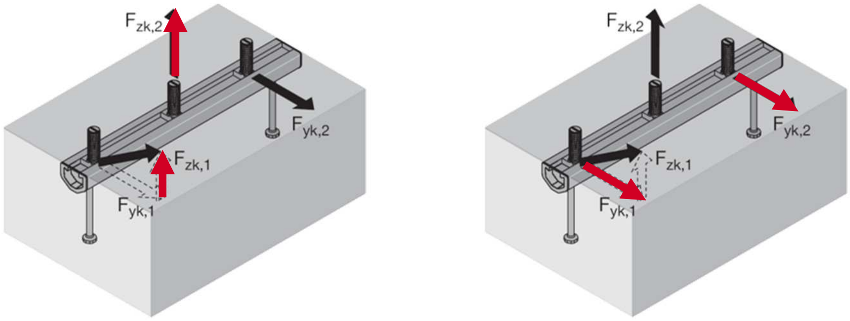
2.1.1 Tension / Shear lateral – static loads





2.1.2 Tension / Shear lateral – Fire exposure

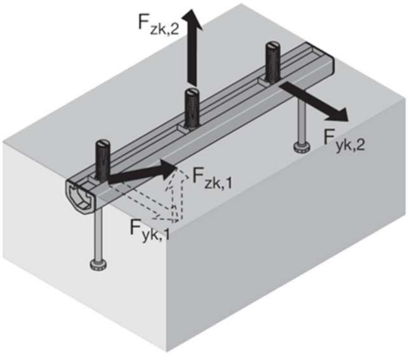


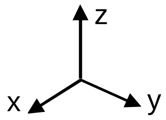


3 Anchor channel design for static loads: Tension/Shear lateral

3.1 Determination of forces acting on screws

3.1.1 External loads

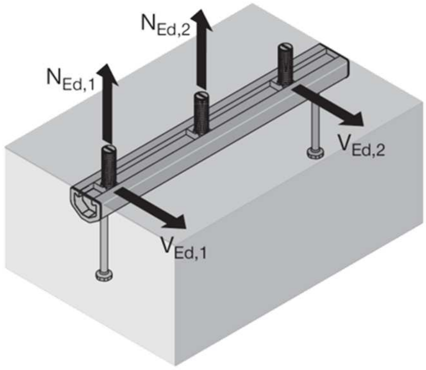




External moments need to be translated into forces acting on screws.

3.1.2 Loads acting on screw

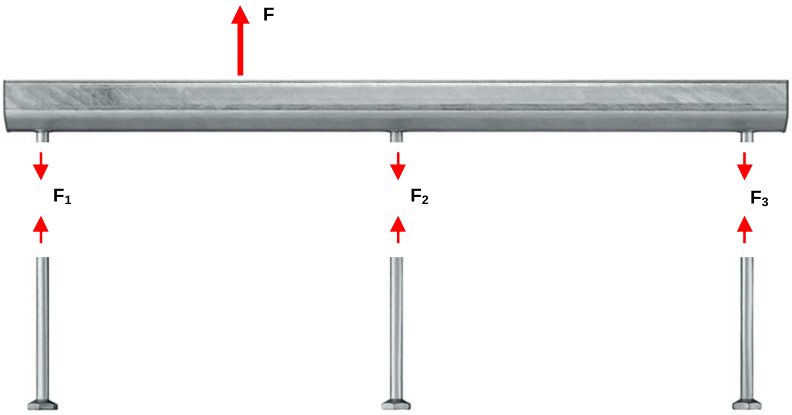
$$V_{Ed,i} = F_{yk,G,i} \cdot \gamma_G + F_{yk,Q,i} \cdot \gamma_Q$$
$$N_{Ed,i} = F_{zk,G,i} \cdot \gamma_G + F_{zk,Q,i} \cdot \gamma_Q$$



$F_{yk,G,i}$ / $F_{zk,G,i}$:	Characteristic dead load acting on screw i
$F_{yk,Q,i}$/ $F_{zk,Q,I}$:	Characteristic live load acting on screw i
γ_G:	Partial safety factor dead load
γ_Q:	Partial safety factor live load

3.2 Determination of forces acting on anchors

For several verifications it is necessary to know the loads acting on the anchors F_i. This requires a distribution of the loads acting on the screws into loads acting on the anchors. Anchor channels with two anchors (short pieces) allow a simplification with the assumption of a simply supported beam with a span length equal to the anchor spacing. In case of more than two anchors a triangular load distribution is assumed. Anchor forces can be determined on this basis separately for both tension and shear.
A linear superimposition of the anchor forces for all loads should be assumed if several loads are acting on the channel.



3.2.1 Anchor channel with more than 2 anchors

$$N^{a}_{Ed,i} = k \cdot A'_i \cdot N_{Ed}$$

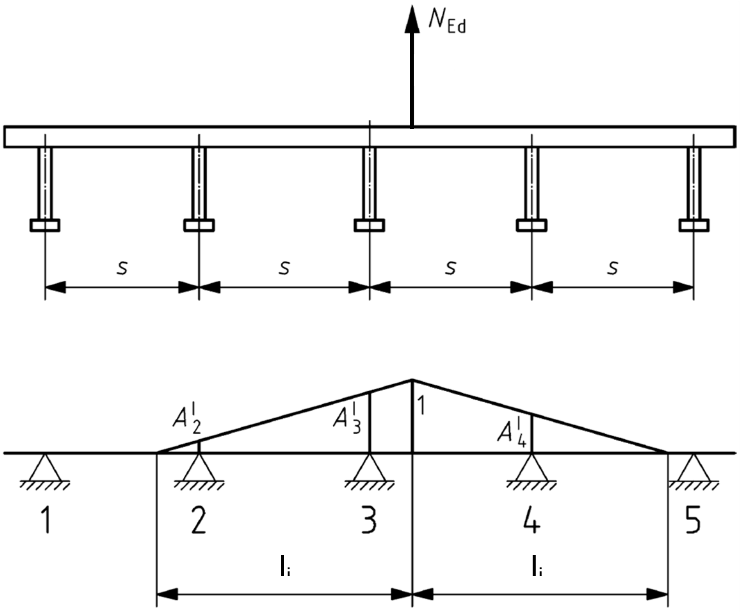
$$V^{a}_{Ed,i} = k \cdot A'_i \cdot V_{Ed}$$

A'_i ... Ordinate at the position of the anchor i of a triangle with the unit height at the position of load N and the base length $2l_i$

n … Number of anchors on the channel within the influence length l_i to either side of the applied load N_{ed} / V_{ed} on special screw

I_y … Moment of inertia of the channel [mm^4], as a simplification used both for distribution of tensile and shear forces

s … Anchor spacing [mm]



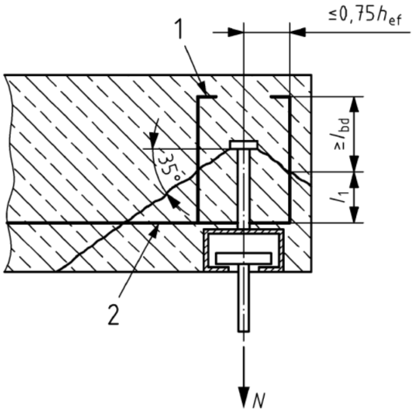
$$k = \frac{1}{\sum_{1}^{n} A'_i}$$

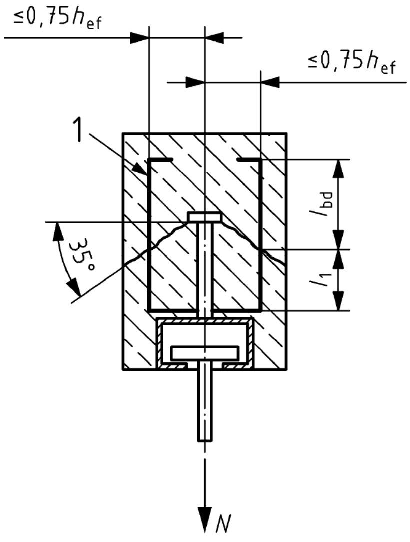
$$l_i = 13 \cdot I_y^{0.05} \cdot s^{0.5} \geq s \quad [mm]$$

Principle: Theorem on intersecting lines (A) with weighting (k)

3.3 Determination of tensile forces in supplementary reinforcement

3.3.1 Tensile force in reinforcement caused by a tensile force N^a_E





1 supplementary reinforcement

2 surface reinforcement

The design forces $N_{Ed,re}$ in the supplementary reinforcement should be calculated using the design load N^a_{Ed} on the anchor.

The supplementary reinforcement to take up tensile loads should comply with the following requirements:

a) For all anchors of a channel the same diameter of the reinforcement should be provided. It should consist of ribbed reinforcing bars (f_{yk} ≤ 500 N/mm^2) with a diameter 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.

b) The supplementary reinforcement should be placed as close to the anchors 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 ≤ 0.75h_{ef}, from the anchor 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 (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 designed to resist the forces arising from the assumed strut and tie model should be provided, taking into account splitting forces according to CEN/TS 1992-4-3:2009: 6.2.6

Concrete cone failure does not need to be verified if the design relies on supplementary reinforcement. In addition, the supplementary reinforcement should be designed to resist the entire load. The reinforcement should be anchored adequately on both sides of the potential failure planes.

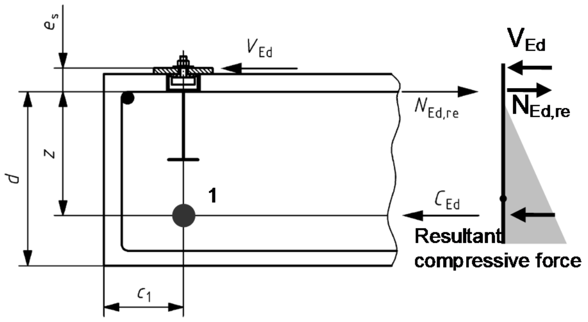
3.3.2 Tensile force in reinforcement caused by a shear force V_{Ed}

Additional force in upper reinforcement caused by shear load V_{Ed} due to offset moment (V_{Ed} and $N_{Ed,re}$ are not in the same action line)

$$\sum M_1 = 0:$$

$$N_{Ed,re} \cdot z - V_{Ed} \cdot (e_S + z) = 0$$

$$N_{Ed,re} = V_{Ed} \cdot \left(\frac{e_S}{z} + 1 \right)$$

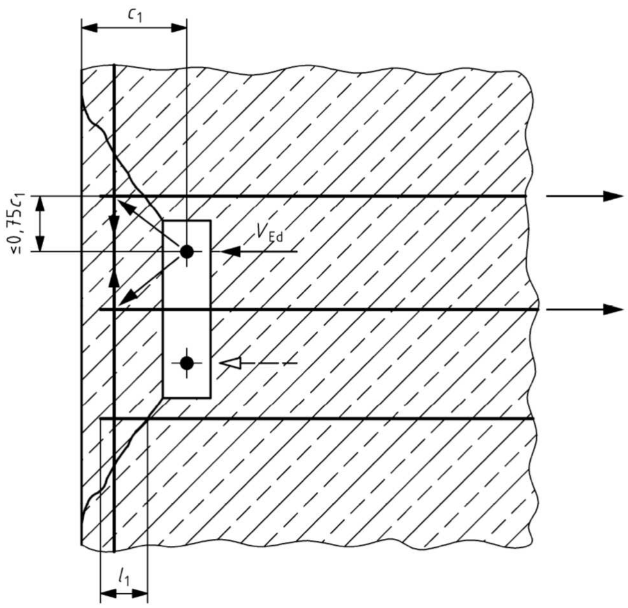


The supplementary reinforcement to take up shear loads should comply with the following requirements:

a) Only bars with a distance ≤ $0.75c_1$ from the anchor should be assumed as effective.

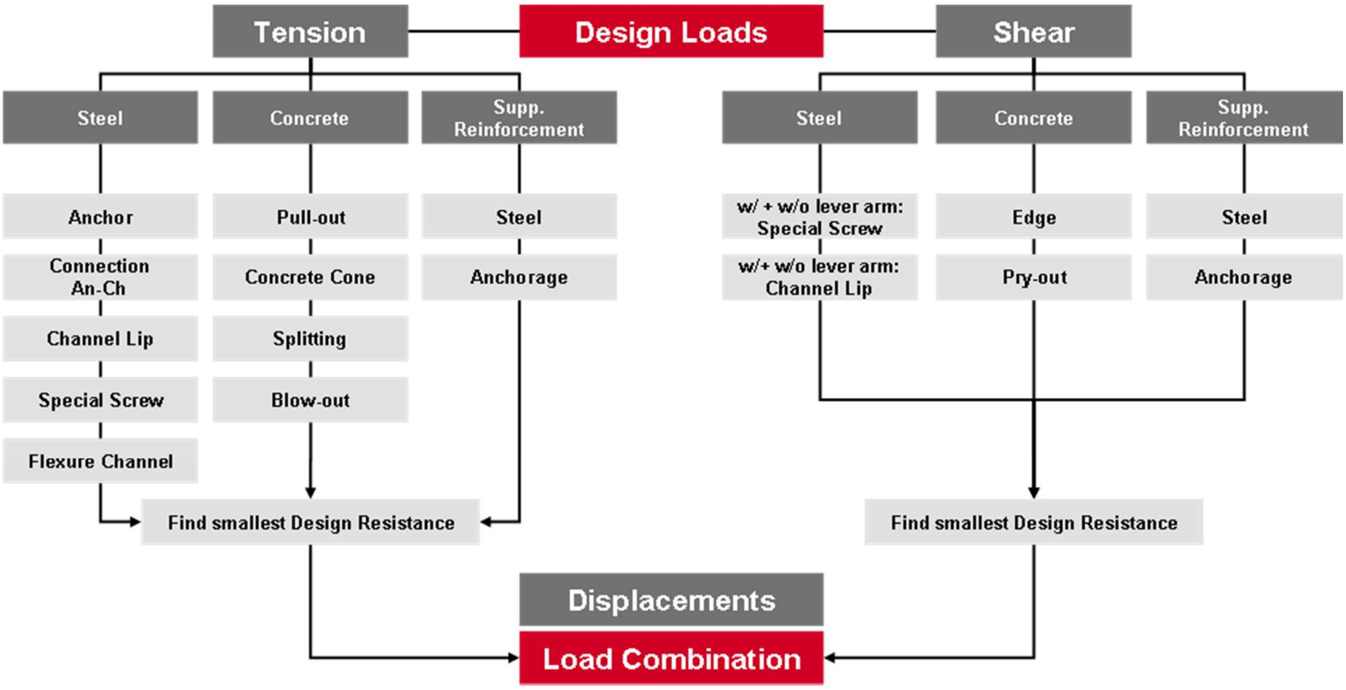
b) The anchorage length l_1 in the concrete breakout body is at least: min $l_1 = 10d_s$, straight bars with or without welded transverse bars and min $l_1 = 4d_s$, bars with a hook, bend or loop.

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. As a simplification it may be assumed that the compression struts have an angle of 45°.



The failure mode “concrete edge failure” does not need verification if the design requires supplementary reinforcement. The supplementary reinforcement should be designed to resist the total load. The reinforcement may be in the form of a surface reinforcement.

3.4 Overview of necessary verifications for anchor channels

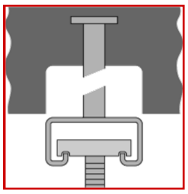


The flow chart depicts the necessary verifications for an anchor channel according to the design model given in CEN 1992-4-3. Both load directions have to be verified separately. The verification paths for shear and tension take all materials involved into account. In case of supplementary reinforcement for higher load resistance this needs to be designed and verified according to a) CEN design rules or b) the ETA approach. In cases where shear and tension occur, verification of combined shear and tension is mandatory.

Design values for the failure modes are given in ETA 11/0006. Verifications for concrete failure and failure of supplementary reinforcement are based on design formulae given in CEN TS 1992-4-3.

3.5 Tension: Design steel resistance $N_{Rd,s,x}$

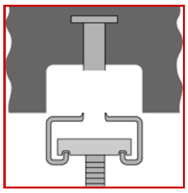
3.5.1 Failure of anchor under consideration



$$N^{a}_{Ed} \le N_{Rd,s,a} = \frac{N_{Rk,s,a}}{\gamma_{Ms}}$$

$N_{Rk,s,a}$; γ_{MS} are given in ETA

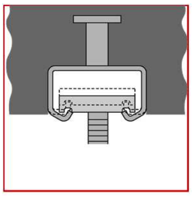
3.5.2 Failure of connection anchor – channel



$$N^{a}_{Ed} \le N_{Rd,s,c} = \frac{N_{Rk,s,c}}{\gamma_{Ms}}$$

$N_{Rk,s,c}$; γ_{MS} are given in ETA

3.5.3 Failure of channel lip



$$N_{Ed} \le N_{Rd,s,l} = \frac{N_{Rk,s,l}}{\gamma_{Ms,l}}$$

$N_{Rk,s,l}$; γ_{MS} are given in ETA

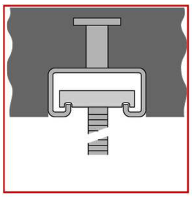
$N_{Rk,s,l}$ has to be reduced if the spacing between neighboring screws is smaller than s_{slb} (specified in ETA, not in CEN) but not smaller than $s_{min,s}$.

s_s… actual spacing between two neighboring screws

s_{slb}… characteristic spacing, depending on channel type, given in ETA

$$N_{Rk,s,l} = 0.5 \cdot \left(1 + \frac{s_s}{s_{slb}}\right) \cdot N_{Rk,s,l} \le 1.0 \cdot N_{Rk,s,c}$$

3.5.4 Failure of special screw

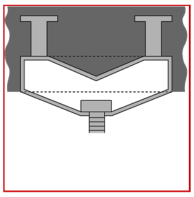


$$N_{Ed} \le N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$$

$N_{Rk,s}$; γ_{MS} are given in ETA

The characteristic tensile resistance of the special screw is identical with the tensile resistance of standard screws.

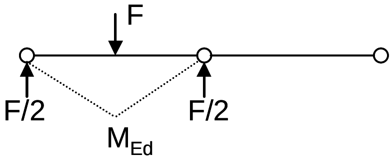
3.5.5 Failure through flexure of channel



$$M_{Ed} \le M_{Rd,sflex} = \frac{M_{Rk,sflex}}{\gamma_{Ms,flex}}$$

$M_{Rk,s,flex}$; $\gamma_{MS,flex}$ are given in ETA

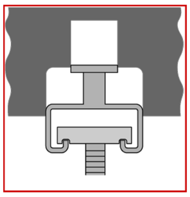
Note: The bending moment M_{ed} in the channel due to tension loads acting on the channel may be calculated assuming a simply supported single span beam with a span length equal to the anchor spacing.



3.6 Tension: Design concrete resistance $N_{Rd,x}$

Verifications for concrete failure modes under tension are comprehensive. Each failure mode has its own characteristic resistance to which several factors are applied by multiplication. These factors depend on various given conditions: edges, corners, member thickness, condition of concrete, neighboring anchors or channels, existing reinforcement, supplementary reinforcement.

3.6.1 Pull-out failure



$$N^{a}_{Ed} \le N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$$

$N_{Rk,p}$; γ_{Mp} are given in ETA

The characteristic resistance $N_{Rk,p}$ is limited by the concrete pressure under the head of the anchor.

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

A_h load bearing area of the head of the anchor

$= \frac{\pi}{4}\left(d_h^2 - d^2\right)$ in case of a round head

$f_{ck,cube}$ characteristic cube strength of concrete

$\psi_{ucr,N}$ = 1.0, for cracked concrete

= 1.4, for non-cracked concrete

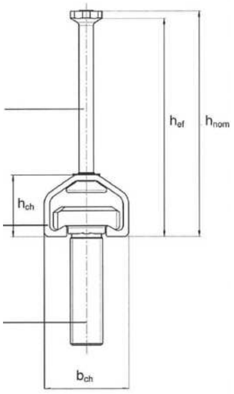
$$N^0_{Rk,c} = 8.5 \cdot \alpha_{ch} \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5}$$

$N^0_{Rk,c}$ … basic characteristic resistance of an anchor

α_{ch} … influence of channel on concrete cone failure; given in ETA

$f_{ck,cube}$ …characteristic cube strength of concrete [N/mm^2]

h_{ef} … anchorage depth [mm]; given in ETA



$\alpha_{s,N}$ … effect of neighboring anchors

s_i … distance between anchor under consideration and the neighboring anchors

$s_{cr,N}$ …characteristic spacing distance; given in ETA

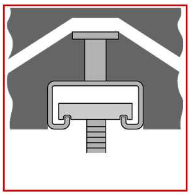
N_i … tensile force of an influencing anchor

N_0 … tensile force of the anchor under consideration

n … number of anchors within a distance $s_{cr,N}$ to both sides of the anchor under consideration

Note: "Anchor under consideration" designates the anchor that is being verified. We investigate the influence of the anchors i=1,2,… within the characteristic spacing of this anchor.

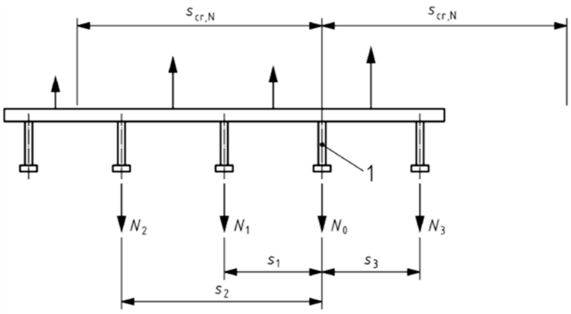
3.6.2 Concrete cone failure



$$N^a_{Ed} \le N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$$

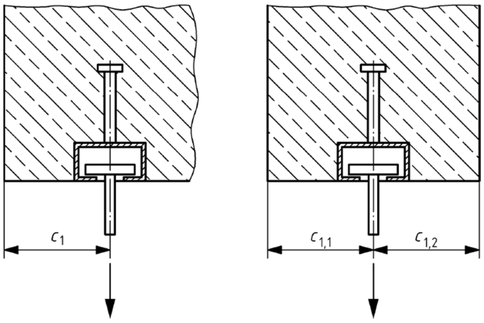
$$N_{Rk,c} = N^0_{Rk,c} \cdot \alpha_{s,N} \cdot \alpha_{e,N} \cdot \alpha_{c,N} \cdot \psi_{re,N} \cdot \psi_{ucr,N}$$

3.6.2.1 Effect of neighboring anchors



$$\alpha_{s,N} = \frac{1}{1 + \sum_{i=1}^{n}\left[\left(1 - \frac{s_i}{s_{cr,N}}\right)^{1.5} \cdot \frac{N_i}{N_0}\right]}$$

3.6.2.2 Effect of edges of the concrete member



$$\alpha_{e,N} = \left(\frac{c_1}{c_{cr,N}}\right)^{0.5} \le 1.0$$

Edges which are smaller than the characteristic edge distance, $c_1 < c_{cr,N}$ have an influence on the design resistance of the concrete. The concrete cone does not develop entirely. Hence, a smaller concrete surface subjected to tensile stresses is activated yielding a smaller resistance against concrete cone break-out. Influenced by the angle of the crack surface the characteristic edge distance is at least 1.5 times the effective embedment depth. The characteristic edge distance is half of the characteristic anchor spacing. In the ETA the minimum values for c_1 (edge) and c_2 (corner) are identical: $c_1 = c_2 = c_{min}$.

Note: c_1 and c_2 refer to the axis of the anchor and not to the outside dimension of the channel.

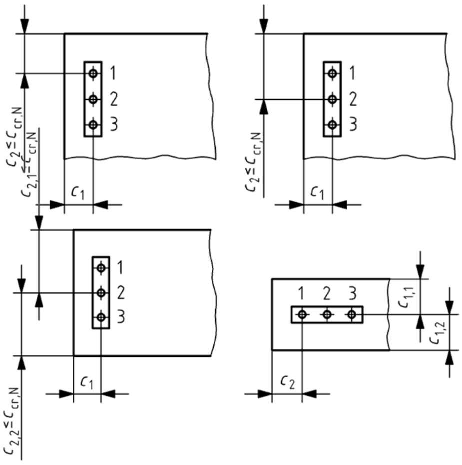
$\alpha_{e,N}$ …effect of edges of the concrete member on the capacity of an anchor

c_1	edge distance of the anchor channel
$c_{cr,N}$	characteristic edge distance; given in ETA

Numerical simulation and testing have proven that in case of 2 edges the minimum value governs the capacity. For that reason only the minimum value of $c_{1,2}$ and $c_{2,2}$ has to be considered.

Note: Check that both $c_{1,1}$ and $c_{1,2}$ are greater or equal c_{min} provided by ETA

3.6.2.3 Effect of a corner of a concrete member



$$\alpha_{c,N} = \left(\frac{c_2}{c_{cr,N}}\right)^{0.5} \le 1.0$$

$\alpha_{c,N}$ …effect of a corner of the concrete member on the capacity of an anchor

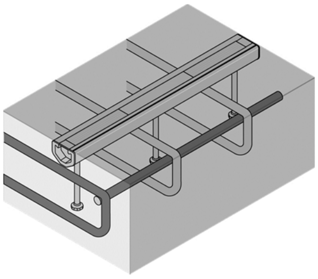
c_2 … corner distance of the anchor under consideration

In contrast to edges, in situations where 2 corners are present the product of both corners has to be considered:

$$\alpha_{c,N} = \left(\frac{c_{2,1}}{c_{cr,N}}\right)^{0.5} \cdot \left(\frac{c_{2,2}}{c_{cr,N}}\right)^{0.5} \le 1.0$$

Note: Check that both $c_{2,1}$ and $c_{2,2}$ are greater or equal to the minimum value c_{min} provided by ETA

3.6.2.4 Effect of shell spalling



$$\psi_{re,N} = 0.5 + \frac{h_{ef}}{200} \leq 1.0$$

$\psi_{re,N}$ … effect of shell spalling

Tensile stresses in concrete caused by existing reinforcement are superimposed by stresses resulting from the anchor channel thus reducing the capacity.

3.6.2.5 Effect of condition of concrete

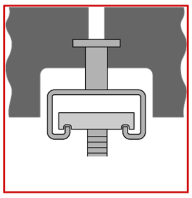
$\psi_{ucr,N}$ = 1.0, for cracked concrete

= 1.4, for non-cracked concrete

Usually reinforced concrete members are cracked. According to CEN TS 1992-4-1 non-cracked concrete may be assumed if it is proven that under service conditions the fastener with its entire embedment depth is located in non-cracked concrete.

It is always conservative to assume that the concrete is cracked if the concrete condition is unknown.

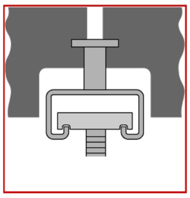
3.6.3 Splitting failure due to installation



This failure mode is avoided if the minimum requirements for edge distance c_{min}, spacing s_{min} and member thickness h_{min} are fulfilled.

c_{min}, s_{min} and h_{min} are given in ETA

3.6.4 Splitting failure due to loading



$$N^{a}_{Ed} \leq N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$$

$$N_{Rk,sp} = N^{0}_{Rk} \cdot \alpha_{s,N} \cdot \alpha_{e,N} \cdot \alpha_{c,N} \cdot \psi_{re,N} \cdot \psi_{ucr,N} \cdot \psi_{h,sp}$$

N^{0}_{Rk} … min ($N_{Rk,p}$; $N^{0}_{Rk,c}$)

$\alpha_{s,N}$ … effect of neighboring anchors

$\alpha_{e,N}$ … effect of edges of the concrete member

$\alpha_{c,N}$ … effect of a corner of the concrete member

$\psi_{re,N}$ … effect of shell spalling

$\psi_{ucr,N}$… effect for concrete conditions

$\psi_{h,sp}$ … effect of member depth h

3.6.4.1 Effect of neighboring anchors

$\alpha_{s,N}$ …effect of neighboring anchors, value is identical with $\alpha_{s,N}$ for concrete cone break-out (3.6.2.1).

3.6.4.2 Effect of edges of the concrete member

$\alpha_{e,N}$ …effect of edges of the concrete member, value is identical with $\alpha_{e,N}$ for concrete cone break-out (3.6.2.2).

3.6.4.3 Effect of a corner of a concrete member

$\alpha_{e,N}$ …effect of a corner of the concrete member, value is identical with (3.6.2.3)

3.6.4.4 Effect of shell spalling

$\psi_{re,N}$ …effect of shell spalling, value is identical with (3.6.2.4).

$\psi_{ucr,N}$ = 1.0, for cracked concrete

= 1.4, for non-cracked concrete

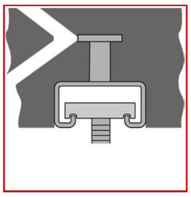
3.6.4.5 Effect of member depth h

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

$\psi_{h,sp}$ … effect of member depth h

Longitudinal reinforcement should be provided along the edge of the member, if the edge distance is smaller than the value $c_{cr,\,sp}$.

3.6.5 Blow-out failure



Verification of blow-out is not needed if $c>0.5h_{ef}$. This requirement is fulfilled for all HAC anchor channels.

3.7 Tension: Design supplementary reinforcement resistance $N_{Rd,re}$

It is possible to add supplementary reinforcement in order to enhance the anchor channel's tensile resistance with respect to concrete failure. In order to activate the reinforcement, cracks in the concrete must run across the embedded rebar in a non-parallel direction. This leads to the requirement that the entire crack load needs to be taken up by the reinforcement. It also must be assured that the force can be introduced safely into the concrete on both sides of the crack. This calls for a proper anchorage.

The loads from the anchor are transferred to the rebars via a strut-and-tie model. Effective supplementary reinforcement has to fulfill several criteria:

1) use rebars of the same diameter for all anchors of one channel

2) choose rebars with a diameter smaller or equal 16mm

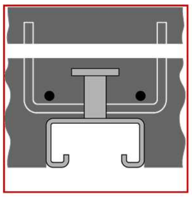
3) use ribbed rebars with a yield strength of less than or equal to 500 MPa

4) use either stirrups or loops

5) place the rebars as close as possible to the anchor, refer to CEN for more details

6) provide a surface reinforcement

3.7.1 Steel failure



$$N_{Ed}^{a} \leq N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$$

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

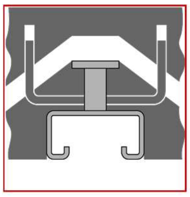
A_s … cross section of one leg of the supplementary reinforcement

f_{yk} … nominal yield strength of the supplementary reinforcement

n… number of rebars

The calculation of the steel capacity of the reinforcement is according to standard reinforced concrete design.

3.7.2 Anchorage failure in the concrete cone



$$N_{Ed}^{a} \le N_{Rd,a} = \frac{N_{Rk,a}}{\gamma_{Mc}}$$

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

l_1 …	anchorage length of the supplementary reinforcement in the assumed failure cone
	$\geq l_{b,min} = 4d_s$ (anchorage with bends, hooks, loops)
	$\geq l_{b,min} = 10d_s$ (anchorage with straight bars)
d_s …	diameter of reinforcement bar
f_{bd} …	design bond strength according to EN 1992-1-1
α …	influencing factor according to EN 1992-1-1; 0.7 hooked bars
n …	number of legs of the supplementary reinforcement effective for one anchor

Calculation of the bond strength of the reinforcement is according to standard reinforced concrete design. (EN 1992-1-1:2004)

3.8 Shear Lateral: Design steel resistance $V_{Rd,s,x}$

3.8.1 Stand-off situation

Note: The channel requires full constraint!

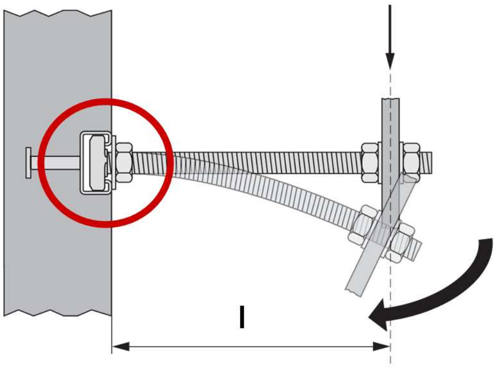
No lever arm can be assumed if:

a) The fixture is made of metal and the area of the fastening is fixed directly to the concrete without an intermediate layer or with a leveling layer of mortar with a compressive strength ≥ 30 N/mm² and a thickness ≤ d/2

b) The fixture is in contact with the fastener over a length of at least $0{,}5 \cdot t_{fix}$.

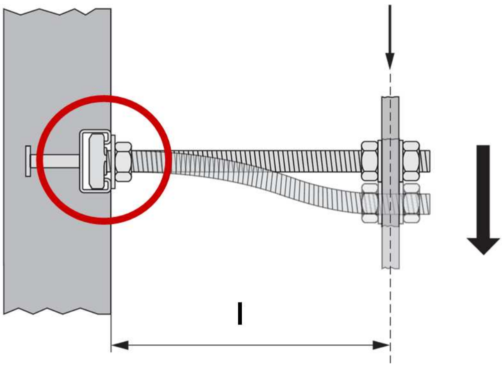
c) The diameter d_f of the hole in the fixture is limited.

Length of the lever arm l:



α=1; fixture can rotate

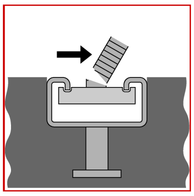
With anchor channels, full constraint can be considered only if the special screw is fastened directly to the channel by a separate nut. If this is not the case, stand-off shear transfer is not permissible.



α=2; fixture cannot rotate

The provisions applicable to stand-off fixtures with anchor channels are similar to those for anchors.

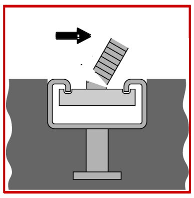
3.8.2 Failure of special screw without lever arm



$$V_{Ed} \le V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$$

$V_{Rk,s}$; γ_{MS} are given in the relevant ETA

3.8.3 Failure of special screw with lever arm



$$V_{Ed} \le V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$$

$V_{Rk,s}$; γ_{MS} are given in the relevant ETA

$$V_{Rk,s} = \frac{\alpha_M \cdot M_{Rk,s}}{l}$$

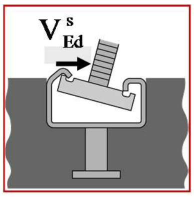
$M^0_{Rk,s}$ … characteristic bending resistance of special screw given in ETA

α_M… degree of restraint of anchor channel

l lever arm

$$M_{Rk,s} = M^0_{Rk,s} \cdot \left(1 - N_{Ed}/N_{Rd,s}\right)$$

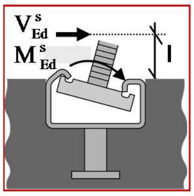
3.8.4 Failure of local flexure of channel lip without lever arm



$$V_{Ed} \le V_{Rd,s,l} = \frac{V_{Rk,s,l}}{\gamma_{Ms,l}}$$

$V_{Rk,s,l}$; $\gamma_{MS,l}$ are given in ETA

3.8.5 Failure of local flexure of channel lip with lever arm



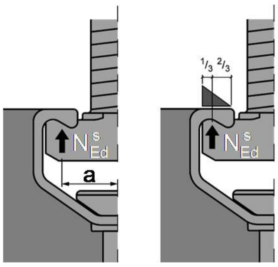
$$N^s_{Ed} \le 0.5 N_{Rd,s,l} = \frac{0.5 \cdot N_{Rk,s,l}}{\gamma_{Ms,l}}$$

$N_{Rk,s,l}$; γ_{MS} are given in ETA

$$N^s_{Ed} = \frac{M^s_{Ed}}{2 \cdot a}$$

a … distance between screw axis and resultant force

$$M^s_{Ed} = \frac{l \cdot V^s_{Ed}}{\alpha_M}$$



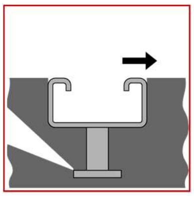
l … lever arm

α_M… degree of restraint of anchor channel

Shear loads with a lever arm first require a translation of the resulting moment into a tensile load acting on the channel lip. Having translated the moment into a corresponding tensile force acting on the channel lip, verification of the channel lip is similar to verifications under pure tensile loads – the only difference is that only one lip is loaded in tension and therefore the given design resistance (ETA) of the channel lip under tension is reduced by 50%.

3.9 Shear lateral: Design concrete resistance $V_{Rd,x}$

3.9.1 Pry-out failure



$$V_{Ed}^{a} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$$

γ_{Mc} given in ETA

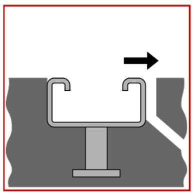
$$V_{Rk,cp} = k_5 \cdot N_{Rk,c}$$

$N_{Rk,c}$: according to the verification of concrete cone failure under tensile load, determined for the anchors loaded in shear

k_5… given in ETA, (Hilti HAC anchor channel: k_5=2.0) in case of additional shear reinforcement: k_5*0.75

Pry-out is a failure mode where concrete break-out occurs due to shear loading at the back of the channel. As the concrete cone looks similar to the concrete cone that occurs under tensile loads, the resistant pry-out load is based on the resistance of concrete cone break-out under tensile load multiplied by the factor k_5.

3.9.2 Concrete edge failure



$$V_{Ed}^{a} \leq V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$$

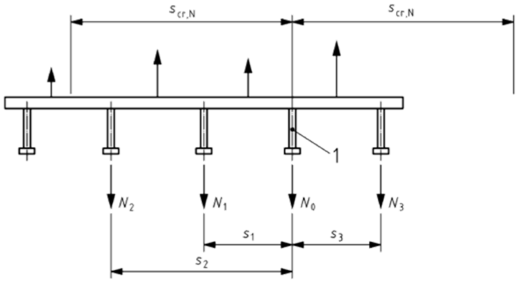
$$V_{Rk,c} = V_{Rk,c}^{0} \cdot \alpha_{s,V} \cdot \alpha_{c,V} \cdot \alpha_{h,V} \cdot \alpha_{90°,V} \cdot \psi_{re,V}$$

$\alpha_{s,V}$ … effect of neighboring anchors
$\alpha_{c,V}$ … effect of a corner of the concrete member
$\alpha_{h,V}$ … effect of thickness of concrete member
$\alpha_{90°,V}$ … effect of load parallel to the edge
$\psi_{re,V}$ … effect of concrete conditions

$$V_{Rk,c}^{0} = \alpha_p \cdot \sqrt{f_{ck,cube}} \cdot c_1^{1.5}$$

α_p … given in ETA
$f_{ck,cube}$ characteristic cube strength of concrete [N/mm^2]
c_1 … edge distance [mm]

3.9.2.1 Effect of neighboring anchors



s_i … distance between anchor under consideration and the neighboring anchors

$s_{cr,V}$ characteristic spacing distance

V_i … shear force of an influencing anchor

V_0 … shear force of the considered anchor

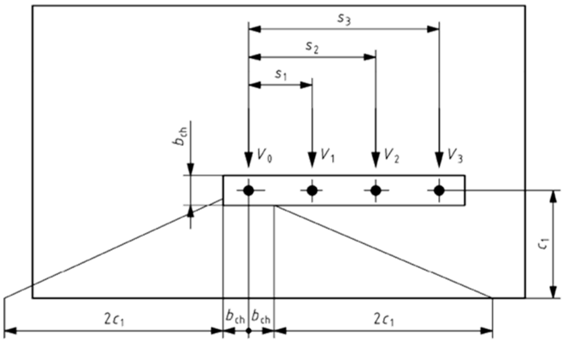
n … number of anchors within a distance $s_{cr,V}$ to both sides of the considered anchor

b_{ch}… width of anchor channel

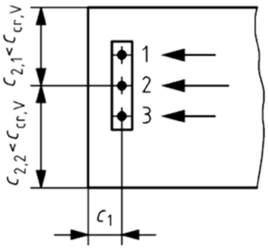
$$s_{cr,V} = 4c_1 + 2b_{ch}$$

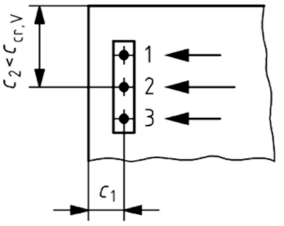
$$\alpha_{s,V} = \frac{1}{1+\sum_{i=1}^{n}\left[\left(1-\frac{s_i}{s_{cr,V}}\right)^{1.5}\cdot\frac{V_i}{V_0}\right]}$$

Overlapping breakout cones of anchors lead to a reduction of the capacity. The factor $\alpha_{s,V}$ accounts for the mutual effect of the anchors loaded in shear.



3.9.2.2 Effect of corner of the concrete member





$\alpha_{c,V}$ … effect of corners of the concrete member

c_2 … corner distance of the anchor channel

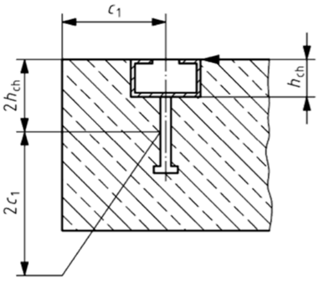
$c_{cr,V}$ … characteristic edge distance, given in ETA

$$c_{cr,V} = 0.5s_{cr,V} = 2c_1 + b_{ch}$$

$$\alpha_{c,V} = \left(\frac{c_2}{c_{cr,V}}\right)^{0.5} \le 1.0$$

For anchors influenced by two corners ($c_2<c_{cr,V}$) the factor $\alpha_{c,V}$ should be calculated for each corner and the product of the factors $\alpha_{c,V}$ should be inserted.

3.9.2.3 Effect of thickness of structural component

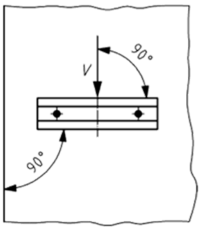


h_{ch} … height of anchor channel
c_1… edge distance

$$h_{cr,V} = 2c_1 + 2h_{ch}$$

$$\alpha_{h,V} = \left(\frac{h}{h_{cr,V}}\right)^{0.5} \leq 1.0$$

3.9.2.4 Effect of load parallel to the edge

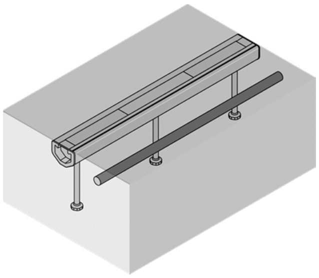


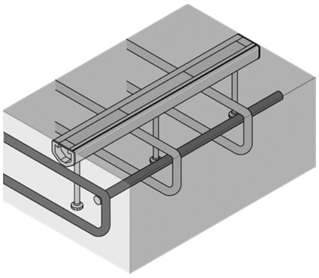
$$\alpha_{90°,V} = 2.5$$

in all other cases $\alpha_{90°,V} = 1$

Engineering judgment is needed in case the angle α slightly deviates from 90°.

3.9.2.5 Effect of anchor channel position





For Hilti channels ($h_{ch} \leq 40$ mm):

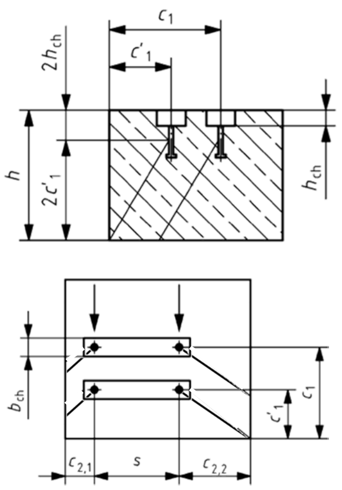
$\psi_{re,V} = 1.0$ anchor channel in cracked concrete without edge reinforcement or stirrups

$\psi_{re,V} = 1.2$ anchor channel in cracked concrete with straight edge reinforcement (≥ ø 12mm)

$\psi_{re,V} = 1.4$ anchor channel in cracked concrete with edge reinforcement and stirrups with a spacing $a \leq 100$mm and $a \leq 2c_1$

$\psi_{re,V} = 1.4$ non-cracked concrete

3.9.2.6 Effect of narrow thin member



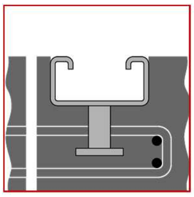
A narrow thin member can be assumed if $c_{2,max} \le c_{cr,V}$ and $h \le h_{cr,V}$. More realistic results may be obtained by using a virtual edge distance c'_1 instead of c_1:

$$c'_1 = \max \begin{cases} (\max(c_{2,1};c_{2,2}) - b_{ch})/2 \\ (h - 2h_{ch})/2 \end{cases}$$

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

3.10 Shear lateral: Design supplementary reinforcement resistance VRd,re: CEN model

3.10.1 Steel failure



$$N_{Ed}^{h} \le N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$$

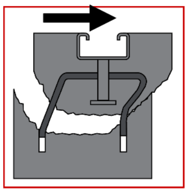
$$N_{Rk,re} = n \cdot A_s \cdot f_{yk}$$

A_s … cross section of one leg of the supplementary reinforcement

f_{yk} … nominal yield strength of the supplementary reinforcement

n… number of legs of the supplementary reinforcement effective for one anchor

3.10.2 Anchorage failure in the concrete cone



$$N_{Ed}^{a} \le N_{Rd,a}$$

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

l_1 … anchorage length of the supplementary reinforcement in the assumed failure cone

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

$\ge l_{b,min} = 10d_s$ (anchorage with straight bars)

d_s … diameter of reinforcement bar

f_{bd} … design bond strength according to EN 1992-1-1

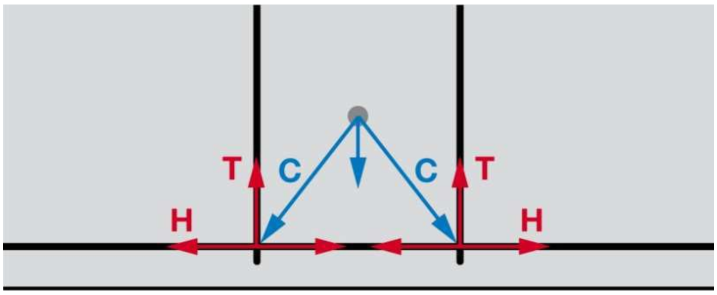
α … influencing factor according to EN 1992-1-1; 0.7 hooked bars

n … number of legs of the supplementary reinforcement effective for one anchor

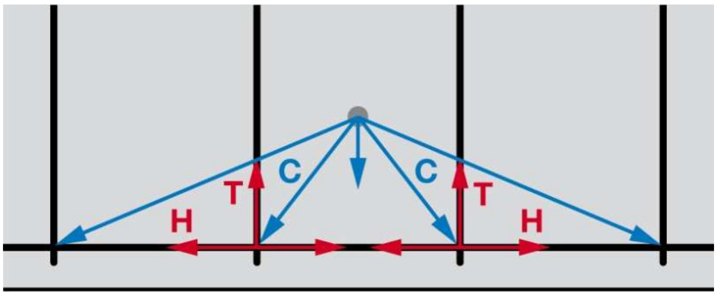
3.11 Shear lateral: Design supplementary reinforcement resistance VRd,re , ETA model

3.11.1 Introductory remarks

The model is based on the assumption that the entire shear load is resisted by the supplementary reinforcement.
The assumed load distribution within the reinforced concrete is described in the following strut-and-tie model: (Shear force towards edge of member, blue arrows compression, red arrows tension)



Single fastener with 2 stirrups



Single fastener with 4 stirrups

The load applied generates a compressive force within the concrete that acts towards the edge of the member. The equilibrium at the node is achieved by a tension force working in the stirrups and horizontal tensile forces in the edge reinforcement. Longitudinal reinforcement is essential for effectiveness of the stirrups.

The design resistance of the stirrups is influenced by several factors:
The chosen yield strength f_{yk} and cross section of the reinforcement A_s, control the behavior and are one of the limiting factors for the maximum load taken up by the reinforcement.
The chosen rebar layout influences how much of the reinforcement can be activated and taken into account for resistance. In tests it was found that not only the steel properties of the reinforcement limit the ultimate capacity but also the edge distance of the stirrups. The further the supplementary reinforcement is away from the edge, the lower the activated reinforcement value becomes and, hence, the lower the ultimate capacity.

This relation is mirrored in the equation which defines the upper limit of the ultimate capacity of supplementary shear reinforcement:

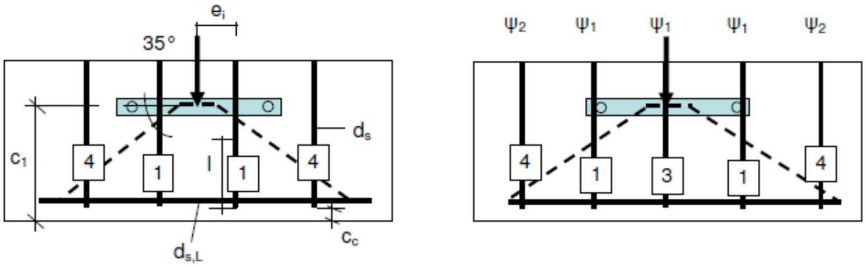
$$V_{Rk,c,re,max} = 4.2 \cdot c_1^{-0.12} \cdot V_{Rk,c}$$

The resistance to a shear load with supplementary reinforcement is described by the following equation:

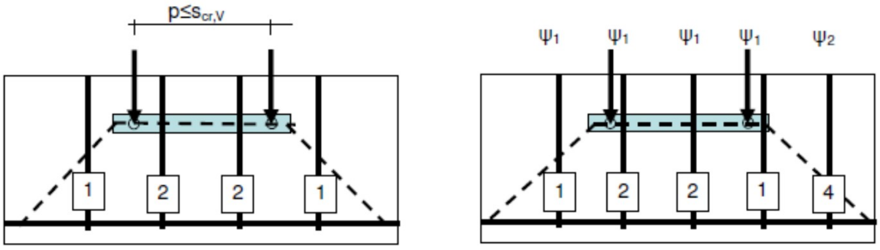
$$V_{Rk,c,re} = V_{Rk,c,hook} + V_{Rk,c,bond} \leq V_{Rk,c,re,max}$$

This is made up of the resistance due to the hook geometry of the stirrup and the bond behavior of the reinforcement with the concrete.

The “hook resistance” takes into consideration the beneficial geometry of the reinforcement. The stirrup acts as a hook that hinders concrete break-out. Depending on the position of the stirrup and the load applied, its influence can vary considerably. In order to achieve good results and avoid over-estimation of the behavior of the supplementary reinforcement, ψ factors are applied to the “hook resistance”. These factors reduce the value of the hook capacity $V_{Rk,c,hook}$ representing more realistically the effectiveness of a rebar against concrete edge failure. The following pictures illustrate the determination of the ψ factors.



Determination of different ψ factors for a single load:



Determination of different ψ factors for two loads

ψ_1 = 0.67 for stirrups:

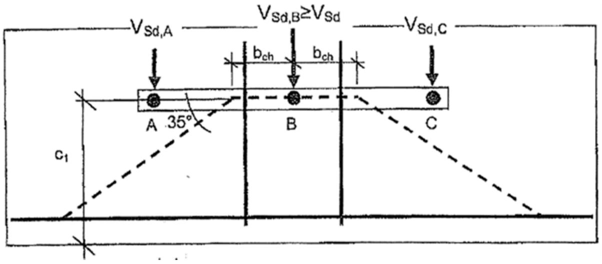
adjacent to a shear load $\boxed{1}$

at the location of a shear load $\boxed{3}$

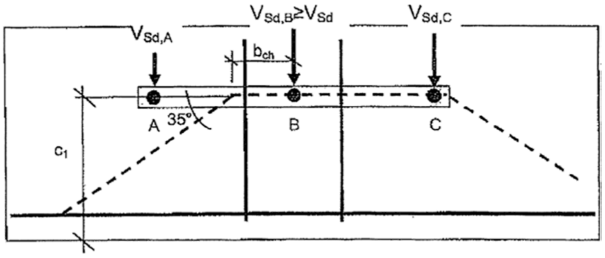
between 2 shear loads acting on an anchor channel (distance between the loads $p \leq s_{cr,V}$) $\boxed{2}$

ψ_2 = 0.11 for other stirrups in the concrete cone $\boxed{4}$

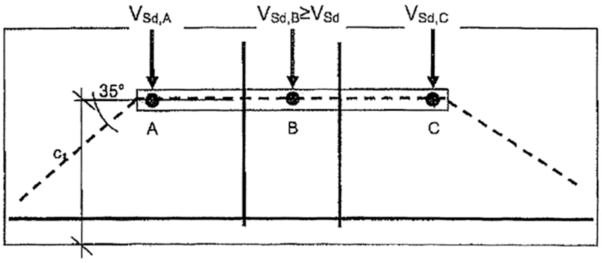
In general, the bond resistance of a rebar is influenced by the bar diameter, bond stress and the embedment length. For the special case of anchor channels with supplementary reinforcement the allowed assumed embedment length depends on the typical crack pattern that develops under shear loads. The following three typical crack patterns have been observed:



a) Ratio of shear load of both neighboring anchors to the anchor carrying the highest load is less than 0.8



b) Ratio of shear load of one neighboring anchor to the anchor carrying the highest load is less than 0.8 and one ratio is equal to or greater than 0.8



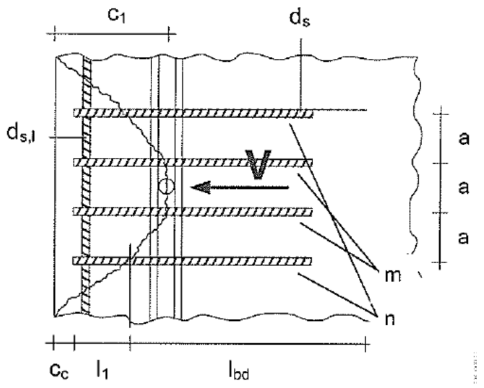
c) Ratio of shear load of both neighboring anchors to the anchor carrying the highest load is equal to or greater than 0.8

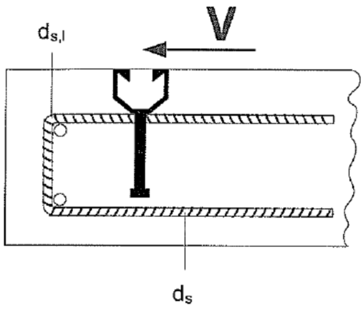
Depending on the load situation, anchor under consideration and stirrup layout it is possible to calculate the embedment depth:

$$V_{Rk,c,bond} = \sum_{j=1}^{m+n} \left(\pi \cdot d_s \cdot l_j \cdot f_{bk} \right)$$

3.11.2 Verification for anchor channels for shear loads with reinforcement

(only for loading perpendicular to the edge)





$$V_{Ed} \leq V_{Rd,re} = V_{Rk,re}/\gamma_M \qquad V_{Ed} = \max(V_{Ed}; V^a_{Ed})$$

$$V_{Rk,re} = V_{Rk,c,re}/x$$

$$V_{Rk,c,re} = V_{Rk,c,hook} + V_{Rk,c,bond} \leq V_{Rk,c,re,max}$$

$$\leq \sum_{m+n} A_s \cdot f_{yk}$$

The entire shear force on the decisive anchor is taken up by the reinforcement!

Note: HAC-10 is not covered by this model.

$$V_{Rk,c,hook} = \sum_{j=1}^{m}\left(\psi_1 \cdot \psi_3 \cdot \psi_4 \cdot A_s \cdot f_{y,k} \cdot \left(\frac{f_{ck}}{30}\right)^{0.1}\right) + \sum_{j=1}^{n}\left(\psi_2 \cdot \psi_3 \cdot \psi_4 \cdot A_s \cdot f_{y,k} \cdot \left(\frac{f_{ck}}{30}\right)^{0.1}\right)$$

$$V_{Rk,c,bond} = \sum_{j=1}^{m+n}\left(\pi \cdot d_s \cdot l_j \cdot f_{bk}\right)$$

$$V_{Rk,c,re,max} = 4.2 \cdot c_1^{-0.12} \cdot V_{Rk,c}$$

$$V_{Rk,c} = V^0_{Rk,c} \cdot \alpha_{s,V} \cdot \alpha_{c,V} \cdot \alpha_{h,V}$$

Reinforcement requirements

$$50\text{ mm} \leq a \leq \begin{cases} s \\ 150\text{mm} \\ (c_1 - c_c + 0.7b_{ch} - 4d_S)/0.35) \\ c_1 - c_c \end{cases}$$

ψ_1 = 0.67 for stirrups:

- For stirrups at the location of a shear load
- For stirrups between 2 shear loads acting on an anchor channel (distance between the loads $p \leq s_{cr,V}$ according to table 16 ETA 11/0006)

ψ_2 = 0.11 for other stirrups in the concrete cone

$\psi_3 = (d_{s,L}/d_S)^{2/3}$

d_s = diameter of stirrup [mm]

$d_{s,L}$ = diameter of edge bars [mm]

$$\psi_4 = \left(\frac{l_j}{c_1}\right)^{0.4} \cdot \left(\frac{10}{d_s}\right)^{0.25}$$

l_j = anchorage length of a stirrup leg in the concrete cone [mm]
$= c_1 - c_c - 0{,}7 \cdot (e_j - b_{ch})$ [mm] for stirrups crossed diagonally by the assumed crack
$= c_1 - c_c$ [mm] for stirrups directly under the load or for stirrups crossed orthogonally by the assumed crack
$\geq 4 \cdot d_s$

c_c= concrete cover [mm]

e_j= distance to the stirrup leg to the point of load action [mm]

b_{ch}= width of anchor channel [mm] (according to Table 2)

$f_{y,k}$… characteristic yield strength of the reinforcement [N/mm^2]

f_{ck}… characteristic concrete strength measured on cubes with a side length of 150 mm [N/mm^2]

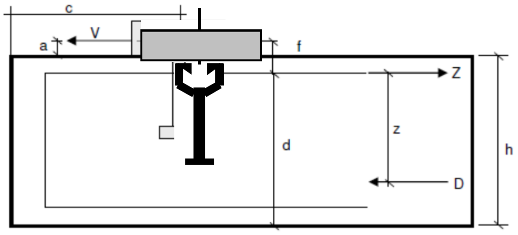
f_{bk}… characteristic bond strength [N/mm^2]

m… number of stirrups in the assumed concrete cone with ψ_1

n… number of stirrups in the assumed concrete cone with ψ_2

a… spacing of stirrups

x… $e_s/z+1$ [-], factor taking into account eccentricity between reinforcement force and load



e_s… distance between reinforcement and shear force acting on the anchor channel

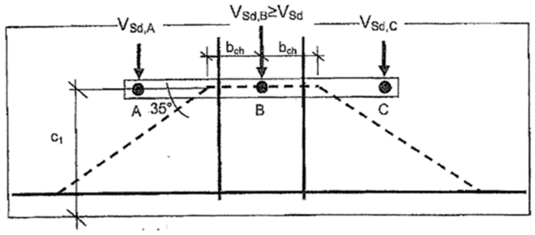
z≈ 0.85d [mm] internal lever arm of the concrete member

d= $\min(2h_{ef}, 2c_1)$

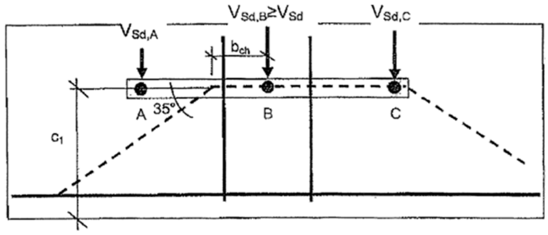
$V^0_{Rk,c}$ …according to CEN/TS 1992-4-3:2009, section 6.3.5.3

V^a_{Ed} …according to CEN/TS 1992-4-1:2009, section 3.2.2

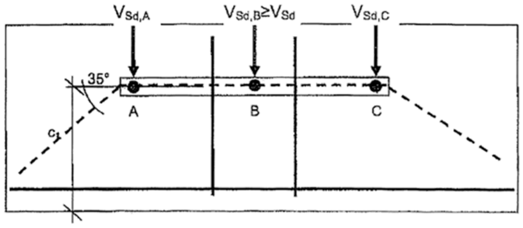
3.11.3 Crack pattern



Ratio of shear load of both neighboring anchors to the anchor carrying the highest load is less than 0.8



Ratio of shear load of one neighboring anchor to the anchor carrying the highest load is < 0.8 and one ratio is ≥ 0.8



Ratio of shear load of both neighboring anchors to the anchor carrying the highest load is equal to or greater than 0.8

3.12 Combined tension and shear loading

3.12.1 Anchor channels without supplementary reinforcement

$$\beta_N^2 + \beta_V^2 \leq 1 \qquad (1)$$

with

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

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

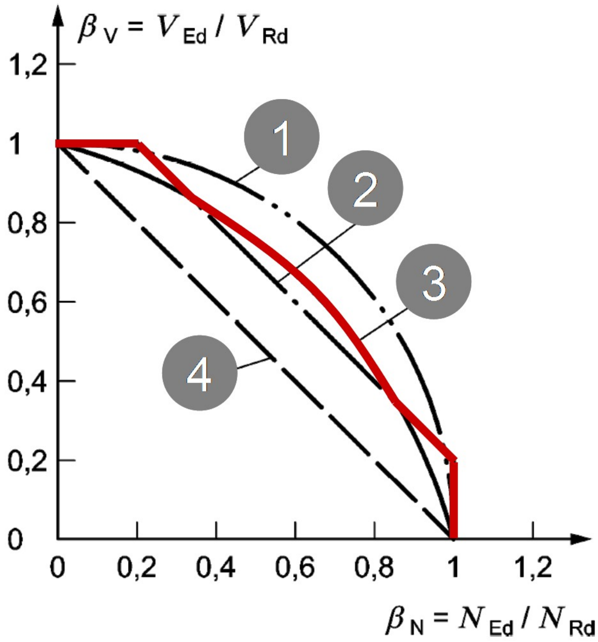
$$\beta_N + \beta_V \leq 1.2 \qquad (2)$$

$$\beta_N^{1.5} + \beta_V^{1.5} \leq 1 \qquad (3)$$

with

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

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



(1) Steel failure for tension and shear

(2),(3) Other failure modes for tension and shear

(4) Supplementary reinforcement to bear shear forces and anchor channels close to the edge

3.12.2 Anchor channels with supplementary reinforcement

$$\beta_N + \beta_V \leq 1 \qquad (4)$$

with

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

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

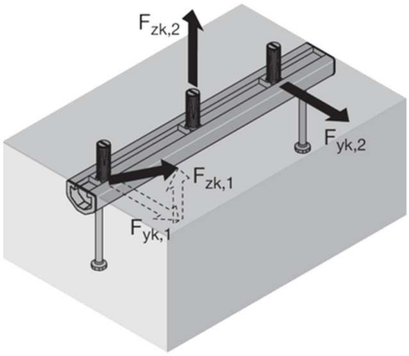
Quadratic interaction can be used (formula for circles with the power of 2 (graph 1)) only in cases where steel failure occurs under both tension and shear. Where other failure modes or a combination of steel and concrete failure occur, either tri-linear superposition (graph 2) or a parabola with the power of 1.5 can be applied. Linear interpolation has to be chosen (graph 4) only in cases where supplementary reinforcement takes up shear loads and the channel is placed closed to the concrete edge.

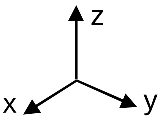
4 Anchor channel design for load case fire: Tension/Shear lateral

4.1 Determination of forces acting on screws

4.1.1 External loads

External moments need to be translated into forces acting on screws.

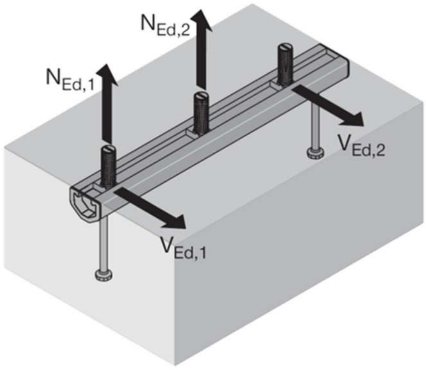




4.1.2 Loads acting on screw

$$V_{Ed,i,fi} = F_{yk,G,fi,i} \cdot \gamma_{G,fi} + F_{yk,Q,fi,i} \cdot \gamma_{Q,fi}$$
$$N_{Ed,i,fi} = F_{zk,G,fi,i} \cdot \gamma_{G,fi} + F_{zk,Q,fi,i} \cdot \gamma_{Q,fi}$$

$F_{yk,fi,i}$;	Characteristic value of action under fire exposure acting on screw i
$F_{yk,fi,i}$:	Characteristic value of action under fire exposure acting on screw i
$\gamma_{F,fi}$:	Partial safety factor for action under fire exposure; (usually $\gamma_{F,fi} = 1.0$)

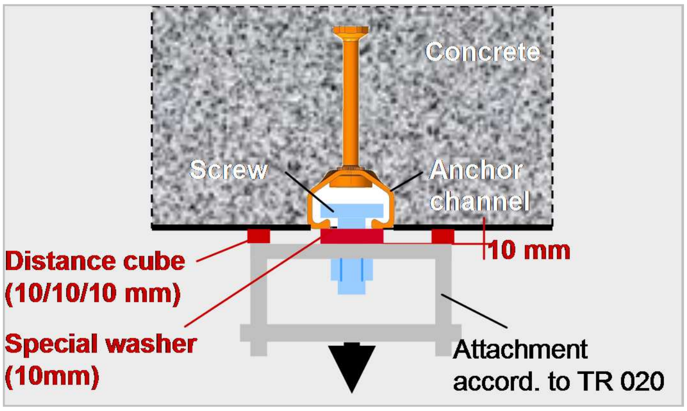


4.2 Determination of forces acting on anchors

Anchor forces are determined accordingly to static design. (see 3.2).
N^a_{Ed} and V^a_{Ed} are renamed into $N^a_{Ed,fi}$ and $V^a_{Ed,fi}$.

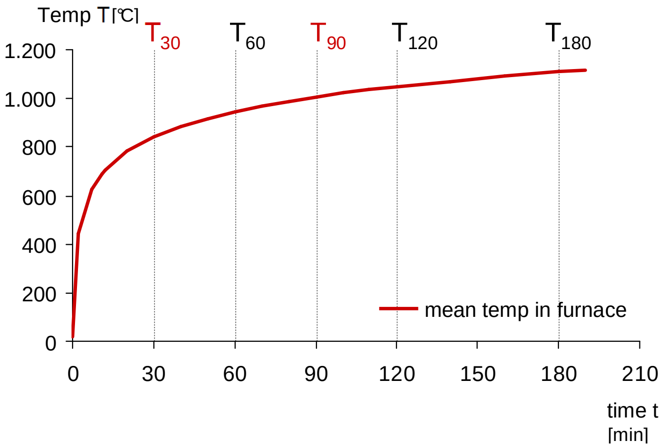
4.3 Fire Testing according to TR020

4.3.1 Test set-up according to TR020



- Tension and shear covered
- New test-setup according to TR020 (distance cube) → fire rating for anchors and anchor channels on the same basis
- All screw/channel combinations tested, no extrapolation of results

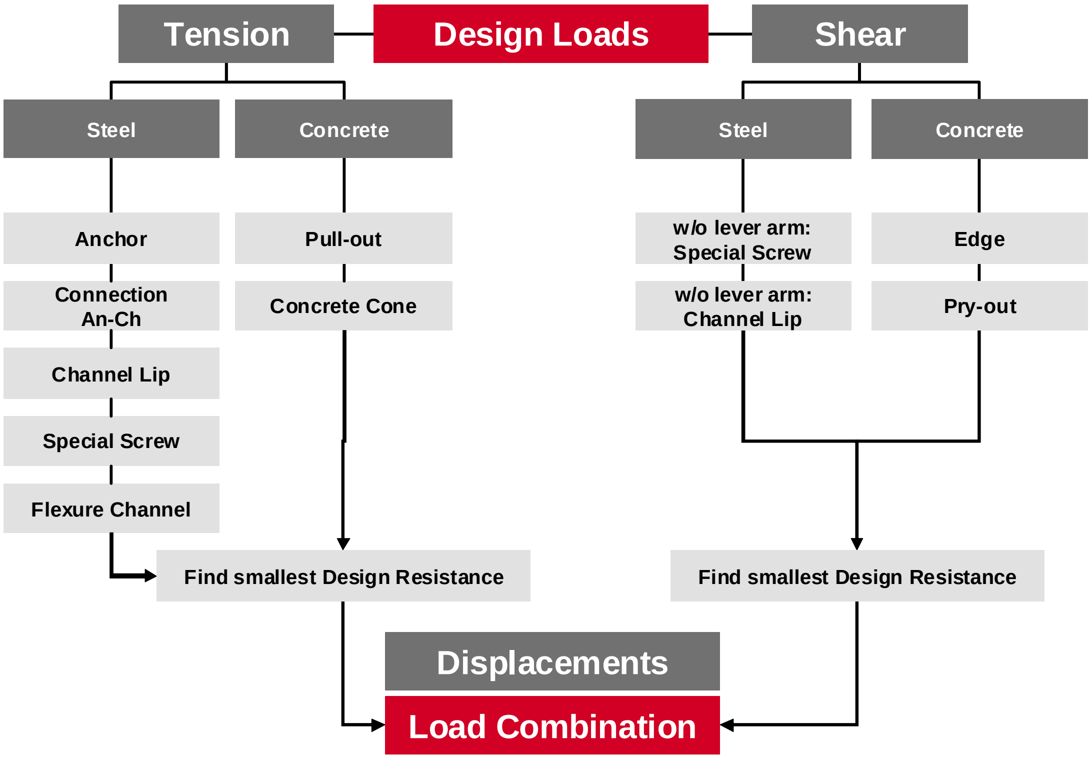
4.3.2 International Standard Temperature Curve (ISO 834, DIN 4102 T.2)



Basic facts about HAC and new ETA fire

- Steel failure governing
- In cases of fire exposure to more than one side → increase edge distance to c ≥ 300 mm or c ≥ $2h_{ef}$
- Fire rating is based upon standard time / temperature curve
- No fatigue load, no $V_{parallel}$
- Rating of anchor channels according to DIN 4102: A1 (not burning, no organic constituent parts)

4.4 Overview of necessary verifications for anchor channels in the event of fire



In principal, all verifications that have to be performed for static loading are relevant for verifications in the event of fire. Only verifications for supplementary reinforcement and concrete splitting can be omitted (blow-out is not critical anyway). Shear load with lever arm is not taken into consideration.
The steel resistance under elevated temperatures decreases dramatically. Hence, for all steel verifications altered values have to be considered. These values were determined in fire tests. Concrete as well undergoes some kind of degradation under high temperatures. On the other side, fire events are regarded as extraordinary load cases. For that reason, safety factors are reduced, $\gamma_{MS,fi} = 1.0$.

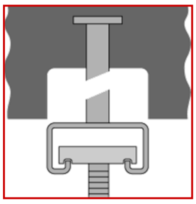
The characteristic spacing and edge distance $c_{cr,N,fi}$ and $s_{cr,N,fi}$ are increased compared to “cold” design.

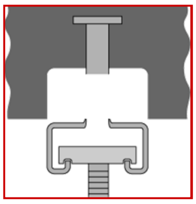
All values are based on a minimum concrete strength C20/25. Higher concrete grades will not influence the capacity in the event of fire. Lower concrete grades than C20/25 are not allowed. The calculations are always based on the assumption that the concrete is a cracked concrete.

A reduction of the fire resistance class of the concrete member due to the anchor channel is not evaluated in the approval.

4.5 Tension: Design resistance $N_{Rd,fi}$ for fire

4.5.1 Failure of anchor, connection anchor–channel, and channel lip



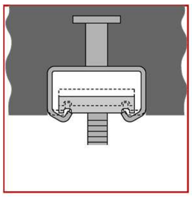


$N_{Rk,s,,fi}$; $\gamma_{MS,fi}$ are given in ETA

$\gamma_{MS,fi} = 1.0$

$$N^{a}_{Ed} \leq N_{Rd,s,fi} = \frac{N_{Rk,s,fi}}{\gamma_{Ms,fi}}$$

4.5.2 Failure of channel lip

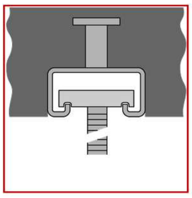


$N_{Rk,s,,fi}$; $\gamma_{MS,fi}$ are given in ETA

$\gamma_{MS,fi} = 1.0$

$$N_{Ed} \leq N_{Rd,s,fi} = \frac{N_{Rk,s,fi}}{\gamma_{Ms,fi}}$$

4.5.3 Failure of special screw

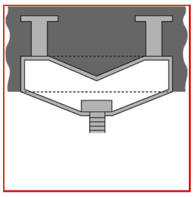


$$N_{Ed} \leq N_{Rd,s,fi} = \frac{N_{Rk,s,s,fi}}{\gamma_{Ms,fi}}$$

$N_{Rk,s,s,fi}$; $\gamma_{MS,fi}$ are given in ETA

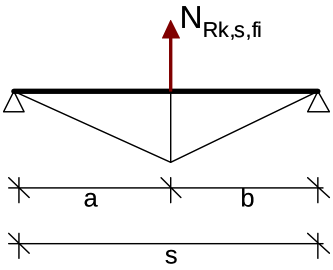
$\gamma_{MS,fi} = 1.0$

4.5.4 Failure of flexure of channel



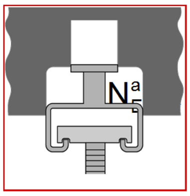
$$M_{Ed} \leq M_{Rd,s,flex,fi} = \frac{M_{Rk,s,flex,fi}}{\gamma_{Ms,flex,fi}}$$

$$M_{Rk,s,flex,fi} = \frac{\alpha_r}{4} \frac{N_{Rk,s,fi} \cdot a \cdot b}{s}$$



α_r: degree of constraint

4.5.5 Pull-out failure



$$N_{Rd,p,fi} = \frac{N_{Rk,p,fi}}{\gamma_{Mp,fi}}$$

$N_{Rk,p,fi}$; $\gamma_{Mc,fi}$ are given in ETA

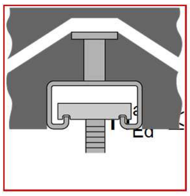
$\gamma_{Mc,fi} = 1.0$

According to TR020, chapter 2.2.1.2

$$N_{Rk,p,fi(90)} = 0.25 \cdot N_{Rk,p}$$

$N_{Rk,p}$ initial value of the characteristic resistance in cracked concrete C20/25 for pull-out failure under normal temperature acc to CEN/TS 1992-4-1, Annex D

4.5.6 Concrete cone failure



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

$c_{cr,N,fi}$; $s_{cr,N,fi}$; $\gamma_{Mc,fi,}$ are given in ETA

$\gamma_{Mc,fi} = 1.0$

All α factors have to be calculated according to CEN/TS 1992-4-3, "cold design", under consideration of the increased values for $c_{cr,N,fi}$ and $s_{cr,N,fi}$.

According to TR020, chapter 2.2.1.3

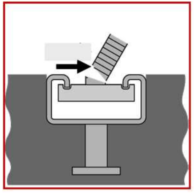
$$N^0_{Rk,c,fi} = \frac{h_{ef}}{200} \cdot N^0_{Rk,c}$$

$$N_{Rk,c,fi} = N^0_{Rk,c,fi} \cdot \alpha_{s,N,fi} \cdot \alpha_{e,N,fi} \cdot \alpha_{c,N,fi} \cdot \psi_{re,N} \cdot \psi_{ucr,N}$$

$N^0_{Rk,c}$ initial value of the characteristic resistance in cracked concrete C20/25 for concrete cone failure under normal temperature acc. to CEN/TS 1992-4-1, Annex D

4.6 Shear: Design resistance $V_{Rd,fi}$ for fire

4.6.1 Failure of special screw without lever arm



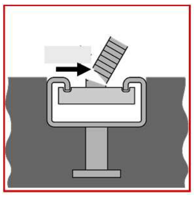
$$V_{Ed} \leq V_{Rd,s,fi} = \frac{V_{Rk,s,fi}}{\gamma_{Ms,fi}}$$

$V_{Rk,s,fi}$; $\gamma_{MS,fi}$ are given in ETA

$\gamma_{Ms,fi} = 1.0$

4.7 Shear: Design resistance $V_{Rd,fi}$ for fire

4.7.1 Failure of special screw without lever arm

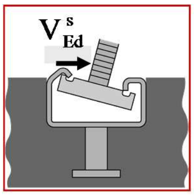


$$V_{Ed} \leq V_{Rd,s,fi} = \frac{V_{Rk,s,fi}}{\gamma_{Ms,fi}}$$

$V_{Rk,s,fi}$; $\gamma_{MS,fi}$ are given in ETA

$\gamma_{Ms,fi} = 1.0$

4.7.2 Failure of local flexure of channel lip without lever arm

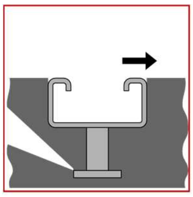


$$V_{Ed} \leq V_{Rd,s,l,fi} = \frac{V_{Rk,s,l,fi}}{\gamma_{Ms,fi}}$$

$V_{Rk,s,l,fi}$; $\gamma_{MS,l,fi}$ are given in ETA

$\gamma_{Ms,fi} = 1.0$

4.7.3 Pry-out failure



$$V^{a}_{Ed} \leq V_{Rd,cp,fi} = \frac{V_{Rk,cp,fi}}{\gamma_{Mc,fi}}$$

$V_{Rk,s,fi}$; $\gamma_{Mc,fi}$,k_5 are given in ETA

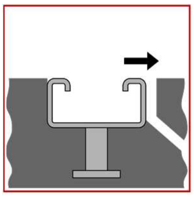
$\gamma_{Mc,fi} = 1.0$

$k_5 = 2.0$

According to TR020, chapter 2.2.2.2

$$V_{Rk,cp,fi} = k_5 \cdot N_{Rk,c,fi}$$

4.7.4 Concrete edge failure



$$V^{a}_{Ed} \leq V_{Rd,c,fi} = \frac{V_{Rk,c,fi}}{\gamma_{Mc,fi}}$$

$$V_{Rk,c,fi} = V^{0}_{Rk,c,fi} \cdot \alpha_{s,V,fi} \cdot \alpha_{c,V,fi} \cdot \alpha_{h,V,fi} \cdot \alpha_{90°,V} \cdot \psi_{re,V}$$

$\gamma_{Mc,fi}$; $c_{cr,V,fi}$; $s_{cr,V,fi}$; are given in ETA

$\gamma_{Mc,fi} = 1.0$

According to TR020, chapter 2.2.2.3

$$V^{0}_{Rk,c,fi} = 0.25 \cdot V^{0}_{Rk,c}$$

All α factors have to be calculated according to CEN/TS 1992-4-3, “cold design”, under consideration of the increased values for $c_{cr,V,fi}$ and $s_{cr,V,fi}$.

4.8 Combined tension and shear loading for fire

4.8.1 Anchor channels without supplementary reinforcement

$$\beta_N^2 + \beta_V^2 \le 1 \qquad (1)$$

with

$\beta_N = N_{Ed}/N_{Rd} \le 1$

$\beta_V = V_{Ed}/V_{Rd} \le 1$

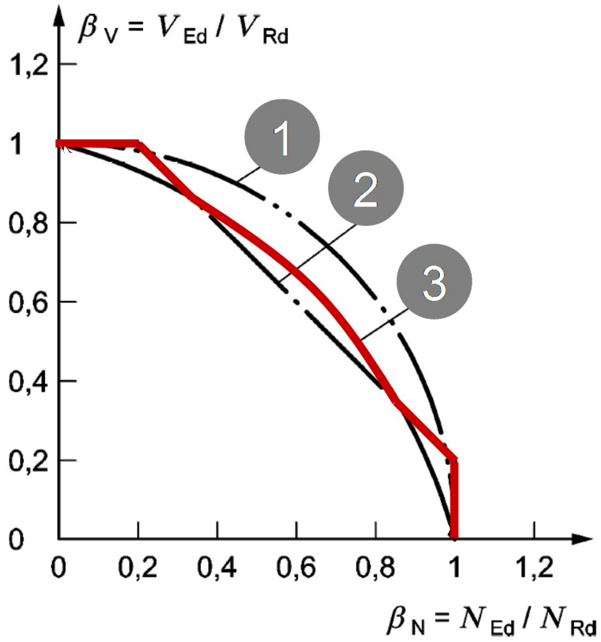
$$\beta_N + \beta_V \le 1.2 \qquad (2)$$

$$\beta_N^{1.5} + \beta_V^{1.5} \le 1 \qquad (3)$$

with

$\beta_N = N_{Ed}/N_{Rd} \le 1$

$\beta_V = V_{Ed}/V_{Rd} \le 1$



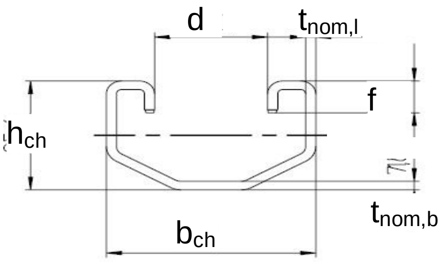
(1) Steel failure for tension and shear
(2),(3) Other failure modes for tension and shear

There is no difference to the interaction mode compared to „cold design”. However, there is no interaction model for rebar failure. In general it is assumed that reinforcement does not contribute to the resistance of anchor channels since concrete spalling due to thermal impact reduces the capacity of reinforcement dramatically.

5 Technical data for the HAC anchor channel system

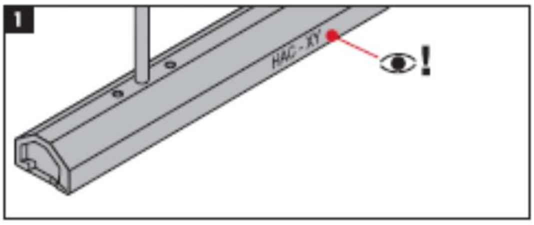
5.1 General

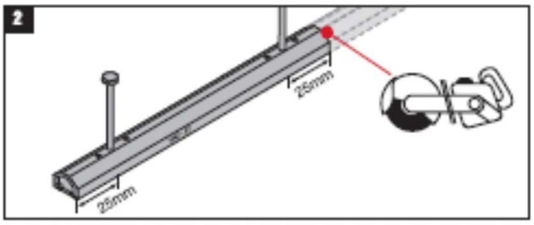
Anchor Channel	Dimensions					
	b_{ch}	h_{ch}	$t_{nom,b}$	$t_{nom,l}$	d	f
	[mm]					
HAC-10	26.2	16.7	1.60	1.60	12.0	1.60
HAC-20	27.5	18.0	2.25	2.25	12.0	2.25
HAC-30	41.3	25.6	2.00	2.00	22.3	7.50
HAC-40	40.9	28.0	2.25	2.25	19.5	4.50
HAC-50	41.9	31.0	2.75	2.75	19.5	5.30
HAC-60	43.4	35.5	3.50	3.50	19.5	6.30
HAC-70	45.4	40.0	4.50	4.50	19.5	7.40

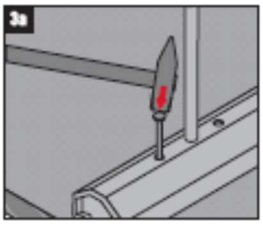


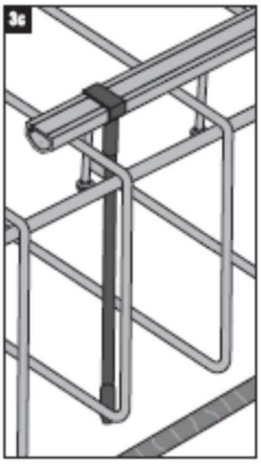
5.2 Instruction for use

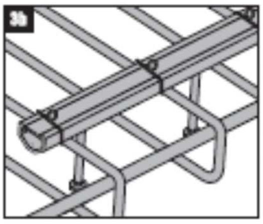
5.2.1 HAC

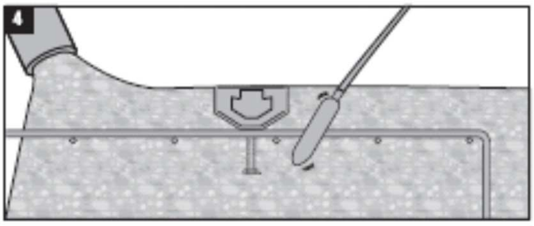


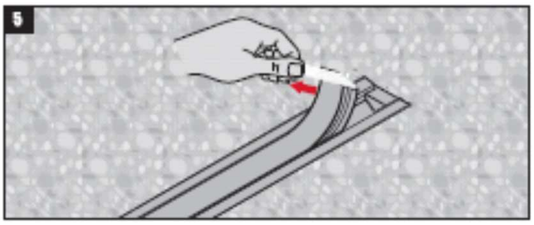




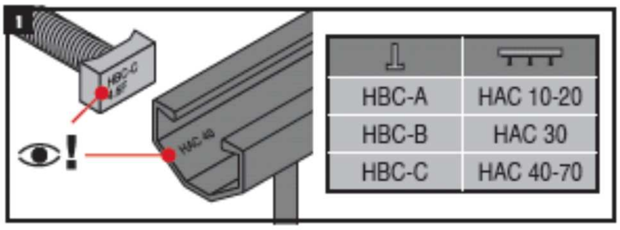




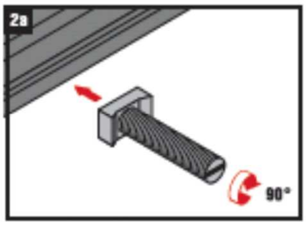


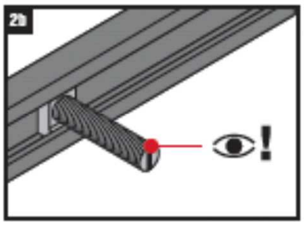


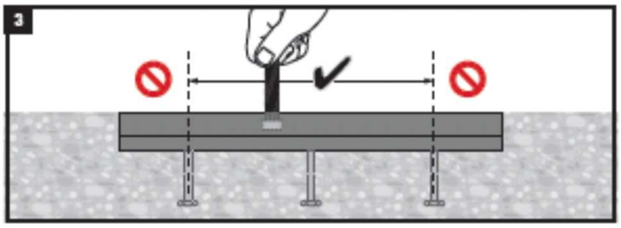
5.2.2 HBC

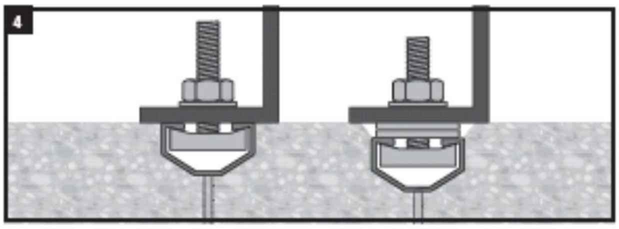


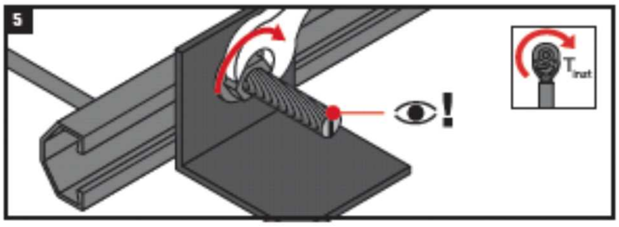
HBC-A	HAC 10-20
HBC-B	HAC 30
HBC-C	HAC 40-70





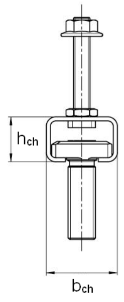




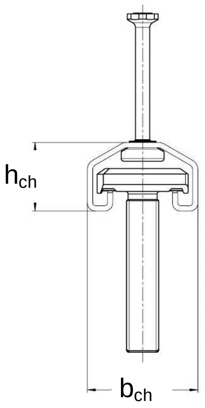


5.3 HAC Hilti Anchor Channel

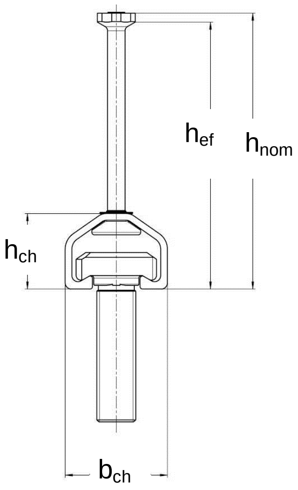
HAC 10 / 20



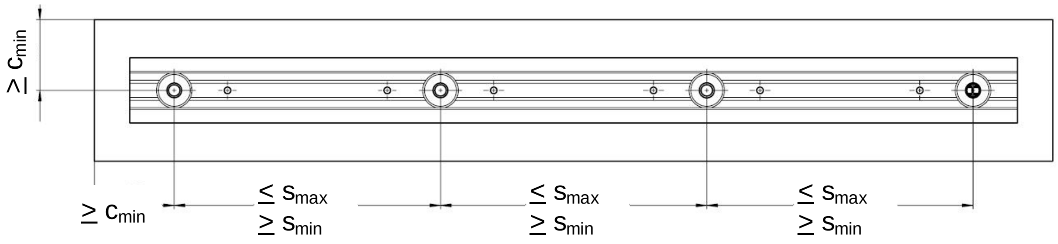
HAC 30



HAC 40 / 50 / 60 / 70



Valid for all profile types:



Anchor channel	Dimensions							
	b_{ch}	h_{ch}	Anchor spacing		End spacing	min channel length	h_{ef}	c_{min}
			s_{min}	s_{max}				
	[mm]							
HAC-10	26.2	16.7	50	200	25	100	45	40
HAC-20	27.5	18.0	50	200	25	100	76	50
HAC-30	41.3	25.6	50	250	25	100	68	50
HAC-40	40.9	28.0	100	250	25	150	91	50
HAC-50	41.9	31.0	100	250	25	150	106	75
HAC-60	43.4	35.5	100	250	25	150	148	100
HAC-70	45.4	40.0	100	250	25	150	175	100

5.4 HBC special screws

Dimensions of special screws

Anchor channel	Special screw type	Dimensions		
		Ø	Length	t_{fix}
		[mm]		
HAC-10 HAC-20	HBC-A	8	15-100	1 – 26
		10	15-175	3 – 83.5
		12	20-200	10 – 130
HAC-30	HBC-B	8	15-150	11 – 81
		10	15-175	18 – 78
		12	20-200	15 – 125
HAC-40 HAC-50 HAC-60 HAC-70	HBC-C	10	20-200	8 – 78
		12	20-200	5 – 100
		16	20-300	1 – 120
		20	20-300	15 – 115
HAC-40 HAC-50	HBC-C-E	12	20-200	17 – 127
		16	20-300	23 – 263
HAC-40 HAC-50 HAC-60 HAC-70	HBC-C-N	16	20-200	20 – 30
		20	20-300	25 – 65

5.5 Material properties

Part	Material	
Channel profile	Carbon steel:	EN 10149-2; EN 10051 hot-dip galv. ≥ 55 μm 2) (HAC-10 and HAC-20)
	Carbon steel:	EN 10025-2 hot-dip galv. ≥ 55 μm 2) (HAC-30 to HAC-50)
	Carbon steel:	EN 10025-2 hot-dip galv. ≥ 70 μm 2) (HAC-60 and HAC-70)
Rivet	Carbon steel:	hot-dip galv. ≥ 45 μm 3)
Anchor	Carbon steel:	hot-dip galv. ≥ 45 μm 3)
HILTI special screw shaft and thread according to EN ISO 4018	Carbon steel:	steel grade 4.6 / 8.8 in dependence on electroplated ≥ 8 μm 1)
	Carbon steel:	steel grade 4.6 / 8.8 in dependence on EN ISO 898-1 4) hot-dip galv. ≥ 45 μm 3))
	Stainless steel: steel grade 50	1.4401/ 1.4404/ 1.4571/ 1.4362/ 1.4578/ 1.4439 EN ISO 3506-1 / EN10088-2
Washer EN ISO 7089 and EN ISO 7093-1 production class A, 200 HV	Carbon steel:	EN 10025-2 electroplated ≥ 5 μm 1)
	Carbon steel:	EN 10025-2 hot-dip galv. > 45 μm 3)
	Stainless steel:	1.4401/ 1.4404/ 1.4571/ 1.4362/ 1.4578/ 1.4439 EN 10088
Hexagonal nuts DIN 934 5) EN ISO 4032	Carbon steel:	class 5 / 8; EN 20898-2 electroplated ≥ 8 μm 1)
	Carbon steel:	class 5 / 8; EN 20898-2 hot-dip galv. ≥ 45 μm 3)
	Stainless steel: class 70	1.4401/ 1.4404/ 1.4571/ 1.4362/ 1.4578/ 1.4439 EN ISO 3506-2 / EN 10088-2

1) Electroplated according to EN ISO 4042, A3K

2) Hot-dip galv. according to EN ISO 1461:2009-10 (Mean coating thickness (minimum))

3) Hot-dip galv. according to ISO 1461:1999 (Mean coating thickness (minimum))

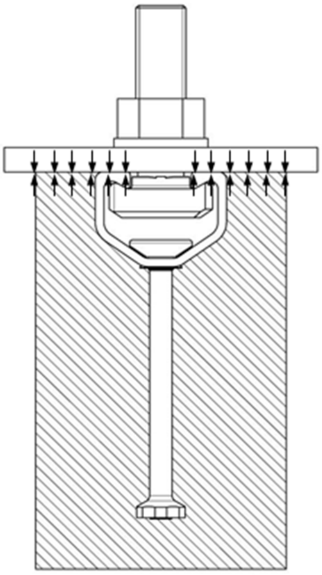
4) Properties according to EN ISO 898-1 only in threaded part of screw

5) DIN 934 only for special screw grade 4.6 and stainless steel

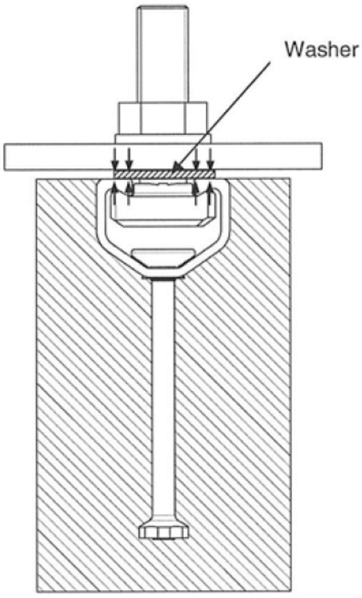
5.6 Setting torque T_{inst} for HAC-10 through HAC-30

	Special screw type		Min. spacing screw s_{min}	Setting torque T_{inst}		
		Ø		general	Steel – steel contact	
				4.6; 8.8; A4-50	4.6; A4-50	8.8
		[mm]		[Nm]		
HAC-10	HBC-A	8	40	8	8	-
		10	50	15	15	-
		12	60	15	25	-
HAC-20		8	40	8	8	-
		10	50	15	15	-
		12	60	25	25	-
HAC-30	HBC-B	8	40	8	8	-
		10	50	15	15	-
		12	60	30	25	-

General

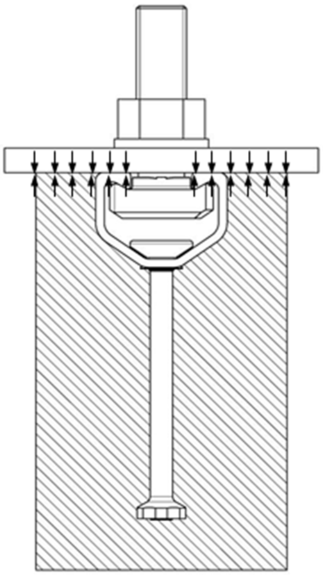


Steel – Steel

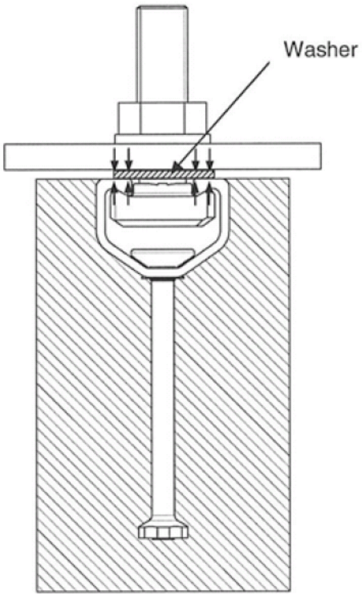


5.7 Tightening torque T_{inst} for HAC-40 through HAC-70

General



Steel – Steel



Anchor channel	Special screw type		Min. spacing screw s_{min}	Tightening torque T_{inst}		
		Ø		general	Steel – steel contact	
				4.6; 8.8; A4-50	4.6; A4-50	8.8
		[mm]		[Nm]		
HAC-40	HBC-C HBC-C-E HBC-C-N	10	50	15	15	48
		12	60	25	25	70
		16	80	60	60	200
		20	100	75	120	400
HAC-50		10	50	15	15	48
		12	60	25	25	70
		16	80	60	60	200
		20	100	120	120	400
HAC-60		10	50	15	15	48
		12	60	25	25	70
		16	80	60	60	200
		20	100	120	120	400
HAC-70		10	50	15	15	48
		12	60	25	25	70
		16	80	60	60	200
		20	100	120	120	400

5.8 Characteristic resistance for steel failure of the channel

	Data according ETA-11/0006, issued 2012-02-28						
Anchor channel	HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Tensile, anchor, $N_{Rk,s,a}$ [kN]	13	29	18	33	33	52	76
γ_{Ms}	1.8						
Tensile, connection channel anchor $N_{Rk,s,c}$ [kN]	9	18	18	25	33	52	73
$\gamma_{Ms,ca}$	1.8						
Tensile, local flexure of channel lip $N_{Rk,s,l}$ [kN]	9	18	20	25	35	52	73
$\gamma_{Ms,l}$	1.8						
Flexure, resistance of channel $M_{Rk,s,flex}$ [Nm]	446	622	721	1013	1389	2117	3066
$\gamma_{Ms,flex}$	1.15						
Shear, local flexure of channel lip $V_{Rk,s,l}$ [kN]	12	18	19	35	51	67	79
$\gamma_{Ms,l}$	1.8						

5.9 Characteristic resistance for steel failure of special screw type HBC-A, HBC-B, HBC-C, HBC-C-E, HBC-C-N

			Data according ETA-11/0006, issued 2012-02-28				
Special screw Ø			M8	M10	M12	M16	M20
Tensile, $N_{Rk,s}$ [kN]	HBC-A	4.6	14.6	23.2	33.7	-	-
		A4-50	18.3	29.0	42.2	-	-
	HBC-B	4.6	14.6	23.2	33.7	-	-
		A4-50	18.3	29.0	42.2	-	-
	HBC-C HBC-C-E HBC-C-N	4.6	-	23.2	33.7	62.8	98.0
		8.8	-	46.4	67.4	125.6	196.0
		A4-50	-	29.0	42.2	78.5	122.5
γ_{Ms}		4.6	2.00				
		8.8	1.50				
		A4-50	2.86				
Shear $V_{Rk,s}$ [kN]	HBC-A	4.6	7.3	11.6	16.8	-	-
		A4-50	9.2	14.5	21.1	-	-
	HBC-B	4.6	7.3	11.6	20.2	-	-
		A4-50	9.2	14.5	24.0	-	-
	HBC-C HBC-C-E HBC-C-N	4.6	-	13.9	20.2	37.6	58.8
		8.8	-	23.2	33.7	62.7	97.9
		A4-50	-	17.4	25.3	47.0	73.4
γ_{Ms}		4.6	1.67				
		8.8	1.25				
		A4-50	2.38				
Flexure $M^0_{Rk,s}$ [Nm]	HBC-A	4.6	15.0	29.9	52.4	-	-
		A4-50	18.7	37.4	65.5	-	-
	HBC-B	4.6	15.0	29.9	52.4	-	-
		A4-50	18.7	37.4	65.5	-	-
	HBC-C HBC-C-E HBC-C-N	4.6	-	29.9	52.4	133.2	259.6
		8.8	-	59.8	104.8	266.4	519.3
		A4-50	-	37.4	65.5	166.5	324.5
γ_{Ms}		4.6	1.67				
		8.8	1.25				
		A4-50	2.38				

5.10 Design tensile pull-out failure

$$N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}} \cdot \psi_c \cdot \psi_{ucr,N}$$

Anchor channel			Data according ETA-11/0006, issued 2012-02-28						
			HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Characteristic resistance, $N_{Rk,p}$ for C20/25 [kN]			20.37	31.73	13.36	17.20	24.55	38.74	53.44
Amplification factor for concrete strength [-]	C12/15	Ψ_c	0.60						
	C16/20		0.80						
	C20/25		1.00						
	C25/30		1.20						
	C30/37		1.48						
	C35/45		1.80						
	C40/50		1.99						
	C45/55		2.20						
	≥C50/60		2.40						
Factor for uncracked concrete [-]		$\Psi_{ucr,N}$	1.4						
$\gamma_{Mp} = \gamma_{Mc}$ 1)			1.5						

1) In absence of other national regulations

5.11 Design tensile concrete cone failure

$$N_{Rd,c} = \frac{N^0_{Rk,c}}{\gamma_{Mc}} \cdot \alpha_{s,N} \cdot \alpha_{e,N} \cdot \alpha_{c,N} \cdot \psi_c \cdot \psi_{re,N} \cdot \psi_{ucr,N}$$

			Data according ETA-11/0006, issued 2012-02-28						
Anchor channel			HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Characteristic resistance, $N^0_{Rk,c}$ for C20/25 [kN]			10.42	24.75	20.59	33.31	42.86	74.30	98.00
Amplification factor for concrete strength [-]	C12/15	Ψ_c	0.77						
	C16/20		0.89						
	C20/25		1.00						
	C25/30		1.10						
	C30/37		1.22						
	C35/45		1.34						
	C40/50		1.41						
	C45/55		1.48						
	≥C50/60		$= (f_{ck,cube} / 25\ N/mm^2)^{1/2}$						
Effect of neighboring anchors [-] [1]		$\alpha_{s,N}$	$\alpha_{s,N} = \frac{1}{1+\sum_{i=1}^{n}\left[\left(1-\frac{s_i}{s_{cr,N}}\right)^{1.5} \cdot \frac{N_i}{N_0}\right]}$						
Characteristic spacing of anchor [mm]		$s_{cr,N}$	222	342	314	390	432	512	538
Effect of edges of the concrete member [-] [1]		$\alpha_{e,N}$	$\alpha_{e,N} = \left(\frac{c_1}{c_{cr,N}}\right)^{0.5} \leq 1.0$						
Characteristic edge distance of anchor [mm]		$c_{cr,N}$	111	171	157	195	216	256	269
Effect of corner of the concrete member [-] [1]		α_{cN}	$\alpha_{c,N} = \left(\frac{c_2}{c_{cr,N}}\right)^{0.5} \leq 1.0$						
Factor for shell spalling [-]		$\Psi_{re,N}$	$0.5+h_{ef} / 200 \leq 1.0$						
Factor for un-cracked concrete [-]		$\Psi_{ucr,N}$	1.4						
$\gamma_{Mp} = \gamma_{Mc}$ [2]			1.5						

[1] Values depending on influencing loads, anchor channel length, concrete geometry, etc. No pre-calculated values given.

[2] In absence of other national regulations

5.12 Design tensile splitting failure:

Verification of splitting due to installation not relevant if min. values for h, s, c are fulfilled

	Data according ETA-11/0006, issued 2012-02-28						
Anchor channel	HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
h_{min} [mm]	60	92.5	80	104	119.5	162.5	190
s_{min} [mm]	50	50	50	100	100	100	100
c_{min} [mm]	40	50	50	50	75	100	100

5.13 Design shear pry out failure

$$V_{Rd,cp} = k_5 \cdot \frac{N_{Rk,c}}{\gamma_{Mc}}$$

		Data according ETA-11/0006, issued 2012-02-28						
Anchor channel		HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Factor for shear resistance 1)	k_5	2.0						
$\gamma_{Mp} = \gamma_{Mc}$ 2)		1.5						

1) Without supplementary reinforcement. In case of supplementary reinforcement the factor k_5 should be multiplied by 0.75

2) In absence of other national regulations

5.14 Design shear concrete edge failure

$$V_{Rd,c} = \frac{V^0_{Rk,c}}{\gamma_{Mc}} \cdot \alpha_{s,V} \cdot \alpha_{c,V} \cdot \alpha_{h,V} \cdot \alpha_{90°,V} \cdot \psi_{re,V} \cdot \psi_c$$

			Data according ETA-11/0006, issued 2012-02-28						
Anchor channel			HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Characteristic resistance, $V^0_{Rk,c} / \cdot c_1^{1.5}$ for C20/25 [kN]			15.00	20.00	17.50	20.00	20.00	20.00	20.00
Amplification factor for concrete strength [-]	C12/15	ψ_c	0.77						
	C16/20		0.89						
	C20/25		1.00						
	C25/30		1.10						
	C30/37		1.22						
	C35/45		1.34						
	C40/50		1.41						
	C45/55		1.48						
	≥C50/60		$= (f_{ck,cube} / 25\ N/mm^2)^{1/2}$						
Effect for neighboring anchors [-]		$\alpha_{s,V}$	$\alpha_{s,V} = \frac{1}{1 + \sum_{i=1}^{n}\left[\left(1 - \frac{s_i}{s_{cr,V}}\right)^{1.5} \cdot \frac{V_i}{V_0}\right]}$						
Characteristic spacing of anchor [mm]		$s_{cr,V}$	$4c_1+52.4$	$4c_1+55$	$4c_1+82.6$	$4c_1+81.8$	$4c_1+83.8$	$4c_1+86.8$	$4c_1+90.8$
Effect of corner of the concrete member [-]		$\alpha_{c,V}$	$\alpha_{c,V} = \left(\frac{c_2}{c_{cr,V}}\right)^{0.5} \leq 1.0$						
Characteristic edge distance of anchor [mm]		$c_{cr,N}$	$2c_1+26.2$	$2c_1+27.5$	$2c_1+41.3$	$2c_1+40.9$	$2c_1+41.9$	$2c_1+43.4$	$2c_1+45.4$
Effect of thickness of structural component [-]		$\alpha_{h,V}$	$\alpha_{h,V} = \left(\frac{h}{h_{cr,V}}\right)^{\frac{1}{2}} \leq 1.0$						
Characteristic height [mm]		$h_{cr,V}$	$2c_1+16.7$	$2c_1+18.0$	$2c_1+25.6$	$2c_1+28.0$	$2c_1+31.0$	$2c_1+35.5$	$2c_1+40.0$
Effect of load parallel to the edges [-]		$\alpha_{90°,V}$	$2.5^{2)}$						
Effect of reinforcement [-]		$\psi_{re,V}$	1.0 anchor channel in cracked concrete without edge reinforcement or stirrups						
			1.2 anchor channel in cracked concrete with straight edge reinforcement (≥ ø 12mm)						
			1.4 anchor channel in cracked concrete with edge reinforcement and stirrups with a spacing a ≤ 100mm and a ≤ $2c_1$ or uncracked concrete						
$\gamma_{Mp} = \gamma_{Mc}$ 1)			1.5						

1) In absence of national regulations

2) In all other cases $\alpha_{90°,V}=1.0$

5.15 Characteristic fire resistance for steel failure of channel in cracked concrete C20/25

		Data according ETA-11/0006, issued 2012-02-28						
Anchor channel		HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Tensile, anchor, connection channel anchor, local flexure of channel lip, $N_{Rk,s,fi}$ [1][kN]	R30	0.9	1.4	2.5	2.8	5.7	5.7	5.7
	R60	0.7	1.1	1.8	2.3	4.0	4.0	4.0
	R90	0.5	0.7	1.1	1.7	2.3	2.3	2.3
$\gamma_{Ms,fi}$ [2]		1.0						
Shear, local flexure of channel lip $V_{Rk,s,l,fi}$ [kN]	R30	0.9	1.4	2.5	2.8	5.7	5.7	5.7
	R60	0.7	1.1	1.8	2.3	4.0	4.0	4.0
	R90	0.5	0.7	1.1	1.7	2.3	2.3	2.3
$\gamma_{Ms,fi}$ [2]		1.0						

[1] Max. resistance in conjunction of biggest Hilti special screw HBC

[2] In absence of other national regulations the safety factor $\gamma_{Ms,fi}$ = 1.0 under fire exposure is recommended

5.16 Characteristic fire resistance for steel failure of special screw type HBC-A, HBC-B, HBC-C

			Data according ETA-11/0006, issued 2012-02-28				
Special screw Ø			M8	M10	M12	M16	M20
Tensile, $N_{Rk,s,s,fi}$ [kN]	HBC-A	R30	0.6	1.3	1.4	-	-
		R60	0.5	1.0	1.1	-	-
		R90	0.3	0.6	0.7	-	-
	HBC-B	R30	1.0	1.7	2.5	-	-
		R60	0.8	1.3	1.8	-	-
		R90	0.6	0.9	1.1	-	-
	HBC-C	R30	-	2.5	3.1	5.7	5.7
		R60	-	1.9	2.5	4.0	4.0
		R90	-	1.3	1.9	2.3	2.3
$\gamma_{Ms,fi}$ [1]			1.00				
Shear $V_{Rk,s}$ [kN]	HBC-A	R30	7.3	11.6	16.8	-	-
		R60					
		R90	9.2	14.5	21.1	-	-
	HBC-B	R30	7.3	11.6	20.2	-	-
		R60					
		R90	9.2	14.5	24.0	-	-
	HBC-C	R30	-	13.9	20.2	37.6	58.8
		R60	-	23.2	33.7	62.7	97.9
		R90	-	17.4	25.3	47.0	73.4
$\gamma_{Ms,fi}$ [1]			1.00				

[1] In absence of other national regulations the safety factor $\gamma_{Ms,fi}$ = 1.0 under fire exposure is recommended

5.17 Design tensile pull-out failure under fire in cracked concrete C20/25

$$N_{Rd,p,fi} = 0.25 \cdot \frac{N_{Rk,p}}{\gamma_{Mc,fi}} \cdot \psi_c$$

(≤R90) acc. to CEN/TS 1992-4-1, Annex D

Anchor channel	Data according ETA-11/0006, issued 2012-02-28						
	HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Characteristic resistance, $N_{Rk,p}$ for C20/25, normal temperature [kN]	20.37	31.73	13.36	17.20	24.55	38.74	53.44
$\gamma_{Mc,fi}$ [1]	1.0						
Design resistance, $N_{Rd,p,fi}$ for C20/25 cracked concrete [kN]	5.09	7.93	3.34	4.30	6.14	9.69	13.36

[1] In absence of other national regulations the safety factor $\gamma_{Mc,fi}$ = 1.0 under fire exposure is recommended

5.18 Design tensile concrete cone failure under fire in cracked concrete C20/25

$$N^0_{Rk,c,fi} = \frac{h_{ef}}{200} \cdot N^0_{Rk,c}$$ **(≤R90) acc. to CEN/TS 1992-4-1, Annex D**

$$N_{Rd,c,fi} = \frac{N^0_{Rk,c,fi}}{\gamma_{Mc,fi}} \cdot \alpha_{s,N,fi} \cdot \alpha_{e,N,fi} \cdot \alpha_{c,N,fi} \cdot \cdot \psi_{re,N}$$

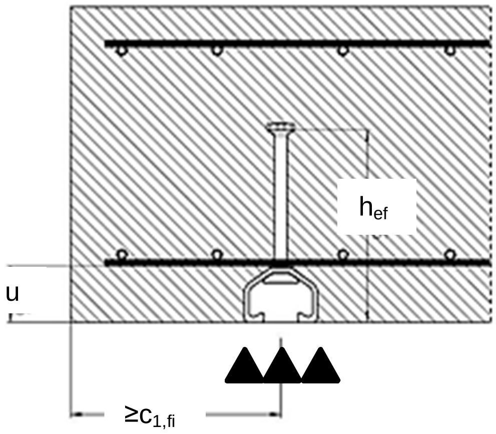
			Data according ETA-11/0006, issued 2012-02-28						
Anchor channel			HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Characteristic resistance, $N^0_{Rk,c}$ for C20/25, normal temperature [kN]			10.42	24.75	20.59	33.31	42.86	74.30	98.00
Effect of neighboring anchors [-] [1]		$\alpha_{s,N,fi}$	$\alpha_{s,N,fi} = \frac{1}{1+\sum_{i=1}^{n}\left[\left(1-\frac{s_i}{s_{crN,fi}}\right)^{1.5} \cdot \frac{N_i}{N_0}\right]}$						
Anchor spacing [mm]		$s_{cr,N,fi}$	$4h_{ef}$						
		$s_{min,fi}$	50	50	50	100	100	100	100
Effect of edges of the concrete member [-]		$\alpha_{e,N,fi}$	$\alpha_{e,N,fi} = \left(\frac{c_1}{c_{cr,N,fi}}\right)^{0.5} \leq 1.0$						
Characteristic edge distance of anchor [mm]		$c_{cr,N,fi}$	$2h_{ef}$						
		$c_{min,fi}$	$2h_{ef}$ [1] max $(2h_{ef};\ 300\text{mm})$ [2]						
Effect of corner of the concrete member [-]		$\alpha_{c,N,fi}$	$\alpha_{c,N,fi} = \left(\frac{c_2}{c_{cr,N,fi}}\right)^{0.5} \leq 1.0$						
Factor for shell spalling [-]		$\Psi_{re,N}$	$0.5+h_{ef} / 200 \leq 1.0$						
$\gamma_{Mc,fi}$ [3]			1.0						
Axial spacing	R30	u [mm]	35				50		
	R60		35				50		
	R90		45				50		

[1] Fire exposure from one side only

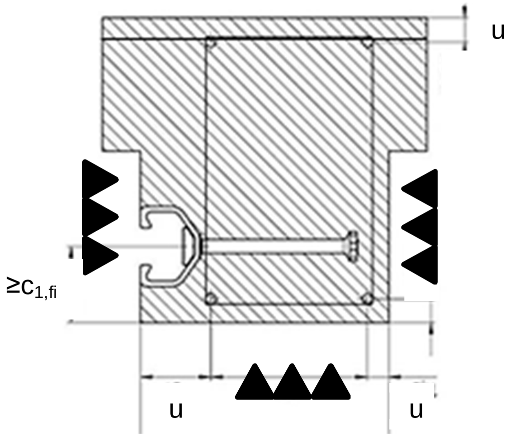
[2] Fire exposure from more than one side

[3] In absence of other national regulations the safety factor $\gamma_{Mc,fi}$ = 1.0 under fire exposure is recommended

Fire Exposure from one side only



Fire Exposure from more than one side



5.19 Design shear pry out failure under fire in cracked concrete C20/25

$$V_{Rd,cp,fi} = k_5 \cdot \frac{N_{Rk,c,fi}}{\gamma_{Mc,fi}}$$

		Data according ETA-11/0006, issued 2012-02-28						
Anchor channel		HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Factor for shear resistance [1]	k_5	2.0						
$\gamma_{Mc,fi}$ [2]		1.0						

[1] Without supplementary reinforcement. In case of supplementary reinforcement the factor k_5 should be multiplied by 0.75

[2] In absence of other national regulations the safety factor $\gamma_{Mc,fi}$ = 1.0 under fire exposure is recommended

5.20 Design shear concrete edge failure under fire in cracked concrete C20/25

$V^0_{Rk,c,fi} = 0.25 \cdot V^0_{Rk,c}$ **(≤R90) acc. to CEN/TS 1992-4-1, Annex D**

$$V_{Rd,c} = \frac{V^0_{Rk,c,fi}}{\gamma_{Mc,fi}} \cdot \alpha_{s,V,fi} \cdot \alpha_{c,V,fi} \cdot \alpha_{h,V,fi} \cdot \alpha_{90°,V,fi} \cdot \psi_{re,V}$$

		Data according ETA-11/0006, issued 2012-02-28						
Anchor channel		HAC-10	HAC-20	HAC-30	HAC-40	HAC-50	HAC-60	HAC-70
Characteristic resistance, $V^0_{Rk,c}/\cdot c_1^{1.5}$ for C20/25 under normal temperature[kN]		15.00	20.00	17.50	20.00	20.00	20.00	20.00
Effect for neighboring anchors [-]	$\alpha_{s,V,fi}$	$\alpha_{s,V,fi} = \frac{1}{1+\sum_{i=1}^{n}\left[\left(1-\frac{s_i}{s_{cr,V,fi}}\right)^{1.5} \cdot \frac{V_i}{V_0}\right]}$						
Characteristic spacing of anchor [mm]	$s_{cr,V,fi}$	$4c_1+52.4$	$4c_1+55$	$4c_1+82.6$	$4c_1+81.8$	$4c_1+83.8$	$4c_1+86.8$	$4c_1+90.8$
Effect of corner of the concrete member [-]	$\alpha_{c,V,fi}$	$\alpha_{c,V,fi} = \left(\frac{c_2}{c_{cr,V,fi}}\right)^{0.5} \leq 1.0$						
Characteristic edge distance of anchor [mm]	$c_{cr,N,fi}$	$2c_1+26.2$	$2c_1+27.5$	$2c_1+41.3$	$2c_1+40.9$	$2c_1+41.9$	$2c_1+43.4$	$2c_1+45.4$
Effect of thickness of structural component [-]	$\alpha_{h,V,fi}$	$\alpha_{h,V,fi} = \left(\frac{h}{h_{cr,V,fi}}\right)^{1/2} \leq 1.0$						
Characteristic height [mm]	$h_{cr,V,fi}$	$2c_1+16.7$	$2c_1+18.0$	$2c_1+25.6$	$2c_1+28.0$	$2c_1+31.0$	$2c_1+35.5$	$2c_1+40.0$
Effect of load parallel to the edges [-]	$\alpha_{90°,V,fi}$	2.5[2]						
Effect of reinforcement [-]	$\psi_{re,V}$	1.0 anchor channel in cracked concrete without edge reinforcement or stirrups						
		1.2 anchor channel in cracked concrete with straight edge reinforcement (≥ ø 12mm)						
		1.4 anchor channel in cracked concrete with edge reinforcement and stirrups with a spacing a ≤ 100mm and a ≤ $2c_1$ or uncracked concrete						
$\gamma_{Mc,fi}$ [1]		1.0						

[1] In absence of other national regulations the safety factor $\gamma_{Mc,fi}$ = 1.0 under fire exposure is recommended

[2] In all other cases $\alpha_{90°,V,fi}$ =1.0

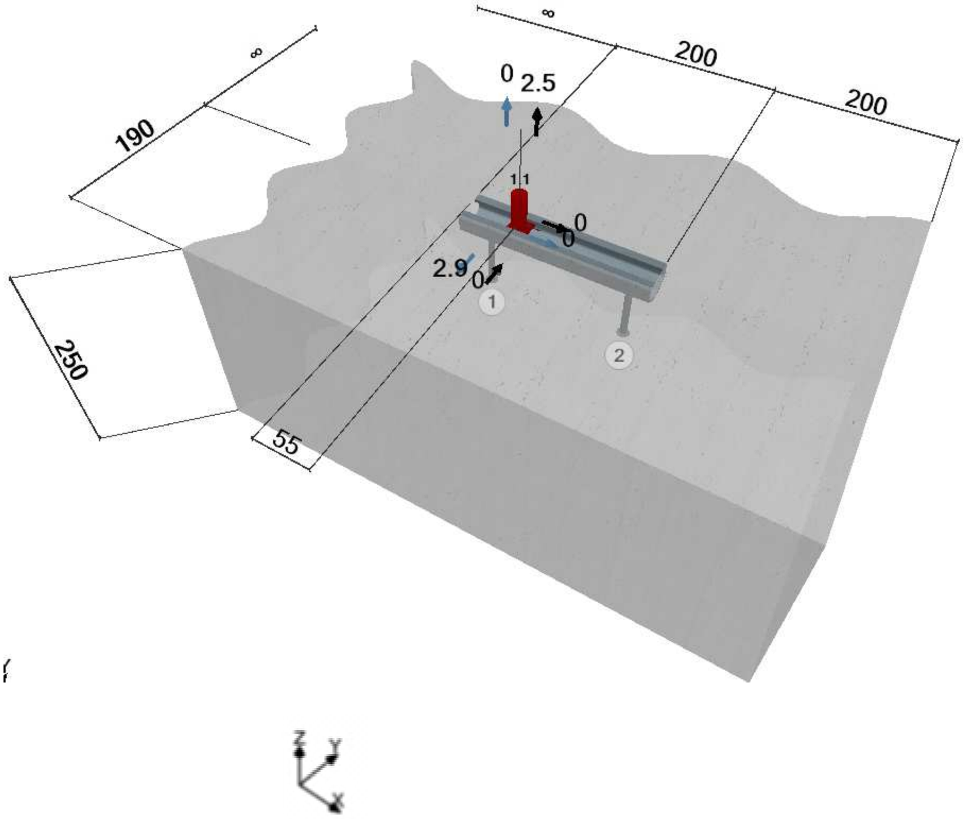
6 Design examples

6.1 Example 1: Anchor channel subjected to static load (2-legged anchor channel)

6.1.1 Anchoring conditions

System, basic values

Anchor channel	HAC-40F, 200 mm (2 anchors)
Hilti special screw	HBC-C-N 8.8F M16 x 50
Concrete	Cracked concrete, C30/37
Stand-off	no
Characteristic tensile dead load	2.5 kN
Characteristic shear live load	2.9 kN
Member thickness h	250 mm
Reinforcement conditions (tension)	ø≥12mm with a spacing of s≥150mm
Reinforcement conditions (shear)	With edge reinforcement ds ≥ 12 mm
Reinforcement conditions (splitting)	Reinforcement for w≤0.3mm present
Effective embedment depth of anchor h_{ef}	91 mm
Width of channel b_{ch}	40.9 mm
Height of channel h_{ch}	28.0 mm
Moment of inertia channel I_y	21452 mm^4
Anchor spacing 200mm s	150 mm



Steel failure TENSION, characteristic values and safety factors

Steel failure, anchor	$N_{Rk,s,a}$	33.0 kN
Steel failure, connection channel anchor	$N_{Rk,s,c}$	25.0 kN
Steel failure, local flexure of channel lips for $s_s \geq s_{slb}$	$N_{Rk,s,l}$	25.0 kN
Characteristic flexure resistance of channel	$M_{Rk,s,flex}$	1.013 kNm
Steel failure Hilti-special screw	$N_{Rk,s,s}$	125.6 kN
Partial safety factor, Hilti-special screw	$\gamma_{Ms,s}$	1.50
Partial safety factor, anchor	γ_{Ms}	1.80
Partial safety factor, connection channel anchor	$\gamma_{Ms,ca}$	1.80
Partial safety factor, local flexure of channel lips	$\gamma_{Ms}=$	1.80
Partial safety factor, flexure resistance of channel	$\gamma_{Ms,flex}$	1.15

Steel failure SHEAR, characteristic values and safety factors

Steel failure, local flexure of channel lip	$V_{Rk,s,l}$	35.0 kN
Steel failure, local flexure of channel lip, shear parallel	$V_{Rk,s,l,II}$	14.5 kN
Steel failure Hilti special screw	$V_{Rk,s}$	62.7 kN
Partial safety factor local flexure of channel lip	$\gamma_{Ms,l}$	1.8
Partial safety factor local flexure of channel lip	$\gamma_{Ms,l,II}$	1.8
Partial safety factor Hilti special screw (shear)	$\gamma_{Ms,s}$	1.25

Concrete failure TENSION, characteristic values and safety factors

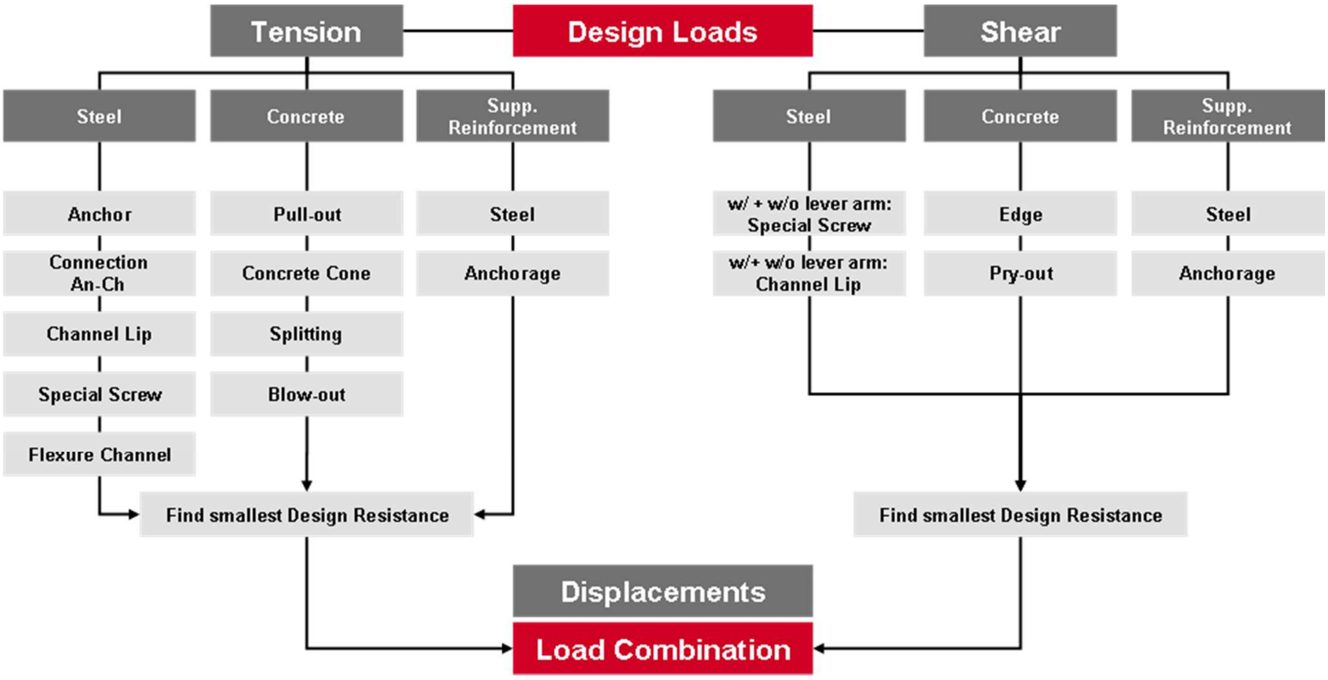
Pull-out failure resistance in cracked concrete C12/15	$N_{Rk,p}$, C12/15	10.3 kN
Effective anchorage depth	h_{ef}	91 mm
Characteristic edge distance	$c_{cr,N}$	195 mm
Characteristic spacing	$s_{cr,N}$	390 mm
Amplification factor of $N_{Rk,p}$ for C30/37	ψ_c	2.47
Factor for anchor channel influencing concrete cone	α_{ch}	0.903
Partial safety factor concrete	γ_{Mc}	1.5
Partial safety factor for pull-out	$\gamma_{Mc,p}$	1.5

Concrete failure SHEAR, characteristic values and safety factors

Factor k in equation (31) of CEN/TS 1992-4-3	k_5	2.0
Product of factor αp and $\psi_{re,V}$	$\alpha_p\ \psi_{re,V}$	4.8
Effect of thickness of structural component = $(h/h_{cr,V})^{1/2}$	$\alpha_{h,V}$	0.757
Characteristic height = $2(c_1 + h_{ch})$	$h_{cr,V}$	436 mm
Characteristic edge distance = $2c_1 + b_{ch}$	$c_{cr,V}$	421 mm
Characteristic spacing = $4c_1 + 2b_{ch}$	$s_{cr,V}$	842 mm
Partial safety factor concrete	γ_{Mc}	1.5

General remarks

According to CEN 1994-4-3 the following verifications have to be done:



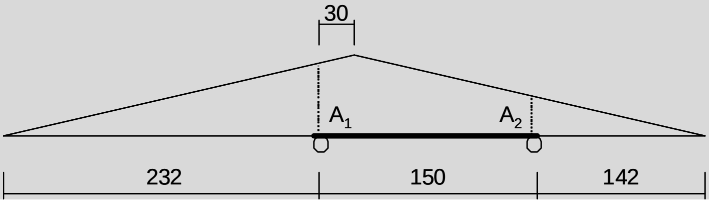
The verifications are calculated with the directly acting load and with the distributed anchor load, respectively. For this reason, the distributed loads acting on the anchor have to be calculated first. Please note that these loads heavily depend on the load position of the acting external load. In other words, the verification is only valid for the given load position of the screw.

6.1.2 Determination of acting forces

Direct forces acting on screw

Design tensile load	$N_{Ed} = \gamma \cdot F_{z,G}$	$N_{Ed} = 1.35 \cdot 2.5 = 3.38\text{kN}$
Design shear load	$V_{Ed} = \gamma \cdot F_{y,Q}$	$V_{Ed} = 1.5 \cdot (-2.9) = -4.35\text{kN}$
Influence length	$l_i = 13 \cdot I_y^{0.05} \cdot s^{0.5} \geq s$	$l_i = 13 \cdot 21452^{0.05} \cdot \sqrt{150} = 262\text{mm} \geq s$

Forces acting on anchors

Load distribution scheme based on influence length l_i		
Calculate A_i on basis of theorem of intersecting lines		$A'_1 = \frac{262-30}{262} = 0.885$ $A'_2 = \frac{262-150+30}{262} = 0.542$
Weighting factor	$k = \frac{1}{\sum_1^n A'_i}$	$k = \frac{1}{0.885+0.542} = 0.70$

Tensile force anchor 1	$N^a_{Ed,1} = k \cdot A'_1 \cdot N_{Ed}$	$N^a_{Ed,1} = 0.7 \cdot 0.885 \cdot 3.375kN = 2.09\ kN$
Tensile force anchor 2	$N^a_{Ed,2} = k \cdot A'_2 \cdot N_{Ed}$	$N^a_{Ed,2} = 0.7 \cdot 0.542 \cdot 3.375kN = 1.28\ kN$
Shear force anchor 1	$V^a_{Ed,1} = k \cdot A'_1 \cdot V_{Ed}$	$V^a_{Ed,1} = 0.7 \cdot 0.885 \cdot 4.35kN = 2.69\ kN$
Shear force anchor 2	$V^a_{Ed,2} = k \cdot A'_2 \cdot V_{Ed}$	$V^a_{Ed,2} = 0.7 \cdot 0.542 \cdot 4.35kN = 1.65\ kN$

6.1.3 Tensile loading

Design steel resistance anchor

	$N_{Rd,s,a} = \frac{N_{R,k,s,a}}{\gamma_{Ms}}$	$N_{Rd,s,a} = \frac{33.0kN}{1.8} = 18.3kN$

Design steel resistance connection anchor - channel

	$N_{Rd,s,c} = \frac{N_{R,k,s,c}}{\gamma_{Ms,ca}}$	$N_{Rd,s,c} = \frac{25.0kN}{1.8} = 13.9kN$

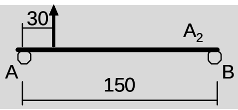
Design steel resistance local flexure of channel lip

	$N_{Rd,s,l} = \frac{N_{R,k,s,l}}{\gamma_{Ms,l}}$	$N_{Rd,s,l} = \frac{25.0kN}{1.8} = 13.9kN$

Design steel resistance special screw

	$N_{Rd,s,s} = \frac{N_{R,k,s,s}}{\gamma_{Ms,s}}$	$N_{Rd,s,s} = \frac{125.6kN}{1.50} = 83.7kN$

Design steel resistance flexure of channel

Determination of acting moment based on single supported beam		$A = \frac{120}{150} \cdot 3.375kN = 2.7kN$
		$M_{Ed} = 2.7kN \cdot 0.03m = 0.081kNm$
	$M_{Rd,s,flex} = \frac{M_{Rk,s,flex}}{\gamma_{Ms,flex}}$	$M_{Rd,s,flex} = \frac{1013Nm}{1.15} = 0.881kNm$

Design concrete pull-out resistance

Cracked concrete pull-out resistance	$N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mc,p}} \cdot \psi_c \cdot \psi_{ucr}$	$N_{Rd,p} = \frac{10.3}{1.5} \cdot 2.47 \cdot 1.0 = 16.96kN$

Design concrete cone resistance

Basic resistance	$N^0_{Rk,c} = 8.5 \cdot \alpha_{ch} \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5}$	$N^0_{Rk,c} = 8.5 \cdot 0.903 \cdot \sqrt{37} \cdot 91^{1.5} = 40.5kN$
Effect of neighboring anchors, anchor 1	$\alpha_{s,N} = \frac{1}{1 + \sum_{i=1}^{n} \left[\left(1 - \frac{s_i}{s_{cr,N}} \right)^{1.5} \cdot \frac{N_i}{N_0} \right]}$	$\alpha^1_{s,N} = \frac{1}{1 + \sum_{i=1}^{1} \left[\left(1 - \frac{150}{390} \right)^{1.5} \cdot \frac{1.28}{2.09} \right]} = 0.772$
Effect of neighboring anchors, anchor 2		$\alpha^2_{s,N} = \frac{1}{1 + \sum_{i=1}^{1} \left[\left(1 - \frac{150}{390} \right)^{1.5} \cdot \frac{2.09}{1.28} \right]} = 0.560$

Effect of edges	$\alpha_{e,N} = \left(\frac{c_1}{c_{cr,N}}\right)^{0.5} \leq 1.0$	$\alpha_{e,N} = \left(\frac{190}{195}\right)^{0.5} = 0.987$
Effect of corner 1	$\alpha_{c,N} = \left(\frac{c_2}{c_{cr,N}}\right)^{0.5} \leq 1.0$	$\alpha^1_{c,N} = \left(\frac{\infty}{195}\right)^{0.5} = \infty > 1.0$
Effect of corner 2		$\alpha^2_{c,N} = \left(\frac{225}{195}\right)^{0.5} = 1.07 > 1.0$
Effect of shell spalling	$\psi_{re,N} = 0.5 + \frac{h_{ef}}{200} \leq 1.0$	$\Psi_{re,N} = 1.0$ may be taken if local to this anchor channel reinforcement (any diameter) is provided at a spacing ≥ 150 mm
Effect of concrete conditions		$\Psi_{ucr,N} = 1.0$
Characteristic resistance	$N_{Rk,c} = N^0_{Rk,c} \cdot \alpha_{s,N} \cdot \alpha_{e,N} \cdot \alpha_{c,N} \cdot \psi_{re,N} \cdot \psi_{ucr,N}$ Anchor 1: $N^1_{Rk,c} = 40.5 \cdot 0.772 \cdot 0.987 \cdot 1.0 \cdot 1.0 \cdot 1.0 = 30.9\text{kN}$ Anchor 2: $N^2_{Rk,c} = 40.5 \cdot 0.560 \cdot 0.987 \cdot 1.0 \cdot 1.0 \cdot 1.0 = 22.4\text{kN}$	
Design resistance	Anchor 1: $N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}} = 20.6\text{kN}$ Anchor 2: $N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}} = 14.9\text{kN}$	

Design concrete splitting resistance

Verification not necessary since the characteristic resistance for concrete cone failure, concrete blow-out failure and pull-out failure is calculated for cracked concrete and reinforcement resists the splitting forces and limits the crack width to w_k ≤ 0.3 mm.

Design concrete blow-out resistance

Verification not necessary since $c \geq 0.5 \cdot h_{ef}$

$c_1 = 190\text{mm} > 0.5 \cdot 91\text{mm} = 45.5\text{mm}$

6.1.4 SHEAR loading

Design steel resistance special screw without lever arm

	$V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	$V_{Rd,s} = \frac{62.7kN}{1.25} = 50.2kN$

Design steel resistance local flexure channel lip

	$V_{Rd,s,l} = \frac{V_{Rk,s,l}}{\gamma_{Ms,l}}$	$V_{Rd,s,l} = \frac{35kN}{1.8} = 19.4kN$

Design concrete pry-out resistance

Anchor 1	$V^1_{Rd,cp} = \frac{k_5 \cdot N^1_{Rk,c}}{\gamma_{Mc}}$	$V^1_{Rd,cp} = \frac{2 \cdot 30.9kN}{1.5} = 41.2kN$
Anchor 2	$V^2_{Rd,cp} = \frac{k_5 \cdot N^2_{Rk,c}}{\gamma_{Mc}}$	$V^1_{Rd,cp} = \frac{2 \cdot 22.4kN}{1.5} = 29.9kN$

Design concrete edge resistance

Basic resistance including reinforcement condition	$V^0_{Rk,c} = \alpha_p \cdot \psi_{re,V} \cdot \sqrt{f_{ck,cube}} \cdot c_1^{1.5}$	$V^0_{Rk,c} = 4.8 \cdot \sqrt{37} \cdot 190^{1.5} = 76.5kN$
Effect of neighboring anchors, anchor 1	$\alpha_{s,V} = \frac{1}{1+\sum_{i=1}^{n}\left[\left(1-\frac{s_i}{s_{cr,V}}\right)^{1.5} \cdot \frac{V_i}{V_0}\right]}$	$\alpha^1_{s,V} = \frac{1}{1+\sum_{i=1}^{1}\left[\left(1-\frac{150}{842}\right)^{1.5} \cdot \frac{1.65}{2.69}\right]} = 0.686$
Effect of neighboring anchors, anchor 2		$\alpha^2_{s,V} = \frac{1}{1+\sum_{i=1}^{1}\left[\left(1-\frac{150}{842}\right)^{1.5} \cdot \frac{2.69}{1.65}\right]} = 0.451$
Effect of corner 1	$\alpha_{c,V} = \left(\frac{c_2}{c_{cr,V}}\right)^{0.5} \le 1.0$	$\alpha^1_{c,V} = \left(\frac{\infty}{421}\right)^{0.5} = \infty > 1.0$
Effect of corner 2		$\alpha^2_{c,V} = \left(\frac{225}{421}\right)^{0.5} = 0.731$
Effect of thickness of structural component	$\alpha_{h,V} = \left(\frac{h}{h_{cr,V}}\right)^{0.5} \le 1.0$	$\alpha_{h,V} = \left(\frac{250}{436}\right)^{0.5} = 0.757$
Effect of load parallel to edge		$\alpha_{90^\circ,V} = 1.0$
Characteristic resistance	$V_{Rk,c} = V^0_{Rk,c} \cdot \alpha_{s,V} \cdot \alpha_{c,V} \cdot \alpha_{h,V} \cdot \alpha_{90^\circ,V}$ Anchor 1: $V^1_{Rk,c} = 76.5 \cdot 0.686 \cdot 1.0 \cdot 0.757 \cdot 1.0 = 39.7kN$ Anchor 2: $V^2_{Rk,c} = 76.5 \cdot 0.451 \cdot 0.731 \cdot 0.757 \cdot 1.0 = 19.1kN$	
Design resistance	Anchor 1: $V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}} = 26.5kN$ Anchor 2: $V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}} = 12.7kN$	

6.1.5 Combined tension and shear loading

TENSION: Determination of utilization rates direct load (screw loads)

Failure mode	Utilization factor $\beta = \frac{N_{Ed}}{N_{Rd}}$	Utilization factor	Decisive mode
Steel failure local flexure channel lip	β=3.38/13.9	24%	✓
Flexure of channel	β=0.081/0.881	9%	
Special screw	β=3.38/83.7	4%	

TENSION: Determination of utilization rates anchor loads

Failure mode	Utilization factor $\beta_i = \frac{N^a_{Ed,i}}{N_{Rd}}$	Utilization factor	Anchor
Steel failure of anchor	β_1=2.09/18.3	11%	1
	β_2=1.28/18.3	7%	2
Steel failure connection channel – anchor	β_1=2.09/13.9	15%	1
	β_2=1.28/13.9	10%	2
Pull-out	β_1=2.09/16.96	12%	1
	β_2=1.28/16.96	8%	2
Concrete cone failure	β_1=2.09/20.6	10%	1
	β_2=1.28/14.9	9%	2
Splitting failure	N/A		
Blow out	N/A		

SHEAR: Determination of utilization rates direct load (screw loads)

Failure mode	Utilization factor $\beta = \frac{V_{Ed}}{V_{Rd}}$	Utilization factor	Decisive mode
Steel failure special screw	β=4.35/50.2	9%	
Steel failure local channel lip	β=4.35/19.4	23%	✓

SHEAR: Determination of utilization rates anchor loads

Failure mode	Utilization factor $\beta_i = \frac{V^a_{Ed,i}}{V_{Rd}}$	Utilization factor	Anchor
Pry-out	β_1=2.69/41.2	7%	1
	β_2=1.65/29.9	6%	2
concrete edge	β_1=2.69/26.5	10%	1
	β_2=1.65/12.7	13%	2

6.1.6 Load combination direct loads (screw)

Tension: Steel failure local flexure channel lip	24%	
Shear: Steel failure local channel lip	23%	
Interaction steel	$\beta_N^2 + \beta_V^2 \leq 1.0$	$0.24^2 + 0.23^2 = 0.12 \leq 1$

6.1.7 Load combination anchor loads

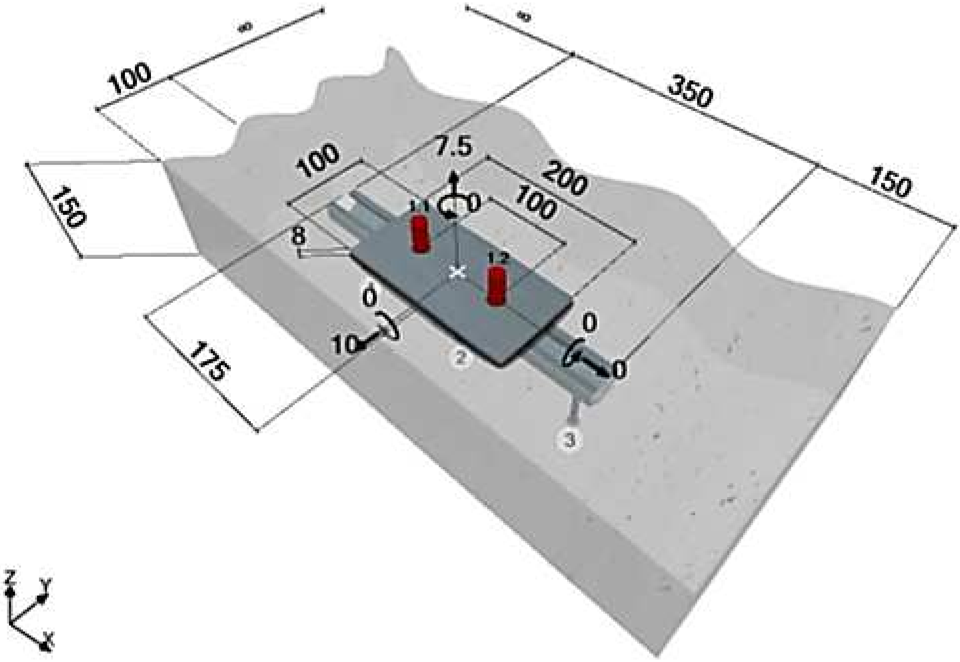
Anchor 1:		
Tension: Connection anchor-channel	15%	
Shear: Concrete failure concrete edge	10%	
Interaction concrete	$\beta_N^{1.5} + \beta_V^{1.5} \leq 1.0$	$0.15^{1.5} + 0.10^{1.5} = 0.09 \leq 1$
Anchor 2:		
Tension: Connection anchor-channel	10%	
Shear: Concrete failure concrete edge	13%	
Interaction concrete	$\beta_N^{1.5} + \beta_V^{1.5} \leq 1.0$	$0.10^{1.5} + 0.13^{1.5} = 0.08 \leq 1$

6.2 Example 2: Anchor channel subjected to static load (3-legged anchor channel)

6.2.1 Anchoring conditions

System, basic values

Anchor channel	HAC-40F, 350 mm (3 anchors)
Hilti special screw	HBC-C 4.6F M16 x 50
Concrete	Cracked concrete, C20/25
Stand-off	no
Design tensile load	7.5 kN
Design shear load	10.0 kN
Member thickness h	150 mm
Reinforcement conditions (tension)	ø≥12mm with a spacing of s≥150mm
Reinforcement conditions (shear)	With edge reinforcement ds ≥ 12 mm
Reinforcement conditions (splitting)	Reinforcement for w≤0.3mm present
Effective embedment depth of anchor h_{ef}	91 mm
Width of channel b_{ch}	40.9 mm
Height of channel h_{ch}	28.0 mm
Moment of inertia channel I_y	21452 mm^4
Anchor spacing 200mm s	150 mm



Steel failure TENSION, characteristic values and safety factors

Steel failure, anchor	$N_{Rk,s,a}$	33.0 kN
Steel failure, connection channel anchor	$N_{Rk,s,c}$	25.0 kN
Steel failure, local flexure of channel lips for $s_s \geq s_{slb}$	$N_{Rk,s,l}$	25.0 kN
Characteristic flexure resistance of channel	$M_{Rk,s,flex}$	1.013 kNm
Steel failure Hilti-special screw	$N_{Rk,s,s}$	62.8 kN
Partial safety factor, Hilti-special screw	$\gamma_{Ms,s}$	2.00
Partial safety factor, anchor	γ_{Ms}	1.80
Partial safety factor, connection channel anchor	$\gamma_{Ms,ca}$	1.80
Partial safety factor, local flexure of channel lips	$\gamma_{Ms}=$	1.80
Partial safety factor, flexure resistance of channel	$\gamma_{Ms,flex}$	1.15

Steel failure SHEAR, characteristic values and safety factors

Steel failure, local flexure of channel lip	$V_{Rk,s,l}$	35.0 kN
Steel failure Hilti special screw	$V_{Rk,s}$	37.6 kN
Partial safety factor local flexure of channel lip	$\gamma_{Ms,l}$	1.8
Partial safety factor Hilti special screw (shear)	$\gamma_{Ms,s}$	1.25

Concrete failure TENSION, characteristic values and safety factors

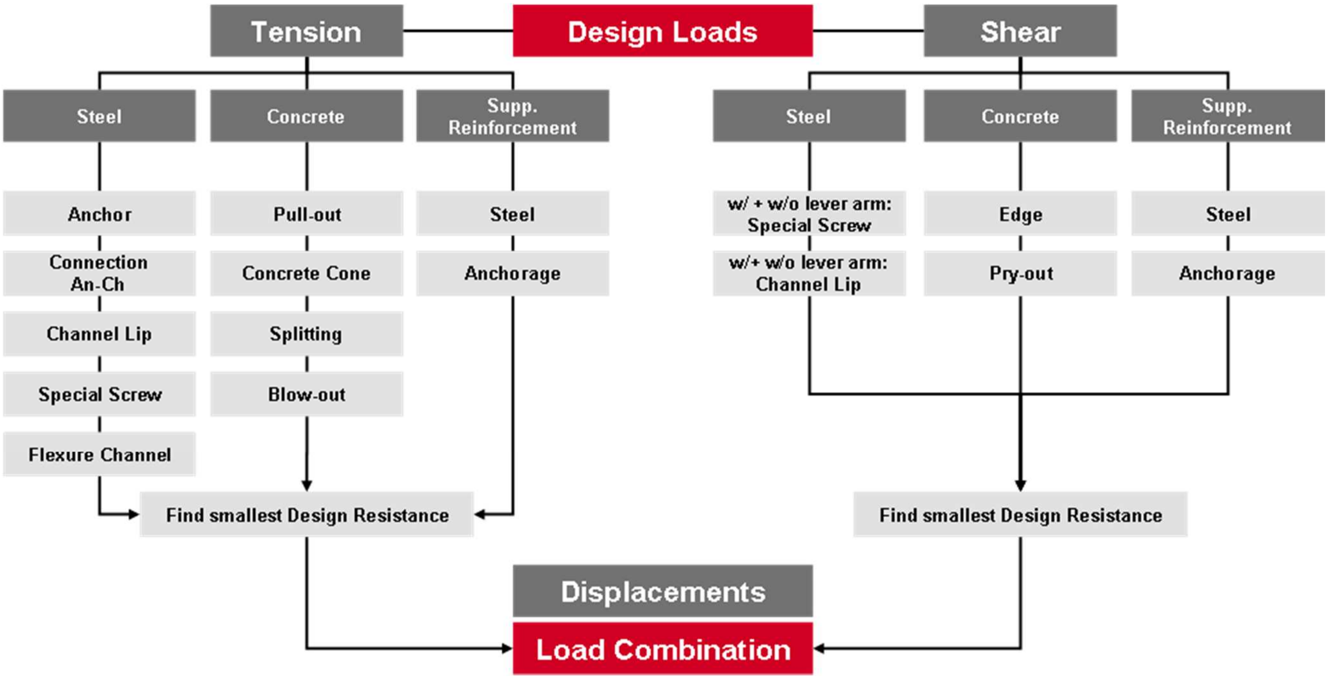
Pull-out failure resistance in cracked concrete C12/15	$N_{Rk,p}$, C12/15	10.3 kN
Effective anchorage depth	h_{ef}	91 mm
Characteristic edge distance	$c_{cr,N}$	195 mm
Characteristic spacing	$s_{cr,N}$	390 mm
Amplification factor of $N_{Rk,p}$ for C20/25	ψ_c	1.67
Factor for anchor channel influencing concrete cone	α_{ch}	0.903
Partial safety factor concrete	γ_{Mc}	1.5
Partial safety factor for pull-out	$\gamma_{Mc,p}$	1.5

Concrete failure SHEAR, characteristic values and safety factors

Factor k in equation (31) of CEN/TS 1992-4-3	k_5	2.0
Product of factor αp and $\psi_{re,V}$	$\alpha_p \psi_{re,V}$	4.8
Effect of thickness of structural component = $(h/h_{cr,V})^{1/2}$	$\alpha_{h,V}$	0.765
Characteristic height = $2(c_1 + h_{ch})$	$h_{cr,V}$	256 mm
Characteristic edge distance = $2c_1 + b_{ch}$	$c_{cr,V}$	241 mm
Characteristic spacing = $4c_1 + 2b_{ch}$	$s_{cr,V}$	482 mm
Partial safety factor concrete	γ_{Mc}	1.5

General remarks

According to CEN 1994-4-3 the following verifications have to be done:



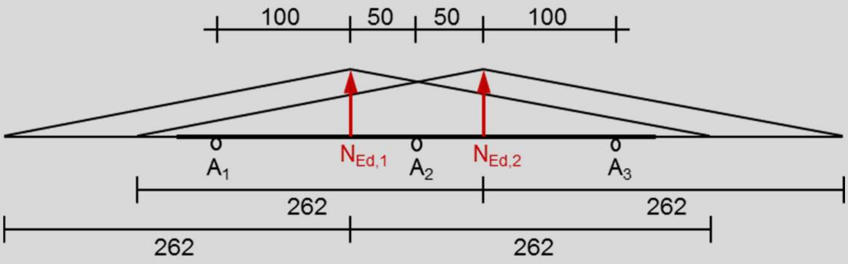
The verifications are calculated with the directly acting load and with the distributed anchor load, respectively. For this reason, the distributed loads acting on the anchor have to be calculated first. Please note that these loads heavily depend on the load position of the acting external load. In other words, the verification is only valid for the given load position of the screw.

6.2.2 Determination of acting forces

Direct forces acting on screw

Design tensile load	N_{Ed}	$N_{Ed,1}$=3.75kN, $N_{Ed,2}$=3.75kN
Design shear load	V_{Ed}	$V_{Ed,1}$=5.00kN; $V_{Ed,2}$=5.00kN
Influence length	$l_i = 13 \cdot I_y^{0.05} \cdot s^{0.5} \geq s$	$l_i = 13 \cdot 21452^{0.05} \cdot \sqrt{150} = 262\text{mm} \geq s$

Forces acting on anchors

Load distribution scheme based on influence length l_i	
Calculate A_i on basis of theorem of intersecting lines	$A'_{1,1} = \frac{262-100}{262} = 0.618$ $\quad A'_{1,2} = \frac{262-200}{262} = 0.237$ $A'_{2,1} = \frac{262-50}{262} = 0.809$ $\quad A'_{2,2} = \frac{262-50}{262} = 0.809$

		$A'_{3,1} = \frac{262-200}{262} = 0.237$ $\quad A'_{3,2} = \frac{262-100}{262} = 0.618$
Weighting factor	$k = \frac{1}{\sum_{1}^{n} A'_i}$	$k_1 = \frac{1}{0.618+0.809+0.237} = 0.601$ $k_2 = \frac{1}{0.237+0.809+0.618} = 0.601$
Tensile force anchor 1	$N^a_{Ed,1} = k_1 \cdot A'_{1,1} \cdot N_{Ed,1} + k_2 \cdot A'_{1,2} \cdot N_{Ed,2}$	$N^a_{Ed,1} = 0.601 \cdot 0.618 \cdot 3.75 + 0.237 \cdot 0.601 \cdot 3.75 = 1.92\ \text{kN}$
Tensile force anchor 2	$N^a_{Ed,2} = k_1 \cdot A'_{2,1} \cdot N_{Ed,2} + k_2 \cdot A'_{2,2} \cdot N_{Ed,2}$	$N^a_{Ed,2} = 0.601 \cdot 0.809 \cdot 3.75 + 0.601 \cdot 0.809 \cdot 3.75 = 3.64\ \text{kN}$
Tensile force anchor 3	$N^a_{Ed,3} = k_1 \cdot A'_{3,1} \cdot N_{Ed,1} + k_2 \cdot A'_{3,2} \cdot N_{Ed,2}$	$N^a_{Ed,3} = 0.237 \cdot 0.601 \cdot 3.75 + 0.601 \cdot 0.618 \cdot 3.75 = 1.92\ \text{kN}$
Shear force anchor 1	$V^a_{Ed,1} = k_1 \cdot A'_{1,1} \cdot V_{Ed,1} + k_2 \cdot A'_{1,2} \cdot V_{Ed,2}$	$V^a_{Ed,1} = 0.601 \cdot 0.618 \cdot 5.00 + 0.237 \cdot 0.601 \cdot 5.00 = 2.57\ \text{kN}$
Shear force anchor 2	$V^a_{Ed,2} = k_1 \cdot A'_{2,1} \cdot V_{Ed,2} + k_2 \cdot A'_{2,2} \cdot V_{Ed,2}$	$V^a_{Ed,2} = 0.601 \cdot 0.809 \cdot 5.00 + 0.601 \cdot 0.809 \cdot 5.00 = 4.86\ \text{kN}$
Shear force anchor 3	$V^a_{Ed,3} = k_1 \cdot A'_{3,1} \cdot V_{Ed,1} + k_2 \cdot A'_{3,2} \cdot V_{Ed,2}$	$V^a_{Ed,3} = 0.237 \cdot 0.601 \cdot 5.00 + 0.601 \cdot 0.618 \cdot 5.00 = 2.57\ \text{kN}$

6.2.3 Tensile loading

Design steel resistance anchor

	$N_{Rd,s,a} = \frac{N_{R,k,s,a}}{\gamma_{Ms}}$	$N_{Rd,s,a} = \frac{33.0\text{kN}}{1.8} = 18.3\text{kN}$

Design steel resistance connection anchor - channel

	$N_{Rd,s,c} = \frac{N_{R,k,s,c}}{\gamma_{Ms,ca}}$	$N_{Rd,s,c} = \frac{25.0\text{kN}}{1.8} = 13.9\text{kN}$

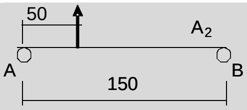
Design steel resistance local flexure of channel lip

	$N_{Rd,s,l} = \frac{N_{R,k,s,l}}{\gamma_{Ms,l}}$	$N_{Rd,s,l} = \frac{25.0\text{kN}}{1.8} = 13.9\text{kN}$

Design steel resistance special screw

	$N_{Rd,s,s} = \frac{N_{R,k,s,s}}{\gamma_{Ms,s}}$	$N_{Rd,s,s} = \frac{62.8\text{kN}}{2.0} = 31.4\text{kN}$

Design steel resistance flexure of channel

Determination of acting moment based on single supported beam		$A = \frac{100}{150} \cdot 3.75\text{kN} = 2.5\text{kN}$

$$M_{Ed} = 2.5\text{kN} \cdot 0.05\text{m} = 0.125\text{kNm}$$

$M_{Rd,s,flex} = \frac{M_{Rk,s,flex}}{\gamma_{Ms,flex}}$	$M_{Rd,s,flex} = \frac{1013Nm}{1.15} = 0.881kNm$

Design concrete pull-out resistance

Cracked concrete pull-out resistance	$N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mc,p}} \cdot \psi_c \cdot \psi_{ucr}$	$N_{Rd,p} = \frac{10.3}{1.5} \cdot 1.67 \cdot 1.0 = 11.47kN$

Design concrete cone resistance

Basic resistance	$N^0_{Rk,c} = 8.5 \cdot \alpha_{ch} \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5}$	$N^0_{Rk,c} = 8.5 \cdot 0.903 \cdot \sqrt{25} \cdot 91^{1.5} = 33.31kN$
Effect of neighboring anchors, anchor 1	$\alpha_{s,N} = \frac{1}{1+\sum_{i=1}^{n}\left[\left(1-\frac{s_i}{s_{cr,N}}\right)^{1.5} \cdot \frac{N_i}{N_0}\right]}$	$\alpha^1_{s,N} = \frac{1}{1+\left[\left(1-\frac{150}{390}\right)^{1.5} \cdot \frac{3.64}{1.92} + \left(1-\frac{150}{390}\right)^{1.5} \cdot \frac{1.92}{1.92}\right]} = 0.417$
Effect of neighboring anchors, anchor 2		$\alpha^2_{s,N} = \frac{1}{1+\left[\left(1-\frac{150}{390}\right)^{1.5} \cdot \frac{1.92}{3.64} + \left(1-\frac{150}{390}\right)^{1.5} \cdot \frac{1.92}{3.64}\right]} = 0.663$
Effect of neighboring anchors, anchor 3		$\alpha^3_{s,N} = \frac{1}{1+\left[\left(1-\frac{150}{390}\right)^{1.5} \cdot \frac{1.92}{1.92} + \left(1-\frac{150}{390}\right)^{1.5} \cdot \frac{3.64}{1.92}\right]} = 0.417$
Effect of edges	$\alpha_{e,N} = \left(\frac{c_1}{c_{cr,N}}\right)^{0.5} \leq 1.0$	$\alpha_{e,N} = \left(\frac{100}{195}\right)^{0.5} = 0.716$
Effect of corner 1	$\alpha_{c,N} = \left(\frac{c_2}{c_{cr,N}}\right)^{0.5} \leq 1.0$	$\alpha^1_{c,N} = \left(\frac{\infty}{195}\right)^{0.5} = \infty > 1.0$
Effect of corner 2		$\alpha^2_{c,N} = \left(\frac{325}{195}\right)^{0.5} = 1.31 > 1.0$
Effect of corner 3		$\alpha^3_{c,N} = \left(\frac{175}{195}\right)^{0.5} = 0.947$
Effect of shell spalling	$\psi_{re,N} = 0.5 + \frac{h_{ef}}{200} \leq 1.0$	$\Psi_{re,N} = 1.0$ may be taken if local to this anchor channel reinforcement (any diameter) is provided at a spacing ≥ 150 mm
Effect of concrete conditions		$\Psi_{ucr,N} = 1.0$
Characteristic resistance	$N_{Rk,c} = N^0_{Rk,c} \cdot \alpha_{s,N} \cdot \alpha_{e,N} \cdot \alpha_{c,N} \cdot \psi_{re,N} \cdot \psi_{ucr,N}$ Anchor 1: $N^1_{Rk,c} = 33.31 \cdot 0.417 \cdot 0.716 \cdot 1.0 \cdot 1.0 \cdot 1.0 = 9.95kN$ Anchor 2: $N^2_{Rk,c} = 33.31 \cdot 0.663 \cdot 0.716 \cdot 1.0 \cdot 1.0 \cdot 1.0 = 15.81kN$ Anchor 3: $N^3_{Rk,c} = 33.31 \cdot 0.417 \cdot 0.716 \cdot 0.947 \cdot 1.0 \cdot 1.0 = 9.42kN$	
Design resistance	Anchor 1: $N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}} = 6.63kN$ Anchor 2: $N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}} = 10.54kN$ Anchor 3: $N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}} = 6.28kN$	

Design concrete splitting resistance

Verification not necessary since the characteristic resistance for concrete cone failure, concrete blow-out failure and pull-out failure is calculated for cracked concrete and reinforcement resists the splitting forces and limits the crack width to $w_k \le 0.3$ mm.

Design concrete blow-out resistance

Verification not necessary since $c \geq 0.5 \cdot h_{ef}$

$c_1 = 100mm > 0.5 \cdot 91mm = 45.5mm$

6.2.4 SHEAR loading

Design steel resistance special screw without lever arm

$$V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}} \qquad V_{Rd,s} = \frac{37.68kN}{1.67} = 22.61kN$$

Design steel resistance local flexure channel lip

$$V_{Rd,s,l} = \frac{V_{Rk,s,l}}{\gamma_{Ms,l}} \qquad V_{Rd,s,l} = \frac{35kN}{1.8} = 19.4kN$$

Design concrete pry-out resistance

Anchor 1	$V^1_{Rd,cp} = \frac{k_5 \cdot N^1_{Rk,c}}{\gamma_{Mc}}$	$V^1_{Rd,cp} = \frac{2 \cdot 9.95kN}{1.5} = 13.27kN$
Anchor 2	$V^2_{Rd,cp} = \frac{k_5 \cdot N^2_{Rk,c}}{\gamma_{Mc}}$	$V^2_{Rd,cp} = \frac{2 \cdot 15.81kN}{1.5} = 21.08kN$
Anchor 3	$V^3_{Rd,cp} = \frac{k_5 \cdot N^3_{Rk,c}}{\gamma_{Mc}}$	$V^3_{Rd,cp} = \frac{2 \cdot 9.42kN}{1.5} = 12.56kN$

Design concrete edge resistance

Basic resistance including reinforcement condition	$V^0_{Rk,c} = \alpha_p \cdot \psi_{re,V} \cdot \sqrt{f_{ck,cube}} \cdot c_1^{1.5}$	$V^0_{Rk,c} = 4.8 \cdot \sqrt{25} \cdot 100^{1.5} = 24.0kN$
Effect of neighboring anchors, anchor 1	$\alpha_{s,V} = \frac{1}{1 + \sum_{i=1}^{n} \left[\left(1 - \frac{s_i}{s_{cr,V}}\right)^{1.5} \cdot \frac{V_i}{V_0} \right]}$	$\alpha^1_{s,V} = \frac{1}{1 + \left[\left(1 - \frac{150}{482}\right)^{1.5} \cdot \frac{4.86}{2.57} + \left(1 - \frac{150}{482}\right)^{1.5} \cdot \frac{2.57}{2.57} \right]} = 0.377$
Effect of neighboring anchors, anchor 2		$\alpha^2_{s,V} = \frac{1}{1 + \left[\left(1 - \frac{150}{482}\right)^{1.5} \cdot \frac{2.57}{4.86} + \left(1 - \frac{150}{482}\right)^{1.5} \cdot \frac{2.57}{4.86} \right]} = 0.623$
Effect of neighboring anchors, anchor 3		$\alpha^1_{s,V} = \frac{1}{1 + \left[\left(1 - \frac{150}{482}\right)^{1.5} \cdot \frac{2.57}{2.57} + \left(1 - \frac{150}{482}\right)^{1.5} \cdot \frac{4.86}{2.57} \right]} = 0.377$
Effect of corner 1	$\alpha_{c,V} = \left(\frac{c_2}{c_{cr,V}}\right)^{0.5} \leq 1.0$	$\alpha^1_{c,V} = \left(\frac{\infty}{241}\right)^{0.5} = \infty > 1.0$

Effect of corner 2	Anchor 1	$\alpha^{1}_{c,V} = \left(\frac{475}{241}\right)^{0.5} = 1.40 > 1.0$
Effect of corner 2	Anchor 2	$\alpha^{2}_{c,V} = \left(\frac{325}{241}\right)^{0.5} = 1.16 > 1.0$
Effect of corner 2	Anchor 3	$\alpha^{3}_{c,V} = \left(\frac{175}{241}\right)^{0.5} = 0.852$
Effect of thickness of structural component	$\alpha_{h,V} = \left(\frac{h}{h_{cr,V}}\right)^{0.5} \leq 1.0$	$\alpha_{h,V} = \left(\frac{150}{256}\right)^{0.5} = 0.765$
Effect of load parallel to edge		$\alpha_{90°,V} = 1.0$
Characteristic resistance	$V_{Rk,c} = V^{0}_{Rk,c} \cdot \alpha_{s,V} \cdot \alpha_{c,V} \cdot \alpha_{h,V} \cdot \alpha_{90°,V}$ Anchor 1: $V^{1}_{Rk,c} = 24.0 \cdot 0.377 \cdot 1.0 \cdot 0.765 \cdot 1.0 = 6.92\text{kN}$ Anchor 2: $V^{2}_{Rk,c} = 24.0 \cdot 0.623 \cdot 1.0 \cdot 0.765 \cdot 1.0 = 11.44\text{kN}$ Anchor 3: $V^{3}_{Rk,c} = 24.0 \cdot 0.377 \cdot 0.852 \cdot 0.765 \cdot 1.0 = 5.90\text{kN}$	
Design resistance	Anchor 1: $V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}} = 4.61\text{kN}$ Anchor 2: $V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}} = 7.63\text{kN}$ Anchor 3: $V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}} = 3.93\text{kN}$	

6.2.5 Combined tension and shear loading

TENSION: Determination of utilization rates direct load (screw loads)

Failure mode	Utilization factor $\beta = \frac{N_{Ed}}{N_{Rd}}$	Utilization factor	Decisive mode
Steel failure local flexure channel lip	β=3.75/13.9	27%	✓
Flexure of channel	β=0.125/0.881	14%	
Special screw (1 and 2)	β=3.75/31.4	12%	

TENSION: Determination of utilization rates anchor loads

Failure mode	Utilization factor $\beta_i = \frac{N^{a}_{Ed,i}}{N_{Rd}}$	Utilization factor	Anchor
Steel failure of anchor	β_1=1.92/18.3	10%	1
	β_2=3.64/18.3	20%	2
	β_3=1.92/18.3	10%	3
Steel failure connection channel – anchor	β_1=1.92/13.9	14%	1
	β_2=3.64/13.9	26%	2
	β_3=1.92/13.9	14%	3
Pull-out	β_1=1.92/11.5	17%	1

	β_2=3.64/11.5	32%	2
	β_3=1.92/11.5	17%	3
Concrete cone failure	β_1=1.92/6.63	29%	1
	β_2=3.64/10.54	35%	2
	β_3=1.92/6.28	31%	3
Splitting failure	N/A		
Blow out	N/A		

SHEAR: Determination of utilization rates direct load (screw loads)

Failure mode	Utilization factor $\beta = \frac{V_{Ed}}{V_{Rd}}$	Utilization factor	Decisive mode
Steel failure special screw	β=5.00/22.61	22%	
Steel failure local channel lip	β=5.00/19.4	26%	✓

SHEAR: Determination of utilization rates anchor loads

Failure mode	Utilization factor $\beta_i = \frac{V^a_{Ed,i}}{V_{Rd}}$	Utilization factor	Anchor
Pry-out	β_1=2.57/13.3	19%	1
	β_2=4.86/21.1	23%	2
	β_3=2.57/12.6	20%	3
concrete edge	β_1=2.57/4.6	56%	1
	β_2=4.86/7.6	64%	2
	β_3=2.57/3.9	66%	3

6.2.6 Load combination direct loads (screw)

Tension: Steel failure local flexure channel lip	27%	
Shear: Steel failure local channel lip	26%	
Interaction steel	$\beta_N^2 + \beta_V^2 \le 1.0$	$0.27^2 + 0.26^2 = 0.14 \le 1$

6.2.7 Load combination anchor loads

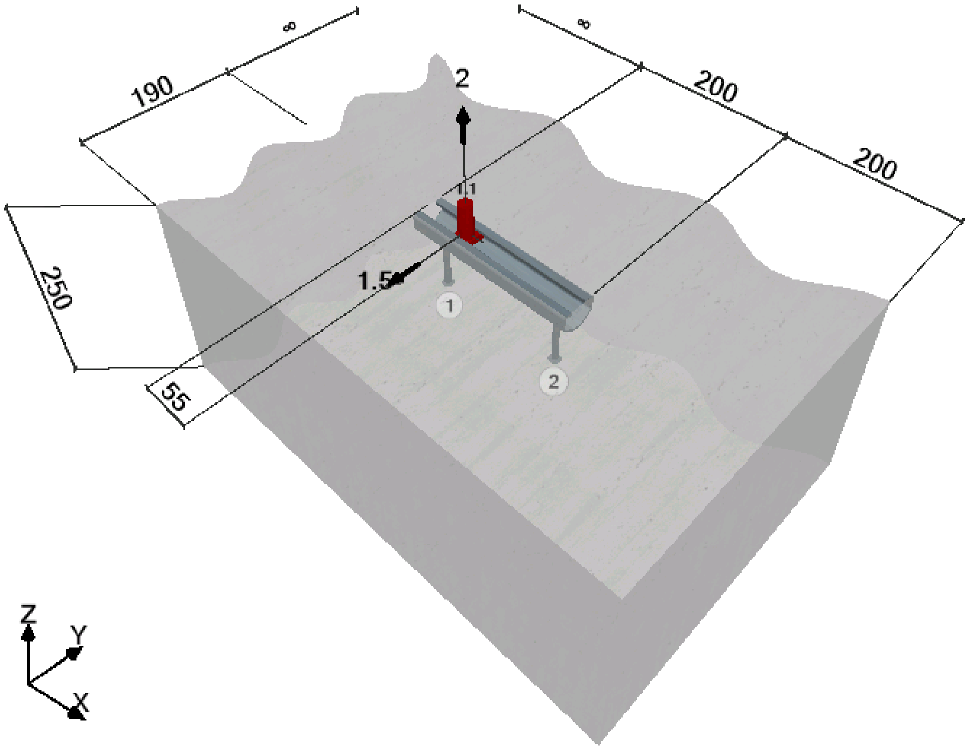
Anchor 1:		
Tension: Concrete Cone	29%	
Shear: Concrete failure concrete edge	56%	
Interaction concrete	$\beta_N^{1.5} + \beta_V^{1.5} \le 1.0$	$0.29^{1.5} + 0.56^{1.5} = 0.58 \le 1$
Anchor 2:		
Tension: Concrete Cone	35%	
Shear: Concrete failure concrete edge	64%	
Interaction concrete	$\beta_N^{1.5} + \beta_V^{1.5} \le 1.0$	$0.35^{1.5} + 0.64^{1.5} = 0.72 \le 1$
Anchor 3:		
Tension: Concrete Cone	31%	
Shear: Concrete failure concrete edge	66%	
Interaction concrete	$\beta_N^{1.5} + \beta_V^{1.5} \le 1.0$	$0.31^{1.5} + 0.66^{1.5} = 0.71 \le 1$

6.3 Example 3: Anchor channel subjected to a fire load (2-legged anchor channel)

6.3.1 Anchoring conditions

System, basic values

Anchor channel	HAC-40F, 200 mm (2 anchors)
Hilti special screw	HBC-C 8.8F M16 x 50
Concrete	Cracked concrete, C20/25
Stand-off	no
Design tensile load	2.0 kN
Design shear load	1.5 kN
Fire exposure	F30, from one side
Member thickness h	250 mm
Reinforcement conditions (tension)	ø≥12mm with a spacing of s≥150mm
Reinforcement conditions (shear)	With edge reinforcement $d_s \geq$ 12 mm
Reinforcement conditions (splitting)	Reinforcement for w≤0.3mm present
Effective embedment depth of anchor h_{ef}	91 mm
Width of channel b_{ch}	40.9 mm
Height of channel h_{ch}	28.0 mm
Moment of inertia channel I_y	21452 mm^4
Anchor spacing s	150 mm



Steel failure TENSION, characteristic values and safety factors, fire

Steel failure, anchor	$N_{Rk,s,a,fi,R30}$	2.8 kN
Steel failure, connection channel anchor	$N_{Rk,s,c,fi\ ,R30}$	2.8 kN
Steel failure, local flexure of channel lips for $s_s \geq s_{slb}$	$N_{Rk,s,l,fi,R30}$	2.8 kN
Characteristic flexure resistance of channel	$M_{Rk,s,flex,fi,R30}$	0.184 kNm
Steel failure Hilti-special screw	$N_{Rk,s,s,fi,R30}$	5.7 kN
Partial safety factor, Hilti-special screw	$\gamma_{Ms,fi}$	1.00
Partial safety factor, anchor	$\gamma_{Ms,fi}$	1.00
Partial safety factor, connection channel anchor	$\gamma_{Ms,fi}$	1.00
Partial safety factor, local flexure of channel lips	$\gamma_{Ms,fi}$	1.00
Partial safety factor, flexure resistance of channel	$\gamma_{Ms,flex,fi}$	1.00

Steel failure SHEAR, characteristic values and safety factors, fire

Steel failure, local flexure of channel lip	$V_{Rk,s,l,fi,R30}$	2.8 kN
Steel failure Hilti special screw	$V_{Rk,s,fi}$	5.7 kN
Partial safety factor local flexure of channel lip	$\gamma_{Ms,l,fi}$	1.0
Partial safety factor Hilti special screw (shear)	$\gamma_{Ms,s,fi}$	1.0

Concrete failure TENSION, characteristic values and safety factors

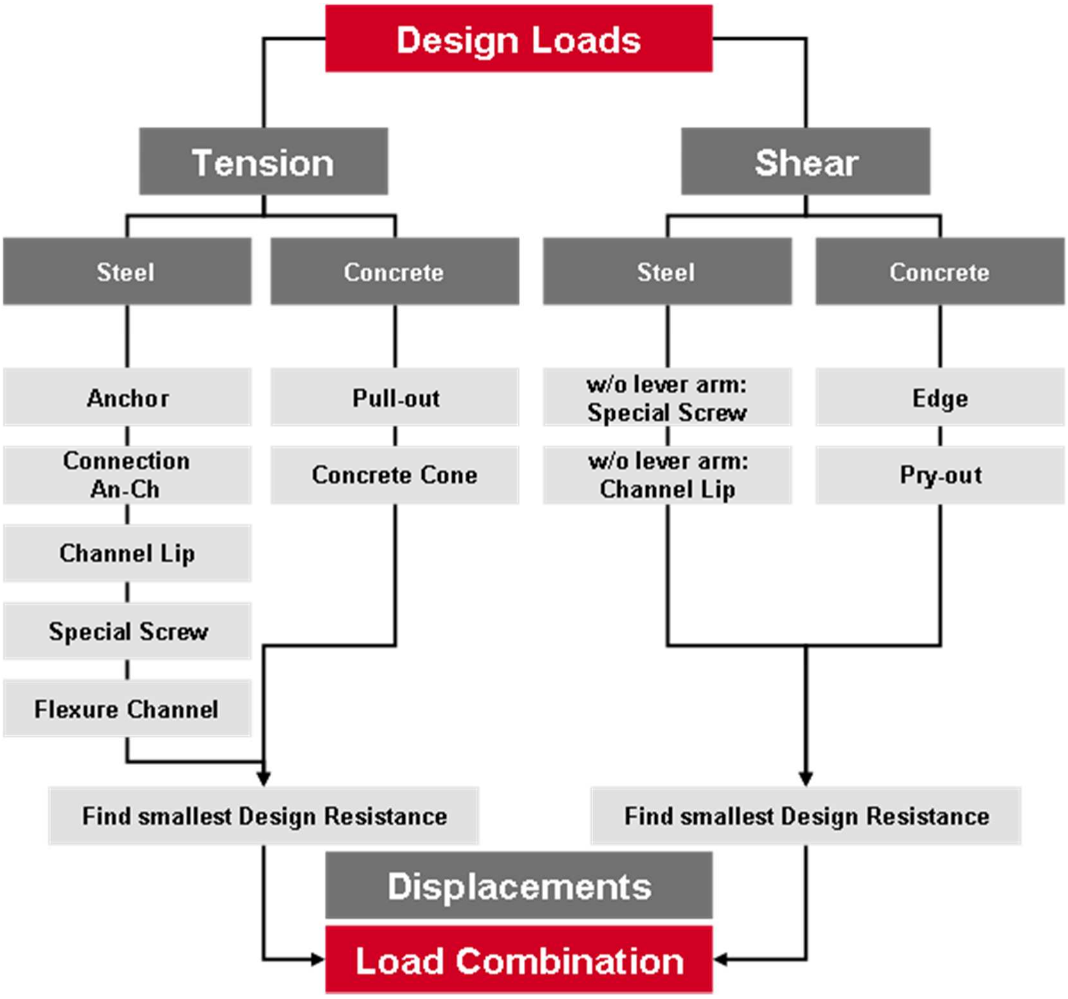
Pull-out failure resistance in cracked concrete C12/15	$N_{Rk,p}$, C12/15	10.3 kN
Effective anchorage depth	h_{ef}	91 mm
Characteristic edge distance	$c_{cr,N,fi}$	260 mm
Characteristic spacing	$s_{cr,N,fi}$	520 mm
Amplification factor of $N_{Rk,p}$ for C30/37	ψ_c	2.47
Factor for anchor channel influencing concrete cone	α_{ch}	0.903
Partial safety factor concrete	$\gamma_{Mc,fi}$	1.0
Partial safety factor for pull-out	$\gamma_{Mc,p,fi}$	1.0

Concrete failure SHEAR, characteristic values and safety factors

Factor k in equation (31) of CEN/TS 1992-4-3	k_5	2.0
Product of factor αp and $\psi_{re,V}$	$\alpha_p\ \psi_{re,V}$	4.8
Effect of thickness of structural component = $(h/h_{cr,V,fi})^{1/2}$	$\alpha_{h,V,fi}$	0.757
Characteristic height = $2(c_1 + h_{ch})$	$h_{cr,V,fi}$	436 mm
Characteristic edge distance = $2c_1 + b_{ch}$	$c_{cr,V,fi}$	421 mm
Characteristic spacing = $4c_1 + 2b_{ch}$	$s_{cr,V,fi}$	842 mm
Partial safety factor concrete	$\gamma_{Mc,fi}$	1.0

General remarks

According to CEN TS 1992-4-3:2009; ETA-11/0006 and TR020 following verifications need to be done:



The verifications for fire loading are calculated with the direct acting load and with the distributed anchor load, respectively, same procedure as shown in example 1 for tensile and shear loading.

For this reason, the distributed loads acting on the anchor have to be calculated first. Please note that these loads heavily depend on the load position of the acting external load. In other words, the verification is only valid for the given load position of the screw.

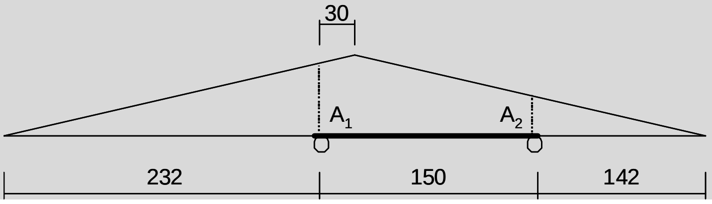
A reduction of the fire resistance class of the concrete member due to the anchor channel is not evaluated in the approval.

6.3.2 Determination of acting forces

Direct forces acting on screw

Design tensile load	$N_{Ed} = \gamma \cdot F_{z,G}$	$N_{Ed} = 2.0$ kN
Design shear load	$V_{Ed} = \gamma \cdot F_{y,Q}$	$V_{Ed} = 1.5$ kN
Influence length	$l_i = 13 \cdot l_y^{0.05} \cdot s^{0.5} \ge s$	$l_i = 13 \cdot 21452^{0.05} \cdot \sqrt{150} = 262mm \ge s$

Forces acting on anchors

Load distribution scheme based on influence length l_i		
Calculate A_i on basis of theorem of intersecting lines		$A_1 = \frac{262-30}{262} = 0.885$ $A_2 = \frac{262-150+30}{262} = 0.542$
Weighting factor	$k = \frac{1}{\sum_1^n A'_i}$	$k = \frac{1}{0.885+0.542} = 0.70$
Tensile force anchor 1	$N^a_{Ed,1} = k \cdot A'_1 \cdot N_{Ed}$	$N^a_{Ed,1} = 0.7 \cdot 0.885 \cdot 2.0kN = 1.239$ kN
Tensile force anchor 2	$N^a_{Ed,2} = k \cdot A'_2 \cdot N_{Ed}$	$N^a_{Ed,2} = 0.7 \cdot 0.542 \cdot 2.0kN = 0.759$ kN
Shear force anchor 1	$V^a_{Ed,1} = k \cdot A'_1 \cdot V_{Ed}$	$V^a_{Ed,1} = 0.7 \cdot 0.885 \cdot 1.5kN = 0.929$ kN
Shear force anchor 2	$V^a_{Ed,2} = k \cdot A'_2 \cdot V_{Ed}$	$V^a_{Ed,2} = 0.7 \cdot 0.542 \cdot 1.5kN = 0.569$ kN

6.3.3 Tensile loading

Design steel resistance anchor

	$N_{Rd,s,a,fi} = \frac{N_{Rk,s,a,fi}}{\gamma_{Ms,a,fi}}$	$N_{Rd,s,a,fi} = \frac{2.8kN}{1.0} = 2.8kN$

Design steel resistance connection anchor - channel

	$N_{Rd,s,c,fi} = \frac{N_{Rk,s,c,fi}}{\gamma_{Ms,c,fi}}$	$N_{Rd,s,c,fi} = \frac{2.8kN}{1.0} = 2.8kN$

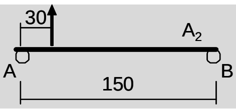
Design steel resistance local flexure of channel lip

	$N_{Rd,s,l,fi} = \frac{N_{Rk,s,l,fi}}{\gamma_{Ms,l,fi}}$	$N_{Rd,s,l,fi} = \frac{2.8kN}{1.0} = 2.8kN$

Design steel resistance special screw

	$N_{Rd,s,s,fi} = \frac{N_{Rk,s,s,fi}}{\gamma_{Ms,s,fi}}$	$N_{Rd,s,s,fi} = \frac{5.7kN}{1.0} = 5.7kN$

Design steel resistance flexure of channel

Determination of acting moment based on single supported beam		$A = \frac{120}{150} \cdot 2.0\text{kN} = 1.6\text{kN}$
	$M_{Rd,s,flex,fi} = \frac{M_{Rk,s,flex,fi}}{\gamma_{Ms,flex,fi}}$	$M_{Rd,s,flex,fi} = \frac{184\ \text{Nm}}{1.0} = 0.184\ \text{kNm}$

Design concrete pull-out resistance fire

Cracked concrete pull-out resistance	$N_{Rk,p} = N_{Rk,p} \cdot \psi_c \cdot \psi_{ucr}$	$N_{Rk,p} = 10.3 \cdot 1.67 \cdot 1.0 = 17.2\text{kN}$
Pull-out resistance fire	$N_{Rd,p,fi} = 0.25 \cdot \frac{N_{Rk,p}}{\gamma_{Mc,p,fi}}$	$N_{Rd,p,fi} = 0.25 \cdot \frac{17.2}{1.0} = 4.3\text{kN}$

Design concrete cone resistance fire

Basic resistance	$N^0_{Rk,c} = 8.5 \cdot \alpha_{ch} \cdot \sqrt{f_{ck,cube}} \cdot h_{ef}^{1.5}$	$N^0_{Rk,c} = 8.5 \cdot 0.903 \cdot \sqrt{25} \cdot 91^{1.5} = 33.31\text{kN}$
Basic Fire resistance	$N^0_{Rk,c,fi} = \frac{h_{ef}}{200} \cdot N^0_{Rk,c}$	$N^0_{Rk,c,fi} = \frac{91}{200} \cdot 33.31 = 15.15\text{kN}$
Effect of neighboring anchors, anchor 1	$\alpha_{s,N,fi} = \frac{1}{1 + \sum_{i=1}^{n} \left[\left(1 - \frac{s_i}{s_{cr,N,fi}}\right)^{1.5} \cdot \frac{N_i}{N_0} \right]}$	$\alpha^1_{s,N,fi} = \frac{1}{1 + \sum_{i=1}^{n} \left[\left(1 - \frac{150}{520}\right)^{1.5} \cdot \frac{0.76}{1.24} \right]} = 0.731$
Effect of neighboring anchors, anchor 2		$\alpha^2_{s,N,fi} = \frac{1}{1 + \sum_{i=1}^{n} \left[\left(1 - \frac{150}{520}\right)^{1.5} \cdot \frac{1.24}{0.76} \right]} = 0.463$
Effect of edges	$\alpha_{e,N,fi} = \left(\frac{c_1}{c_{cr,N,fi}}\right)^{0.5} \leq 1.0$	$\alpha_{e,N,fi} = \left(\frac{190}{260}\right)^{0.5} \leq 0.855$
Effect of corner 1	$\alpha_{c,N,fi} = \left(\frac{c_2}{c_{cr,N,fi}}\right)^{0.5} \leq 1.0$	$\alpha^1_{c,N,fi} = \left(\frac{\infty}{260}\right)^{0.5} = \infty > 1.0$
Effect of corner 2		$\alpha^2_{c,N,fi} = \left(\frac{375}{260}\right)^{0.5} = 1.20 > 1.0$
Effect of shell spalling		$\Psi_{re,N} = 1.0$ may be taken if local to this anchor channel reinforcement (any diameter) is provided at a spacing ≥ 150 mm
Effect of concrete conditions		$\Psi_{ucr,N} = 1.0$
Characteristic Fire resistance	$N_{Rk,c,fi} = N^0_{Rk,c,fi} \cdot \alpha_{s,N,fi} \cdot \alpha_{e,N,fi} \cdot \alpha_{c,N,fi} \cdot \Psi_{re,N} \cdot \Psi_{ucr,N}$ Anchor 1: $N^1_{Rk,c,fi} = 15.15 \cdot 0.731 \cdot 0.855 \cdot 1.0 \cdot 1.0 \cdot 1.0 = 9.47\text{kN}$ Anchor 2: $N^2_{Rk,c} = 15.15 \cdot 0.463 \cdot 0.855 \cdot 1.0 \cdot 1.0 \cdot 1.0 = 5.99\text{kN}$	
Design resistance	Anchor 1: $N_{Rd,c,fi} = \frac{N_{Rk,c,fi}}{\gamma_{Mc,fi}} = 9.47\text{kN}$ Anchor 2: $N_{Rd,c,fi} = \frac{N_{Rk,c,fi}}{\gamma_{Mc,fi}} = 5.99\text{kN}$	

Design concrete splitting resistance

	Verification not necessary since the characteristic resistance for concrete cone failure, concrete blow-out 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.

Design concrete blow-out resistance

	Verification not necessary since $c \geq 0.5 \cdot h_{ef}$ $c_1 = 190mm > 0.5 \cdot 91mm = 45.5mm$

6.3.4 SHEAR loading

Design steel resistance special screw without lever arm

	$V_{Rd,s,fi} = \frac{V_{Rk,s,fi}}{\gamma_{Ms,fi}}$	$V_{Rd,s,fi} = \frac{5.7kN}{1.0} = 5.7kN$

Design steel resistance local flexure channel lip

	$V_{Rd,s,l,fi} = \frac{V_{Rk,s,l,fi}}{\gamma_{Ms,fi}}$	$V_{Rd,s,l,fi} = \frac{2.8kN}{1.0} = 2.8kN$

Design concrete pry-out resistance

Anchor 1	$V^1_{Rd,cp,fi} = \frac{k_5 \cdot N^1_{Rk,c,fi}}{\gamma_{Mc,fi}}$	$V^1_{Rd,cp,fi} = \frac{2 \cdot 9.47kN}{1.0} = 18.94kN$
Anchor 2	$V^2_{Rd,cp,fi} = \frac{k_5 \cdot N^2_{Rk,c,fi}}{\gamma_{Mc,fi}}$	$V^2_{Rd,cp,fi} = \frac{2 \cdot 5.99kN}{1.0} = 11.98kN$

Design concrete edge resistance

Basic resistance including reinforcement condition	$V^0_{Rk,c} = \alpha_p \cdot \psi_{re,V} \cdot \sqrt{f_{ck,cube}} \cdot c_1^{1.5}$	$V^0_{Rk,c} = 4.8 \cdot \sqrt{25} \cdot 190^{1.5} = 62.86kN$
Basic resistance including reinforcement condition, fire	$V^0_{Rk,c,fi} = 0.25 \cdot V^0_{Rk,c}$	$V^0_{Rk,c,fi} = 0.25 \cdot 62.86kN = 15.72kN$
Effect of neighboring anchors, anchor 1	$\alpha_{s,V,fi} = \frac{1}{1 + \sum_{i=1}^{n} \left[\left(1 - \frac{s_i}{s_{cr,V,fi}}\right)^{1.5} \cdot \frac{V_i}{V_0} \right]}$	$\alpha^1_{s,V,fi} = \frac{1}{1 + \sum_{i=1}^{n} \left[\left(1 - \frac{150}{842}\right)^{1.5} \cdot \frac{0.57}{0.93} \right]} = 0.686$
Effect of neighboring anchors, anchor 2		$\alpha^2_{s,V,fi} = \frac{1}{1 + \sum_{i=1}^{n} \left[\left(1 - \frac{150}{842}\right)^{1.5} \cdot \frac{0.93}{0.57} \right]} = 0.451$
Effect of corner 1	$\alpha_{c,V,fi} = \left(\frac{c_2}{c_{cr,V,fi}}\right)^{0.5} \leq 1.0$	$\alpha^1_{c,V,fi} = \left(\frac{\infty}{421}\right)^{0.5} = \infty > 1.0$
Effect of corner 2		$\alpha^2_{c,V,fi} = \left(\frac{225}{421}\right)^{0.5} = 0.731$
Effect of thickness of structural component	$\alpha_{h,V,fi} = \left(\frac{c_2}{h_{cr,V,fi}}\right)^{0.5} \leq 1.0$	$\alpha_{h,V,fi} = \left(\frac{250}{436}\right)^{0.5} = 0.757$
Effect of load parallel to edge		$\alpha_{90°,V} = 1.0$
Characteristic resistance	$V_{Rk,c,fi} = V^0_{Rk,c,fi} \cdot \alpha_{s,V,fi} \cdot \alpha_{c,V,fi} \cdot \alpha_{h,V,fi} \cdot \alpha_{90°,V,fi}$ Anchor 1: $V^1_{Rk,c,fi} = 15.72 \cdot 0.686 \cdot 1.0 \cdot 0.757 \cdot 1.0 = 8.16kN$ Anchor 2: $V^2_{Rk,c,fi} = 15.72 \cdot 0.451 \cdot 0.731 \cdot 0.757 \cdot 1.0 = 3.92kN$	
Design fire resistance	Anchor 1: $V_{Rd,c,fi} = \frac{V_{Rk,c,fi}}{\gamma_{Mc,fi}} = 8.16kN$ Anchor 2: $V_{Rd,c,fi} = \frac{V_{Rk,c,fi}}{\gamma_{Mc,fi}} = 3.92N$	

6.3.5 Combined tension and shear loading

TENSION: Determination of utilization rates direct load (screw loads)

Failure mode	Utilization factor $\beta = \frac{N_{Ed}}{N_{Rd}}$	Utilization factor	Decisive mode
Steel failure local flexure channel lip	$\beta=2.00/2.8$	72%	✓
Flexure of channel	$\beta=0.048/0.175$	28%	
Special screw	$\beta=2.00/5.715$	35%	

TENSION: Determination of utilization rates anchor loads

Failure mode	Utilization factor $\beta_i = \frac{N^a_{Ed,i}}{N_{Rd}}$	Utilization factor	Anchor
Steel failure of anchor	$\beta_1=1.24/2.8$	45%	1
	$\beta_2=0.76/2.8$	27%	2
Steel failure connection channel – anchor	$\beta_1=1.24/2.8$	45%	1
	$\beta_2=0.76/2.8$	27%	2
Pull-out	$\beta_1=1.24/4.3$	29%	1
	$\beta_2=0.76/4.3$	20%	2
Concrete cone failure	$\beta_1=1.24/9.47$	13%	1
	$\beta_2=0.76/5.99$	13%	2
Splitting failure	N/A		
Blow out	N/A		

SHEAR: Determination of utilization rates direct load (screw loads)

Failure mode	Utilization factor $\beta = \frac{V_{Ed}}{V_{Rd}}$	Utilization factor	Decisive mode
Steel failure special screw	$\beta=1.5/5.7$	26%	
Steel failure local channel lip	$\beta=1.5/2.8$	54%	✓

SHEAR: Determination of utilization rates anchor loads

Failure mode	Utilization factor $\beta_i = \frac{V^a_{Ed,i}}{V_{Rd}}$	Utilization factor	Anchor
Pry-out	$\beta_1=0.93/18.9$	5%	1
	$\beta_2=0.57/11.98$	5%	2
concrete edge	$\beta_1=0.93/8.16$	11%	1
	$\beta_2=0.57/3.92$	15%	2

6.3.6 Load combination direct loads (screw)

Tension: Steel failure local flexure channel lip	72%	
Shear: Steel failure local channel lip	54%	
Interaction steel	$\beta_N^2 + \beta_V^2 \leq 1.0$	$0.72^2 + 0.54^2 = 0.81 \leq 1.0$

6.3.7 Load combination anchor loads

Anchor 1:		
Tension: Steel failure of anchor	45%	
Shear: Concrete failure concrete edge	11%	
Interaction concrete	$\beta_N^{1.5} + \beta_V^{1.5} \leq 1.0$	$0.45^{1.5} + 0.11^{1.5} = 0.33 \leq 1.0$
Anchor 2:		
Tension: Steel failure of anchor	27%	
Shear: Concrete failure concrete edge	15%	
Interaction concrete	$\beta_N^{1.5} + \beta_V^{1.5} \leq 1.0$	$0.27^{1.5} + 0.15^{1.5} = 0.20 \leq 1.0$