HILTI ANCHOR CHANNEL SYSTEMS (HAC AND HAC-T)

Canadian Design Guide
19th Edition

CANADIAN DESIGN GUIDE

1.0 Introduction

This section is a supplement to the Hilti North American Product Technical Guide for Hilti anchor channel systems HAC and HAC-T. Hilti anchor channels HAC with Hilti channel bolts HBC-B, HBC-C and HBC-C-N and Hilti anchor channels HAC-T with Hilti channel bolts HBC-T are qualified in accordance with ICC-ES Acceptance Criteria (AC232) for use in cracked and uncracked concrete in ICC-ES Evaluation Service Report ESR-3520. Based on these recognitions, Hilti anchor channel systems are alternatives to cast-in-place anchors and may be used where an engineered design is permitted in accordance with AC232, ACI 318, and ESR-3520.

Since no similar design provision exists in Canada, the following document provides an alternative design method based on Ultimate Limit State Design, described in the provisions of CSA A23.3-14 Annex D. Factored tension and shear loads on the anchor channel systems are defined using the method provided in AC232 and described in section 2.0 of this document. The design resistances of the anchor channel systems are developed based on design criteria of AC232 and CSA A23.3-14. Geometric and design parameters given in tables 1 through 13 are derived from information in ESR-3520.

Note that all figures are adopted (reprinted) from ICC-ES Evaluation Service Report ESR-3520 with permission, and are applicable to Limit State Design criteria. For a detailed explanation of the design method, technical assistance is available by contacting Hilti at 1-800-363-4458 or at www.hilti.ca.

2.0 Factored loads on anchor channel systems

Hilti anchor channels and channel bolts are used to resist static, seismic, and wind loads in tension and shear. Figure 1 demonstrates the load directions including tension load (N_{fa}), shear load perpendicular to the longitudinal channel axis ($V_{fa,y}$), and shear load acting in the direction of the longitudinal channel axis ($V_{fa,x}$) acting on the anchor channels. Refer to the notations in section 4.0 and figures 19 through 22 of this document for definitions and details of the variables noted below.

2.1 Factored tension load (N_{fa})

The tension loads, $N^{a}_{fa,i}$, on an anchor due to a tension load, N_{fa}, acting on the channel shall be computed in accordance with Eq. (1). An example for the calculation of the tension loads acting on the anchors is given in Figure 2.

$$N^{a}_{fa,i} = k \cdot A'_i \cdot N_{fa} \qquad (1)$$

where:

A'_i = ordinate at the position of the anchor i assuming a triangle with the unit height at the position of load N_{fa} and the base length $2\ell_{in}$.

$$k = 1 / \sum A'_i \qquad (2)$$

$$\ell_{in} = 13\,(I_y)^{0.05}\sqrt{s} \geq s\text{, mm} \qquad (3)$$

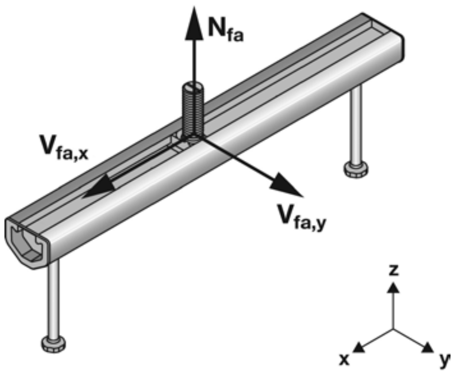
s = anchor spacing, mm

N_{fa} = factored tension load on channel bolt, N

I_y = the moment of inertia of the channel (provided in Table 1 of this document)

If several tension loads are simultaneously acting on the channel, a linear superimposition of the anchor forces for all loads shall be assumed. If the exact position of the load on the channel is not known, the most unfavorable loading position shall be assumed for each failure mode (e.g. load acting over an anchor for the case of failure of an anchor by steel rupture or pull-out and load acting between anchors in the case of bending failure of the channel).

The bending moment, $M_{f,flex}$, on the channel due to tension loads acting on the channel shall be computed assuming a simply supported single span beam with a span length equal to the anchor spacing, s.



Tension load N_{fa}:	z-direction (in direction of anchor)
Shear load $V_{fa,y}$:	y-direction (perpendicular to longitudinal axis of channel)
Longitudinal load $V_{fa,x}$:	x-direction (in direction of longitudinal axis of channel)

Figure 1: Load directions covered by this document

2.2 Factored shear load perpendicular to channel longitudinal axis ($V_{fa,y}$)

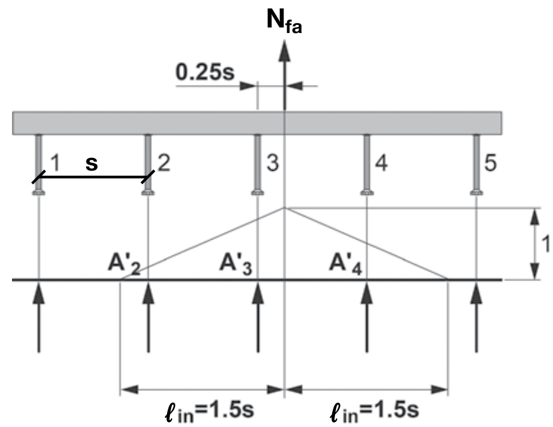
The shear load, $V^a_{fa,y,i}$, on an anchor due to a shear load $V_{fa,y}$ acting on the channel perpendicular to its longitudinal axis shall be computed in accordance with Section 2.1 replacing N_{fa} in Eq. (1) by $V_{fa,y}$.

2.3 Factored shear load in the direction of channel longitudinal axis ($V_{fa,x}$)

The shear load, $V^a_{fa,x,i}$, on an anchor due to a shear load, $V_{fa,x}$, acting on the channel in direction of the longitudinal channel axis shall be computed as follows:

For the verification of the resistance of the anchor channel for failure of the anchor or failure of the connection between anchor and channel, pryout failure, and concrete edge failure in case of anchor channels arranged parallel to the edge without corner effects, the shear load, $V_{fa,x}$, shall be equally distributed to all anchors for anchor channels with not more than three anchors or to three anchors for anchor channels with more than three anchors (see Figure 3). The shear load, $V_{fa,x}$, shall be distributed to those three anchors that result in the most unfavorable design condition (in the example given in Figure 3 the shear load, $V_{fa,x}$, shall be distributed to the anchors 10 to 12).

For the verification of the resistance of the anchor channel for concrete edge failure in case of anchor channels arranged perpendicular to the edge and in case of anchor channels arranged parallel to the edge with corner effects, the shear load, $V_{fa,x}$, shall be equally distributed to all anchors for anchor channels with not more than three anchors or to the three anchors closest to the edge or corner for anchor channels with more than three anchors (see Figure 4).



$$A'_2 = \frac{0.25s}{\ell_{in}} = \frac{1}{6} \qquad N_{fa,1} = N_{fa,5} = 0$$

$$A'_3 = \frac{1.25s}{\ell_{in}} = \frac{5}{6} \qquad N^a_{fa,2} = \frac{1}{6} \cdot \frac{2}{3} \cdot N_{fa} = \frac{1}{9} N_{fa}$$

$$A'_4 = \frac{0.75s}{\ell_{in}} = \frac{1}{2} \qquad N^a_{fa,3} = \frac{5}{6} \cdot \frac{2}{3} \cdot N_{fa} = \frac{5}{9} N_{fa}$$

$$k = \frac{1}{A'_2 + A'_3 + A'_4} = \frac{2}{3} \qquad N^a_{fa,4} = \frac{1}{2} \cdot \frac{2}{3} \cdot N_{fa} = \frac{1}{3} N_{fa}$$

Figure 2: Example for the calculation of anchor forces in accordance with the triangular load distribution method for an anchor channel with five anchors. The influence length is assumed as ℓ_{in} = 1.5s

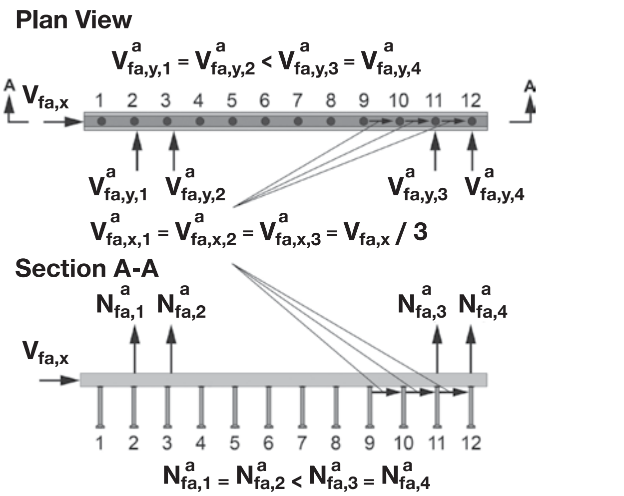
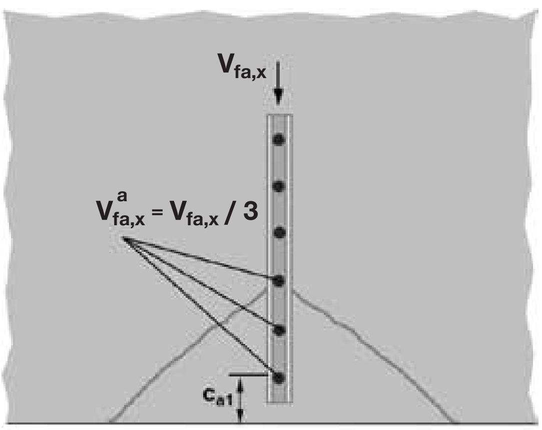
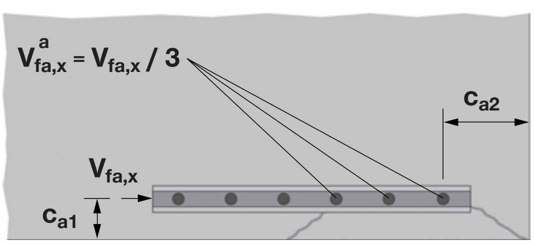


Figure 3: Example for the calculation of anchor forces in case of anchor channels with 12 anchors loaded in shear longitudinal to the channel axis for steel and pryout failure



a) anchor channel installed perpendicular to the edge



b) anchor channel installed parallel to the edge

Figure 4: Example for the calculation of anchor channels with 6 anchors loaded in shear longitudinal to the channel axis for concrete edge failure

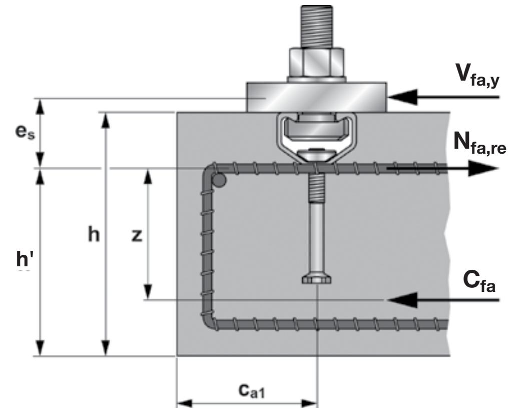


Figure 5: Anchor reinforcement to resist shear loads

2.4 Factored forces related to anchor reinforcement ($N_{fa,re}$)

If tension loads are acting on the anchor channel, the factored tension forces of the anchor reinforcement for one anchor shall be computed for the factored tension load, $N^0_{fa,i}$, of the anchor assuming a strut-and-tie model.

If a shear load, $V_{fa,y}$, is acting on the anchor channel, the resultant factored tension force of the anchor reinforcement $N_{fa,re}$, shall be computed by Eq. (4).

$$N_{fa,re} = V_{fa,y} \left(\frac{e_s}{z} + 1\right), \text{N} \quad (4)$$

where, as illustrated in Figure 5:

e_s = distance between reinforcement and shear force acting on the anchor channel, mm

z = $0.85 \cdot (h - h_{ch} - 0.5d_a) \leq \min(2h_{ef}; 2c_{a1})$

3.0 Resistance of anchor channel systems

The design resistance of anchor channel systems is determined in accordance with CSA A23.3-14 Annex D and this document for the following:

a) Factored steel resistance in tension (Sec. 3.1)

b) Factored concrete breakout resistance in tension (Sec. 3.2)

c) Factored pullout resistance in tension (Sec. 3.3)

d) Factored concrete side-face blowout resistance of anchor channels in tension (Sec. 3.4)

e) Factored steel resistance of anchor channels in shear perpendicular to its longitudinal axis (Sec. 3.5)

f) Factored concrete breakout resistance of an anchor channel in shear perpendicular to its longitudinal axis (Sec. 3.6)

g) Factored concrete pryout resistance of anchor channels in shear perpendicular to the channel axis (Sec. 3.7)

h) Factored steel resistance of anchor channels in shear in the direction of the longitudinal channel axis (Sec. 3.8)

i) Factored concrete breakout resistance of anchor channels in shear in the direction of the longitudinal channel axis (Sec. 3.9)

j) Factored concrete pryout resistance for anchor channels in shear in the direction of the longitudinal channel axis (Sec. 3.10)

Design parameters are provided in Table 1 through Table 12 of this document. Material resistance factors, ϕ_c and ϕ_s, and resistance modification factor, R, as given in CSA A23.3-14 sections 8.4.2, 8.4.3, and D.5.3 and in the tables of this document, as applicable, must be used for load combinations calculated in accordance with Annex C of CSA A23.3-14.

Overall the controlling resistance of the anchor channel N_r and V_r are the lowest design factored resistances determined from all applicable failure modes. N_r is the lowest design factored resistance in tension of an anchor channel system determined from consideration of N_{sar}, N_{scr}, N_{slr}, N_{ssr}, $M_{s,flexr}$, N_{cbr}, (anchor channels without anchor reinforcement to take up tension loads) or N_{car} (anchor channels with anchor reinforcement to take up tension loads), N_{pnr}, and N_{sbr}. $V_{r,y}$ is the lowest design factored resistance in shear perpendicular to the axis of an anchor channel as determined from $V_{sar,y}$, $V_{scr,y}$, V_{ssr}, $V_{ssr,M}$, $V_{slr,y}$, $V_{cbr,y}$ (anchor channel without anchor reinforcement to take up shear loads perpendicular to the channel axis), or $V_{car,y}$ (anchor channel with anchor reinforcement to take up shear loads perpendicular to the channel axis) and $V_{cpr,y}$. $V_{r,x}$ is the lowest design factored resistance in shear acting longitudinal to the channel axis of an anchor channel as determined from $V_{sar,x}$, $V_{scr,x}$, V_{ssr}, $V_{ssr,M}$, $V_{slr,x}$, $V_{cbr,x}$ (anchor channel with or without anchor reinforcement to take up shear loads in the direction of the longitudinal channel axis) and $V_{cpr,x}$. The design factored resistances for all anchors of an anchor channel shall be determined.

For anchor channels in seismic area the design resistances shall be taken as the corresponding seismic design resistances $N_{r,seis}$, $V_{r,x,seis}$ and $V_{r,y,seis}$.

Anchor channels shall satisfy the requirements for edge distance, spacing, and member thickness provided in Table 1 of this document. The critical edge distance, c_{ac}, shall be taken from Table 4 of this document.

For the use of anchor channel systems in lightweight concrete, the modification factor λ shall be taken as 0.75 for all-lightweight concrete and 0.85 for sand-lightweight concrete in accordance with CSA A23.3-14. Linear interpolation shall be permitted if partial sand replacement is used.

3.1 Factored steel resistance in tension

N_{sar} (factored tensile steel resistance of a single anchor), N_{scr} (factored tensile steel resistance of the connection between channel and anchor), and $M_{s,flexr}$ (factored flexural resistance of the anchor channel) are provided in Table 3 of this document.

N_{slr} (factored tensile steel resistance of the local bending of the channel lips) must be taken from Table 3 of this document. This value is valid only if the center to center distance between two channel bolts, s_{chb}, is at least $2b_{ch}$ (see Figure 21 and Figure 22). If this requirement is not met then the value N_{slr} given in Table 3 must be reduced by the factor

$$\frac{1}{1+\sum_{i=2}^{n+1}\left[\left(1-\frac{s_{chb,i}}{2b_{ch}}\right)^2\cdot\frac{N^b_{ua,i}}{N^b_{ua,1}}\right]} \qquad (5)$$

where the center-to-center spacing between channel bolts shall not be less than 3-times the bolt diameter d_s. N_{ssr} (factored tensile resistance of a channel bolt) must be taken from Table 11 of this document.

3.2 Factored concrete breakout resistance in tension

N_{cbr} (factored concrete breakout resistance of a single anchor of anchor channel in tension) shall be determined in accordance with Eq. (6).

$$N_{cbr} = N_{br}\cdot\psi_{s,N}\cdot\psi_{ed,N}\cdot\psi_{co,N}\cdot\psi_{c,N}\cdot\psi_{cp,N}, \text{ N} \qquad (6)$$

The basic concrete breakout resistance of a single anchor in tension in cracked concrete, N_{br}, shall be determined in accordance with Eq. (7).

$$N_{br} = 10\cdot\phi_c\cdot\alpha_{ch.N}\cdot\lambda\cdot\sqrt{f'_c}\cdot h_{ef}^{1.5}\cdot R, \text{ N} \qquad (7)$$

where:

$$\alpha_{ch.N} = \left(\frac{h_{ef}}{180}\right)^{0.15} \leq 1 \qquad (8)$$

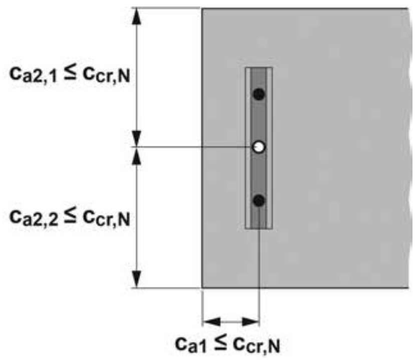
Where anchor channels with h_{ef} > 180 mm are located in an application with three or more edges (see Figure 6) with edge distances less than $c_{cr,N}$ ($c_{cr,N}$ in accordance with Eq. (14)) from the anchor under consideration, the values of h_{ef} used in Eq. (7), (8), and (11) may be reduced to $h_{ef,red}$ in accordance with Eq. (9).

$$h_{ef,red} = \max\left(\frac{c_{a,max}}{c_{cr,N}}\cdot h_{ef};\ \frac{s}{s_{cr,N}}\cdot h_{ef}\right), \text{ mm} \qquad (9)$$

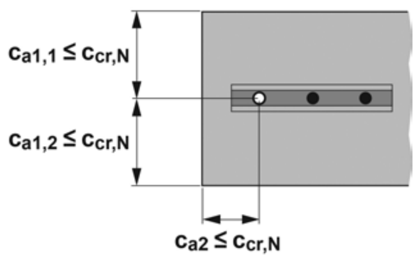
where:

$c_{a,max}$ = maximum value of edge or corner distance, mm

The values $c_{cr,N}$ and $s_{cr,N}$ in Eq. (9) shall be computed with h_{ef}.



a) anchor channel with influence of one edge and two corners



b) anchor channel with influence of two edges and one corner

o anchor under consideration

● adjacent anchor

Figure 6: Examples of anchor channel locations where a reduced value of the embedment depth, $h_{ef,red}$, may be used

The modification factor to account for the influence of location and loading of adjacent anchors, $\psi_{s,N}$, shall be computed in accordance with Eq. (10).

$$\psi_{s,N} = \frac{1}{1 + \sum_{i=2}^{n+1} \left[\left(1 - \frac{s_i}{s_{cr,N}}\right)^{1.5} \cdot \frac{N^a_{fa,i}}{N^a_{fa,1}} \right]} \qquad (10)$$

where, as illustrated in Figure 7:

s_i = distance between the anchor under consideration and adjacent anchor, mm

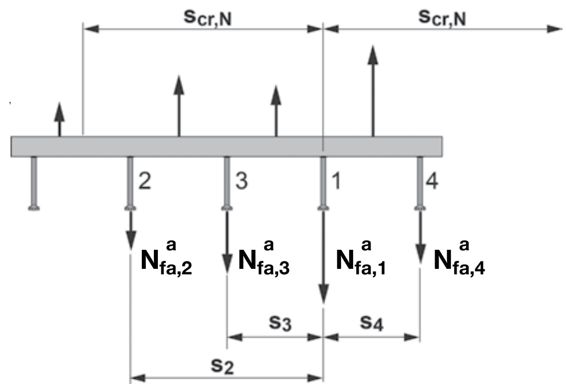
$\leq s_{cr,N}$

$$s_{cr,N} = 2\left(2.8 - \frac{1.3h_{ef}}{180}\right) h_{ef} \geq 3h_{ef}, \text{ mm} \qquad (11)$$

$N^a_{fa,i}$ = factored tension load of an influencing anchor, N

$N^a_{fa,1}$ = factored tension load of the anchor under consideration, N

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



1 = anchor under consideration

2 to 4 = influencing anchors

Figure 7: Example of an anchor channel with non-uniform anchor tension forces

The modification factor for edge effect of anchors loaded in tension, $\psi_{ed,N}$, shall be computed in accordance with Eq. (12) or (13).

If $c_{a1} \geq c_{cr,N}$ then $\psi_{ed,N} = 1.0$ (12)

If $c_{a1} < c_{cr,N}$ then $\psi_{ed,N} = \left(\frac{c_{a1}}{c_{cr,N}}\right)^{0.5} \leq 1.0$ (13)

where:

$$c_{cr,N} = 0.5 s_{cr,N} = \left(2.8 - \frac{1.3h_{ef}}{180}\right) h_{ef} \geq 1.5h_{ef}, \text{ mm} \qquad (14)$$

If anchor channels are located in a narrow concrete member with multiple edge distances $c_{a1,1}$ and $c_{a1,2}$ (as shown in Figure 8b), the minimum value of $c_{a1,1}$ and $c_{a1,2}$ shall be used in place of c_{a1} in Eq. (13).

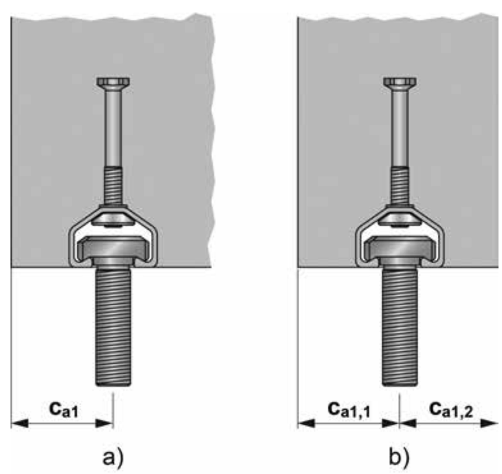


Figure 8: Anchor channel

a) at an edge b) in a narrow member

The modification factor for corner effect for anchors loaded in tension, $\psi_{co,N}$, shall be computed in accordance with Eq. (15) or (16).

If $c_{a2} \geq c_{cr,N}$ then $\psi_{co,N} = 1.0$ (15)

If $c_{a2} < c_{cr,N}$ then $\psi_{co,N} = \left(\frac{c_{a2}}{c_{cr,N}}\right)^{0.5} \leq 1.0$ (16)

where:

c_{a2} = distance of the anchor under consideration to the corner (see Figure 9a, b)

If an anchor is influenced by two corners (see Figure 9c), the factor $\psi_{co,N}$ shall be computed for each of the values $c_{a2,1}$ and $c_{a2,2}$ and the product of the factors, $\psi_{co,N}$, shall be inserted in Eq. (6).

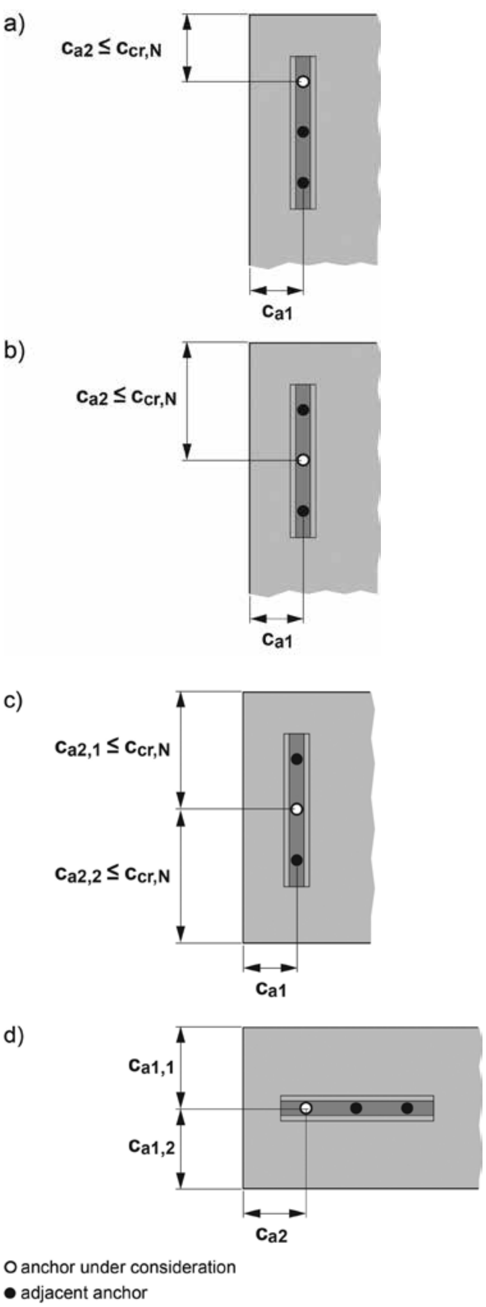
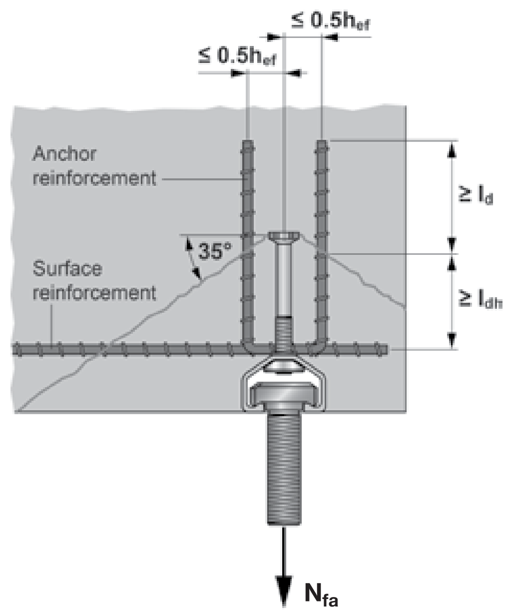


Figure 9: Anchor channel at a corner of a concrete member

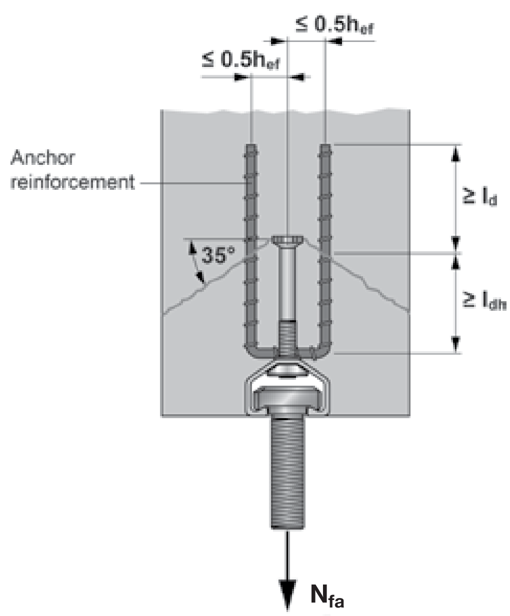
For anchor channels located in a region of a concrete member where analysis indicates no cracking at service load levels, the following modification factor shall be permitted

$\psi_{c,N} = 1.25$

Where analysis indicates cracking at service load levels $\psi_{c,N}$ shall be taken as 1.0. The cracking in the concrete shall be controlled by flexural reinforcement distributed in accordance with CSA A23.3-14 Section 10.6 or equivalent crack control shall be provided by confining reinforcement.



a) at an edge



b) in a narrow member

Figure 10: Arrangement of anchor reinforcement for anchor channels loaded by tension load

The modification factor for anchor channels designed for uncracked concrete without supplementary reinforcement to control splitting, $\psi_{cp,N}$, shall be computed in accordance with Eq. (17) or (18). The critical edge distance, c_{ac}, shall be taken from Table 4 of this document.

If $c_{a,min} \geq c_{ac}$ then $\psi_{cp,N} = 1.0$ (17)

If $c_{a,min} < c_{ac}$ then $\psi_{cp,N} = \left(\frac{c_{a,min}}{c_{ac}}\right)$ (18)

Whereby $\psi_{cp,N}$ as determined in accordance with Eq. (18) shall not be taken less than $c_{cr,N} / c_{ac}$, with $c_{cr,N}$ taken from Eq. (14).

For all other cases, $\psi_{cp,N}$ shall be taken as 1.0.

Where anchor reinforcement is developed in accordance with CSA A23.3-14 Chapter 7 on both sides of the breakout surface for an anchor of an anchor channel, the design resistance of the anchor reinforcement, N_{car}, shall be permitted to be used instead of the concrete breakout resistance, N_{cbr}, in determining N_r. The anchor reinforcement for one anchor shall be designed for the tension force, N^a_{fa}, on this anchor using a strut-and-tie model. The provisions in Figure 10 shall be taken into account when sizing and detailing the anchor reinforcement. Anchor reinforcement shall consist of stirrups made from deformed reinforcing bars with a maximum diameter of 16 mm (No. 5 bar). A resistance modification factor, R, of 1.15 shall be used in the design of the anchor reinforcement.

For anchor channels located parallel to the edge of a concrete member or in a narrow concrete member, the plane of the anchor reinforcement shall be arranged perpendicular to the longitudinal axis of the channel, as shown in Figure 10.

3.3 Factored pullout resistance in tension

For anchors of anchor channels, the factored pullout resistance N_{pnr} shall be computed in accordance with D.6.3.1, D.6.3.4, and D.6.3.6 of CSA A23.3-14.

3.4 Factored concrete side-face blowout resistance of anchor channels in tension

For anchor channels with deep embedment close to an edge ($h_{ef} > 2c_{a1}$) the factored side-face blowout resistance, N_{sbr}, of a single anchor shall be computed in accordance with Eq. (19).

$$N_{sbr} = N^0_{sbr} \cdot \psi_{s,Nb} \cdot \psi_{g,Nb} \cdot \psi_{co,Nb} \cdot \psi_{h,Nb} \cdot \psi_{c,Nb}, \text{ N} \quad (19)$$

The basic factored resistance of a single anchor without influence of neighboring anchors, corner or member thickness effects in cracked concrete, N^0_{sbr}, shall be computed in accordance with Eq. (20).

$$N^0_{sbr} = 10.5 \cdot \Phi_c \cdot c_{a1} \cdot \lambda \cdot \sqrt{A_{brg}} \cdot \sqrt{f'_c} \cdot R, \text{ N} \quad (20)$$

The modification factor accounting for the distance to and loading of neighboring anchors, $\psi_{s,Nb}$, shall be computed in accordance with Eq. (10), however $s_{cr,N}$ shall be replaced by $s_{cr,Nb}$, which shall be computed in accordance with Eq. (21).

$$s_{cr,Nb} = 4c_{a1}, \text{ mm} \quad (21)$$

The modification factor to account for influence of the bearing area of neighboring anchors, $\Psi_{g,Nb}$, shall be computed in accordance with Eq. (22) or Eq. (23).

If $s \geq 4c_{a1}$ then $\psi_{g,Nb} = 1.0$ (22)

If $s < 4c_{a1}$ then $\psi_{g,Nb} = \sqrt{n} + (1 - \sqrt{n}) \cdot \frac{s}{4c_{a1}} \geq 1.0$ (23)

where:

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

The modification factor to account for influence of corner effects, $\psi_{co,Nb}$, shall be computed in accordance with Eq. (24).

$$\psi_{co,Nb} = \left(\frac{c_{a2}}{c_{cr,Nb}}\right)^{0.5} \leq 1.0 \quad (24)$$

where:

c_{a2} = corner distance of the anchor, for which the resistance is computed, mm

$c_{cr,Nb}$ = $2c_{a1}$, mm (25)

If an anchor is influenced by two corners ($c_{a2} < 2c_{a1}$), then the factor, $\psi_{co,Nb}$, shall be computed for $c_{a2,1}$ and $c_{a2,2}$ and the product of the factors shall be inserted in Eq. (19).

The modification factor to account for influence of the member thickness, $\psi_{h,Nb}$ shall be computed in accordance with Eq. (26) or Eq. (27).

If $f > 2c_{a1}$ then $\psi_{h,Nb} = 1.0$ (26)

If $f \leq 2c_{a1}$ then $\psi_{h,Nb} = \frac{h_{ef} + f}{4c_{a1}} \leq \frac{2c_{a1} + f}{4c_{a1}}$ (27)

where:

f = distance between the anchor head and the surface of the concrete member opposite to the anchor channel (see Figure 11), mm

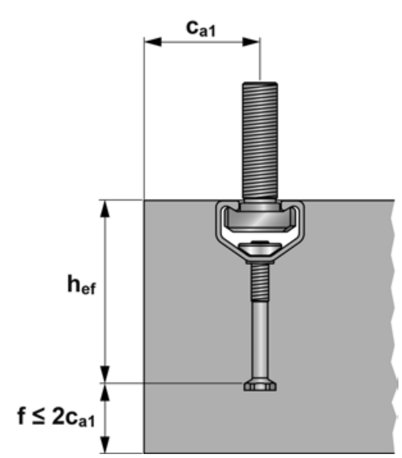


Figure 11: Anchor channel at the edge of a thin concrete member

The following modification factor to account for influence of uncracked concrete, $\psi_{c,Nb}$, shall be permitted:

$\psi_{c,Nb} = 1.25$

For anchor channels located perpendicular to the edge and loaded uniformly, verification is only required for the anchor closest to the edge.

3.5 Factored steel resistance of anchor channel systems in shear perpendicular to its longitudinal axis

For anchor channel systems, the factored steel shear resistance shall be determined as follows:

V_{ssr} (factored resistance of a channel bolt in shear) must be taken from Table 12 of this document.

If the fixture is not clamped against the concrete but secured to the channel bolt at a distance from the concrete surface (e.g. by double nuts), the factored resistance of a channel bolt in shear, $V_{ssr,M}$, shall be computed in accordance with Eq. (28).

$$V_{ssr,M} = \frac{\alpha_M \cdot M_{ssr}}{\ell}, \text{ N} \quad (28)$$

where:

α_M	=	factor to take into account the restraint condition of the fixture
	=	1.0 if the fixture can rotate freely (no restraint)
	=	2.0 if the fixture cannot rotate (full restraint)
M_{ssr}	=	$M^0_{ssr}\left(1 - \frac{N_{fa}}{N_{ssr}}\right)$, N.mm (29)
M^0_{ssr}	=	basic flexural resistance of channel bolt according to Table 12 of this document.
	≤	$0.5N_{slr} \cdot a$
	≤	$0.5N_{ssr} \cdot a$
ℓ	=	lever arm, mm
a	=	internal lever arm, mm, as illustrated in Figure 12

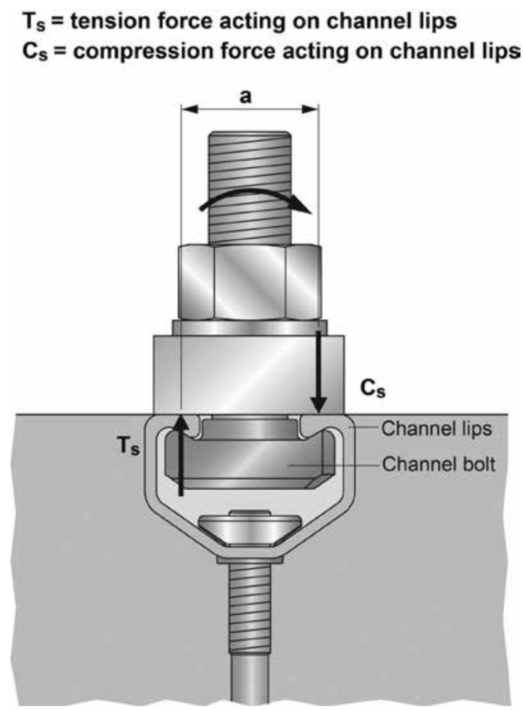


Figure 12: Definition of internal lever arm

$V_{slr,y}$ (factored resistance of the channel lips to take up shear loads perpendicular to the channel transmitted by a channel bolt), $V_{sar,y}$ (factored shear steel resistance perpendicular to the channel axis of a single anchor), and $V_{scr,y}$ (factored shear resistance perpendicular to the channel axis of connection between one anchor and the anchor channel) are provided in Table 5 of this document.

3.6 Factored concrete breakout resistance of an anchor channel in shear perpendicular to its longitudinal axis

The factored concrete breakout resistance, $V_{cbr,y}$, in shear perpendicular to the channel of a single anchor of an anchor channel in cracked concrete shall be computed as follows:

a) For a shear force perpendicular to the edge by Eq. (30)

$$V_{cbr,y} = V_{br} \cdot \psi_{s,V} \cdot \psi_{co,V} \cdot \psi_{c,V} \cdot \psi_{h,V}, \text{ N} \quad (30)$$

b) For a shear force parallel to an edge (as shown in Figure 13), $V_{cbr,y}$ shall be permitted to be 2.5 times the value of the shear force determined from Eq. (30) where the shear force assumed to act perpendicular to the edge.

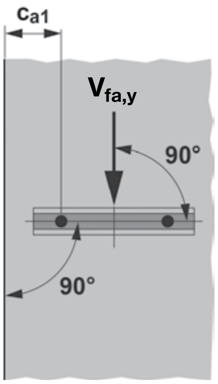


Figure 13: Anchor channel arranged perpendicular to the edge and loaded parallel to the edge

The basic concrete breakout resistance in shear perpendicular to the channel of a single anchor of an anchor channel in cracked concrete, V_{br}, shall be computed in accordance with Eq. (31).

$$V_{br} = \phi_c \cdot \alpha_{ch.v} \cdot \lambda \cdot \sqrt{f'_c} \cdot c_{a1}^{4/3} \cdot R, \text{ N} \quad (31)$$

where:

$\alpha_{ch,V}$ = shall be taken from Table 10 of this document

f'_c = the lesser of the specified concrete compressive resistance and 59 MPa

The modification factor to account for the influence of location and loading of adjacent anchors, $\psi_{s,V}$ shall be computed in accordance with Eq. (32).

$$\psi_{s,V} = \frac{1}{1 + \sum_{i=2}^{n+1} \left[\left(1 - \frac{s_i}{s_{cr,V}}\right)^{1.5} \cdot \frac{V^a_{fa,i}}{V^a_{fa,1}} \right]} \quad (32)$$

where, as illustrated in Figure 14:

s_i = distance between the anchor under consideration and the adjacent anchors $\leq s_{cr,V}$

$s_{cr,V}$ = $4c_{a1} + 2b_{ch}$, mm (33)

$V^a_{fa,i}$ = factored shear load of an influencing anchor, N

$V^a_{fa,1}$ = factored shear load of the anchor under consideration, N

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

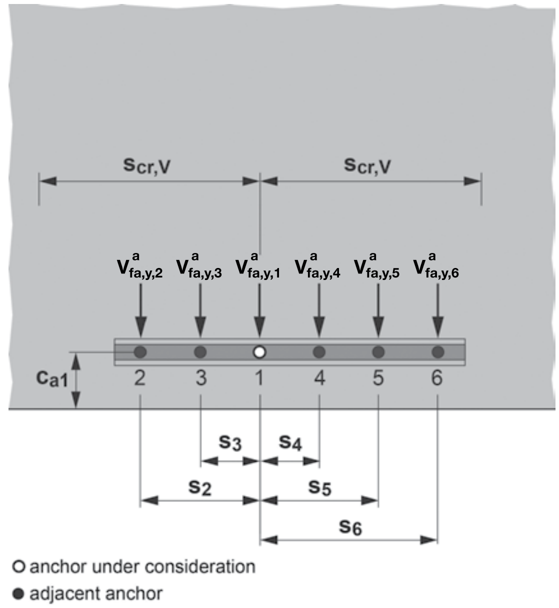


Figure 14: Example of an anchor channel with different anchor shear forces

The modification factor for corner effect for an anchor loaded in shear perpendicular to the channel, $\psi_{co,V}$, shall be computed in accordance with Eq. (34) or (35).

If $c_{a2} \geq c_{cr,V}$ then $\psi_{co,V} = 1.0$ (34)

If $c_{a2} < c_{cr,V}$ then $\psi_{co,V} = \left(\frac{c_{a2}}{c_{cr,V}}\right)^{0.5}$ (35)

where:

$c_{cr,V} = 2c_{a1} + b_{ch}$, mm (36)

If an anchor is influenced by two corners (as shown in Figure 15b), then the factor $\psi_{co,V}$ shall be computed for each corner in accordance with Eq. (34) or (35) and the product of the values of $\psi_{co,V}$ shall be inserted in Eq. (30).

For anchor channels located in a region of a concrete member where analysis indicates no cracking at service load levels, the following modification factor shall be permitted:

$\psi_{c,V} = 1.4$

For anchor channels located in a region of a concrete member where analysis indicates cracking at service load levels, the following modifications shall be permitted:

$\psi_{c,V} = 1.0$ for anchor channels in cracked concrete with no supplementary reinforcement

$\psi_{c,V} = 1.2$ for anchor channels in cracked concrete with edge reinforcement of a No. 4 bar (12.7 mm) or greater between the anchor channel and the edge

$\psi_{c,V} = 1.4$ for anchor channels in cracked concrete containing edge reinforcement with a diameter of 12.7 mm or greater (No. 4 bar or greater) between the anchor channel and the edge, and with the edge reinforcement enclosed within stirrups with a diameter of 12.7 mm or greater (No. 4 or greater) spaced 100 mm maximum

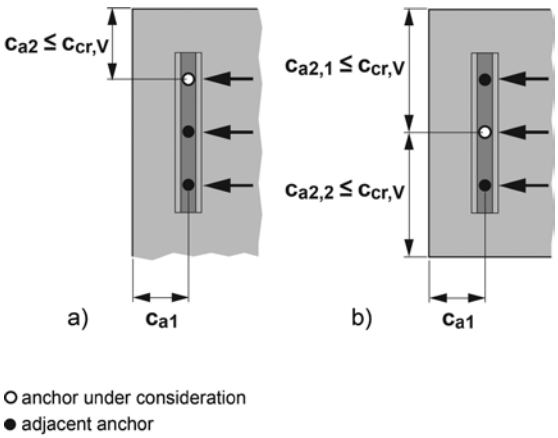


Figure 15: Example of an anchor channel loaded in shear with anchors

a) influenced by one corner

b) influenced by two corners

The modification factor for anchor channels located in a concrete member with $h < h_{cr,V}$, $\psi_{h,V}$ (an example is given in Figure 16), shall be computed in accordance with Eq. (37).

$$\psi_{h,V} \le \left(\frac{h}{h_{cr,V}} \right)^{0.5} \le 1.0 \qquad (37)$$

where:

$$h_{cr,V} = 2c_{a1} + 2h_{ch}, \text{ mm} \qquad (38)$$

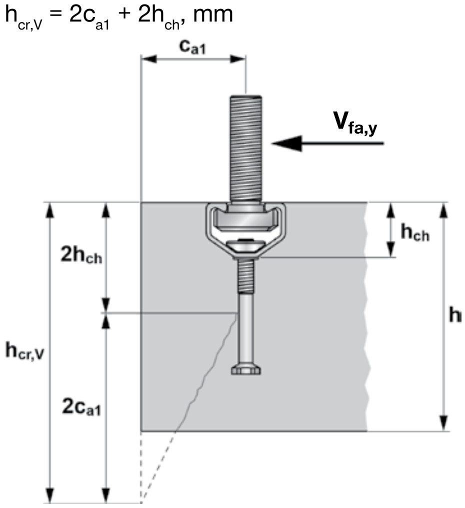
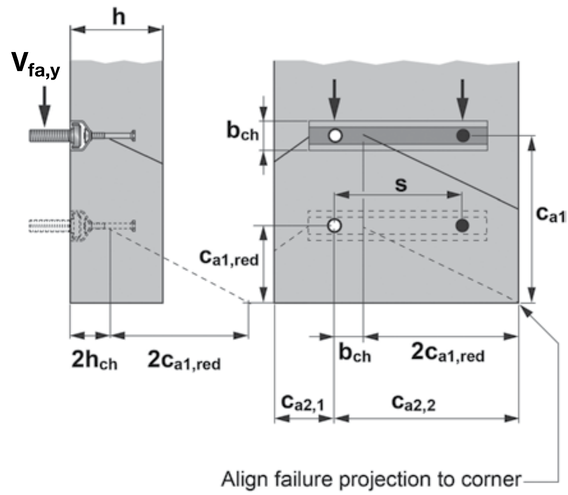


Figure 16: Example of an anchor channel in a member with a thickness $h < h_{cr,V}$

Where an anchor channel is located in a narrow member ($c_{a2,max} < c_{cr,V}$) with a thickness $h < h_{cr,V}$ (see Figure 17), the edge distance c_{a1} in Eq. (31), (33), (36) and (38) shall not exceed the value $c_{a1,red}$ determined in accordance with Eq. (39).

$$c_{a1,red} = \max \left[\frac{C_{a2,max} - b_{ch}}{2} ; \frac{h-2h_{ch}}{2} \right], \text{ mm} \qquad (39)$$

where $c_{a2,max}$ is the largest of the edge distances perpendicular to the longitudinal axis of the channel.



For this example, the value of $c_{a1,red}$ is obtained by moving the failure surface forward until it intersects the corner as shown.

Figure 17: Example of an anchor channel influenced by two corners and member thickness (in this example $c_{a2,2}$ is decisive for the determination of $c_{a1,red}$)

For anchor channels with b_{ch} greater than 28 mm and h_{ch} greater than 15 mm arranged parallel to the edge and loaded by a shear load perpendicular to the edge and anchor reinforcement developed in accordance with CSA A23.3-14 Chapter 7 on both sides of the concrete surface, the design resistance of the anchor reinforcement, $V_{car,y}$, shall be permitted to be used instead of the concrete breakout resistance, $V_{cbr,y}$, in determining $V_{r,y}$.

A resistance modification factor, R, of 1.15 shall be used in the design of the anchor reinforcement. The resistance of the anchor reinforcement assumed in design shall not exceed the value in accordance with Eq. (40). Only anchor reinforcement that complies with Figure 18 shall be assumed as effective.

The maximum resistance of the anchor reinforcement, $V_{car,y,max}$, of a single anchor of an anchor channel shall be computed in accordance with Eq. (40).

$$V_{car,y,max} = \frac{4.2}{c_{a1}^{0.12}} V_{cbr,y}, \text{ N} \qquad (40)$$

where $V_{cbr,y}$ is determined in accordance with Eq. (30).

Anchor reinforcement shall consist of stirrups made from deformed reinforcing steel bars with a maximum diameter of 15.9 mm (No. 5 bar) and straight edge reinforcement with a diameter not smaller than the diameter of the stirrups (as shown in Figure 18). Only one bar at both sides of each anchor shall be assumed as effective. The distance of this bar from the anchor shall not exceed 0.5 c_{a1} and the anchorage length in the breakout body shall be not less than 4 times the bar diameter. The distance between stirrups shall not exceed the smaller of anchor spacing or 152 mm.

The anchor reinforcement of an anchor channel shall be designed for the highest anchor load, $V^a_{fa,y}$, of all anchors but at least for the highest individual shear load, $V^b_{fa,y}$, acting on the channel. This anchor reinforcement shall be arranged at all anchors of an anchor channel.

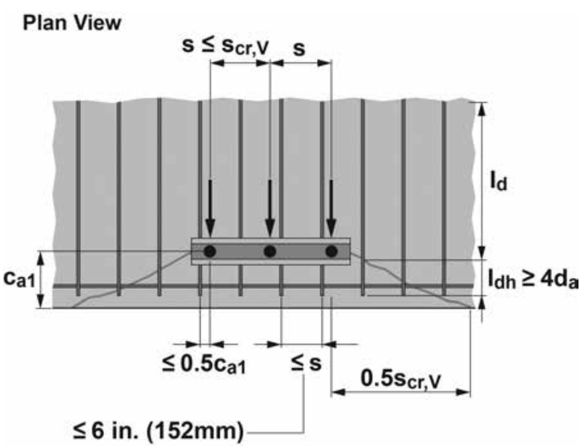


Figure 18: Requirements for detailing of anchor reinforcement of anchor channels

3.7 Factored concrete pryout resistance of anchor channels in shear perpendicular to the channel axis

The factored pryout resistance, $V_{cpr,y}$, in shear of a single anchor of an anchor channel without anchor reinforcement shall be computed in accordance with Eq. (41).

$$V_{cpr} = V_{cpr,x} = V_{cpr,y} = k_{cp} \cdot N_{cbr}, \text{N} \quad (41)$$

where:

k_{cp} = shall be taken from Table 10

N_{cbr} = factored concrete breakout resistance of the anchor under consideration, N, determined in accordance with Section 3.2; however in the determination of the modification factor $\psi_{s,N}$, the values $N^a_{fa,1}$ and $N^a_{fa,i}$ in Eq. (10) shall be replaced by $V^a_{fa,1}$ and $V^a_{fa,i}$, respectively.

The factored pryout resistance, $V_{cpr,y}$, in shear of a single anchor of an anchor channel with anchor reinforcement shall not exceed:

$$V_{cpr} = V_{cpr,x} = V_{cpr,y} = 0.75 \cdot k_{cp} \cdot N_{cbr}, \text{N} \quad (42)$$

with k_{cp} and N_{cbr} as defined above.

3.8 Factored steel resistance of anchor channel systems in shear in the direction of the longitudinal channel axis

V_{ssr} (factored resistance of channel bolt in shear) must be taken from Table 12 of this document.

If the fixture is not clamped against the concrete but secured to the channel bolt at a distance from the concrete surface (e.g. by double nuts), the factored resistance of a channel bolt in shear, $V_{ssr,M}$, shall be computed in accordance with Eq. (28).

$V_{slr,x}$ (factored shear steel resistance in longitudinal channel axis of connection between channel bolt and channel lips) must be taken from Table 6, 7, 8, or Table 9, as applicable.

$V_{sar,x}$ (factored shear steel resistance in longitudinal channel axis of a single anchor) is provided in Table 5.

$V_{scr,x}$ (factored shear resistance in longitudinal channel axis of connection between one anchor and the anchor channel) is provided in Table 5.

3.9 Factored concrete breakout resistance of anchor channels in shear in the direction of the longitudinal channel axis

The factored concrete breakout resistance, $V_{cbr,x}$, in shear acting in longitudinal direction of an anchor channel in cracked concrete shall be computed as follows:

a) For a shear force perpendicular to the edge, by Eq. (D-32) in CSA A23.3-14 Section D.7.2.1. The basic concrete breakout resistance in shear in longitudinal channel axis of a single round anchor in an anchor channel in cracked concrete, V_{br}, shall be computed in accordance with Section D.7.2.2 (CSA A23.3-14).

b) For a shear force parallel to an edge, $V_{cbr,x}$ shall be permitted to be twice the value of the shear force determined from Eq. (D-32), D.7.2.1 (CSA A23.3-14) where the shear force assumed to act perpendicular to the edge.

3.10 Factored concrete pryout resistance for anchor channels in shear in the direction of the longitudinal channel axis

The factored pryout resistance, $V_{cpr,x}$, in shear of a single anchor of an anchor channel without anchor reinforcement shall be computed in accordance with Eq. (41).

The factored pryout resistance, $V_{cpr,x}$, in shear of a single anchor of an anchor channel with anchor reinforcement shall not exceed Eq. (42).

3.11 Interaction of tensile and shear forces

If forces act in more than one direction the combination of loads has to be verified.

Anchor channel systems subjected to combined tensile and shear loads shall be designed to satisfy the following requirements by distinguishing between steel failure of the channel bolt, steel failure modes of the channel and concrete failure modes.

3.11.1 Steel failure of channel bolts under combined loads

For channel bolts, Eq. (43) shall be satisfied.

$$\left(\frac{N^b_{fa}}{N_{ssr}}\right)^2 + \left(\frac{V^b_{fa}}{V_{ssr}}\right)^2 \leq 1.0 \qquad (43)$$

where:

$$V^b_{fa} = \left[\left(V^b_{fa,y}\right)^2 + \left(V^b_{fa,x}\right)^2\right]^{0.5}$$

This verification is not required in case of shear load with lever arm as Eq. (28) accounts for the interaction.

3.11.2 Steel failure modes of anchor channel systems under combined loads

For steel failure modes of anchor channels Eq. (44), Eq. (45) and Eq. (46) shall be satisfied.

$$\max\left(\frac{N^a_{fa}}{N_{sar}};\frac{N^a_{fa}}{N_{scr}}\right)^{\alpha} + \max\left(\frac{V^a_{fa,y}}{V_{sar,y}};\frac{V^a_{fa,y}}{V_{scr,y}}\right)^{\alpha^*} + \max\left(\frac{V^a_{fa,x}}{V_{sar,x}};\frac{V^a_{fa,x}}{V_{scr,x}}\right)^2 \leq 1.0 \qquad (44)$$

where:

$\alpha = 2$ for anchor channels with max $(V_{sar,y}; V_{scr,y}) \leq$ min $(N_{sar}; N_{scr})$

$\alpha = 1$ for anchor channels with max $(V_{sar,y}; V_{scr,y}) >$ min $(N_{sar}; N_{scr})$

It shall be permitted to assume reduced values for $V_{sar,y}$ and $V_{scr,y}$ corresponding to the use of an exponent $\alpha = 2$. In this case the reduced values for $V_{sar,y}$ and $V_{scr,y}$ shall also be used in Section 3.5).

b) At the point of load application:

$$\left(\frac{N^b_{fa}}{N_{slr}}\right)^{\alpha} + \left(\frac{V^b_{fa,y}}{V_{slr,y}}\right)^{\alpha} + \left(\frac{V^b_{fa,x}}{V_{slr,x}}\right)^2 \leq 1.0 \qquad (45)$$

$$\left(\frac{M_{f,flex}}{M_{s,flexr}}\right)^{\alpha} + \left(\frac{V^b_{fa,y}}{V_{slr,y}}\right)^{\alpha} + \left(\frac{V^b_{fa,x}}{V_{slr,x}}\right)^2 \leq 1.0 \qquad (46)$$

where:

$\alpha = 2$ for anchor channels with $V_{slr,y} \leq N_{slr,i}$

$\alpha = 1$ for anchor channels with $V_{slr,y} > N_{slr,i}$

It shall be permitted to assume reduced values for $V_{slr,y}$ corresponding to the use of an exponent $\alpha = 2$. (In this case the reduced value for $V_{slr,y}$ shall also be used in Section 3.5).

3.11.3 Concrete failure modes of anchor channels under combined loads

For concrete failure modes, anchor channels shall be designed to satisfy the requirements given in a) through d).

a) If $\left(\frac{V^a_{fa,y}}{V_{rc,y}}\right) + \left(\frac{V^a_{fa,x}}{V_{rc,x}}\right) \leq 0.2$

then the full strength in tension shall be permitted:

$N_{rc} \geq N^a_{fa}$

b) If $N^a_{fa} \leq 0.2\, N_{rc}$

then the full strength in shear shall be permitted:

$$\left(\frac{V^a_{fa,y}}{V_{rc,y}}\right) + \left(\frac{V^a_{fa,x}}{V_{rc,x}}\right) \leq 1.0$$

c) If $\left(\frac{V^a_{fa,y}}{V_{rc,y}}\right) + \left(\frac{V^a_{fa,x}}{V_{rc,x}}\right) > 0.2$ and $N^a_{fa} > 0.2\, N_{rc}$

Then Eq. (47) applies

$$\left(\frac{N^a_{fa}}{N_{rc}}\right) + \left(\frac{V^a_{fa,y}}{V_{rc,y}}\right) + \left(\frac{V^a_{fa,x}}{V_{rc,x}}\right) \leq 1.2 \qquad (47)$$

d) Alternatively, instead of satisfying the requirements in a) through c), the interaction Eq. (48) shall be satisfied:

$$\left(\frac{N^a_{fa}}{N_{rc}}\right)^{5/3} + \left(\frac{V^a_{fa,y}}{V_{rc,y}}\right)^{5/3} + \left(\frac{V^a_{fa,x}}{V_{rc,x}}\right)^{5/3} \leq 1.0 \qquad (48)$$

4.0 Notations

Equations are provided in SI (metric) units.

b_{ch}	width of channel (see Figure 19), mm
c_a	edge distance of anchor channel, measured from edge of concrete member to axis of the nearest anchor (see Figure 5), mm
c_{a1}	edge distance of anchor channel in direction 1 (see Figure 5), mm
c'_{a1}	net distance between edge of the concrete member and the anchor channel: $c'_{a1} = c_{a1} - b_{ch}/2$, mm
$c_{a1,red}$	reduced edge distance of the anchor channel, as referenced in Eq. (39)
c_{a2}	edge distance of anchor channel in direction 2 (see Figure 9), mm
$c_{a,max}$	maximum edge distance of anchor channel, mm
$c_{a,min}$	minimum edge distance of anchor channel, mm
c_{ac}	edge distance required to develop full concrete capacity in absence of reinforcement to control splitting, mm
c_{cr}	edge distance required to develop full concrete capacity in absence of anchor reinforcement, mm

$c_{cr,N}$	critical edge distance for anchor channel for tension loading for concrete breakout, mm
$c_{cr,Nb}$	critical edge distance for anchor channel for tension loading, concrete blowout, mm
$c_{cr,V}$	critical edge distance for anchor channel for shear loading, concrete edge breakout, mm
d_1	diameter of head of round anchor (see Figure 19), mm
d_2	shaft diameter of round anchor (see Figure 19), mm
d_f	diameter of hole in the fixture, mm
d_a	diameter of anchor reinforcement, mm
d_s	diameter of channel bolt, mm
e_1	distance between shear load and concrete surface, mm
e_s	distance between the axis of the shear load and the axis of the anchor reinforcement resisting the shear load, mm
f	distance between anchor head and surface of the concrete, mm
f'_c	specified compressive strength of concrete, MPa
Φ_c	Material resistance factor for concrete
Φ_s	Material resistance factor for steel component
f_{uta}	specified ultimate tensile strength of anchor, MPa
f_{utc}	specified ultimate tensile strength channel, MPa
f_{utb}	specified ultimate tensile strength of channel bolt, MPa
f_y	specified yield tensile strength of steel, MPa
f_{ya}	specified yield strength of anchor, MPa
f_{yc}	specified yield strength of channel, MPa
f_{ys}	specified yield strength of channel bolt, MPa
h	thickness of concrete member or test member (see Figure 19), mm
h_{ch}	height of channel (see Figure 19), mm
$h_{cr,V}$	critical member thickness, mm
h_{ef}	effective embedment depth (see Figure 19), mm
$h_{ef,min}$	minimum effective embedment depth, mm
$h_{ef,red}$	reduced effective embedment depth, as referenced in Eq. (9), mm
h_{nom}	nominal embedment depth (see Figure 19), mm
k	load distribution factor, as referenced in Eq. (1)
k_{cp}	pryout factor
ℓ_A	nominal embedment depth, minus channel height (see Figure 19), mm
ℓ	lever arm of the shear force acting on the channel bolt, mm
ℓ_{dh}	development length in tension of deformed bar or deformed wire with a standard hook, measured from critical section to outside end of hook, mm
ℓ_{in}	influence length of an external load N_{fa} along an anchor channel, mm
s	spacing of anchors in direction of longitudinal axis of channel, mm
s_{chb}	center-to-center distance between channel bolts in direction of longitudinal axis of channel, mm
s_{cr}	anchor spacing required to develop full concrete capacity in absence of anchor reinforcement, mm
$s_{cr,N}$	critical anchor spacing for tension loading, concrete breakout, mm
s_{max}	maximum spacing between anchor elements in anchor channels, mm
s_{min}	minimum spacing between anchor elements in anchor channels, mm
$s_{cr,Nb}$	critical anchor spacing for tension loading, concrete blowout, mm
$s_{cr,V}$	critical anchor spacing for shear loading, concrete edge breakout, mm
t_h	thickness of head portion of headed anchor (see Figure 19), mm
x	distance between end of channel and nearest anchor, mm
z	internal lever arm of the concrete member, mm
A_{brg}	bearing area of anchor head, mm^2
A_i	ordinate at the position of the anchor i, as illustrated in Figure 2, mm
$A_{se,N}$	effective cross-sectional area of anchor or channel bolt in tension, mm^2
$A_{se,V}$	effective cross-sectional area of channel bolt in shear, mm^2
I_y	moment of inertia of the channel about principal y-axis, mm^4
M_1	bending moment on fixture around axis in direction 1, Nm

M_2	bending moment on fixture around axis in direction 2, Nm
$M_{s,flexr}$	factored flexural resistance of the anchor channel, Nm
M_{ssr}	factored flexural resistance of the channel bolt, v
M^0_{ssr}	basic factored flexural resistance of the channel bolt, Nm
$M_{f,flex}$	bending moment on the channel due to tension loads, v
N_{br}	basic concrete breakout resistance of a single anchor in tension, N
N_{car}	factored resistance of anchor reinforcement to take up tension loads, N
N_{cbr}	factored concrete breakout resistance of a single anchor of anchor channel in tension, N
N_r	lowest factored tension resistance from all appropriate failure modes under tension, N
N_{pr}	factored pullout resistance of a single anchor of an anchor channel in tension, N
N_{pnr}	factored pullout resistance of a single anchor of an anchor channel in tension, N
N_{rc}	factored tension resistance of one anchor from all concrete failure modes (lowest value of N_{cbr} (anchor channels without anchor reinforcement to take up tension loads) or N_{car} (anchor channels with anchor reinforcement to take up tension loads), N_{pnr}, and N_{sbr})
N_{rs}	factored steel resistance of anchor channel loaded in tension (lowest value of N_{sar}, N_{scr} and N_{slr}), N
$N_{rs,a}$	factored tension resistance for steel failure of anchor or connection between anchor and channel (lowest value of N_{sar} and N_{scr})
N_{sar}	factored tensile steel resistance of a single anchor, N
N_{sbr}	factored concrete side-face blowout resistance, N
N^0_{sbr}	basic factored concrete side-face blowout resistance, N
N_{scr}	factored tensile steel resistance of the connection between channel and anchor, N
N_{slr}	factored tensile steel resistance of the local bending of the channel lips, N
N_{ssr}	factored tensile resistance of a channel bolt, N
N^a_{fa}	factored tension load on a single anchor of the anchor channel, N
$N^a_{fa,i}$	factored tension load on anchor i of the anchor channel, N
N^b_{fa}	factored tension load on a channel bolt, N
$N_{fa,re}$	factored tension load acting on the anchor reinforcement, N
T_{inst}	installation torque moment given in installation instructions (MPII), Nm
V_{br}	basic concrete breakout resistance in shear of a single anchor, N
$V_{car,y}$	factored resistance of the anchor reinforcement of one anchor to take up shear loads perpendicular to the channel axis, N
$V_{car,x}$	factored resistance of the anchor reinforcement of one anchor to take up shear loads in longitudinal channel axis, N
$V_{car,y,max}$	maximum value of $V_{car,y}$ of one anchor to be used in design, N
$V_{cbr,y}$	factored concrete breakout resistance in shear perpendicular to the channel axis of an anchor channel, N
$V_{cbr,x}$	factored concrete breakout resistance in shear in longitudinal channel axis of an anchor channel, N
V_{cpr}	factored pry-out resistance of a single anchor ($V_{cpr,x} = V_{cpr,y}$), N
$V_{cpr,y}$	factored pry-out resistance perpendicular to the channel axis of a single anchor, N
$V_{cpr,x}$	factored pry-out resistance in longitudinal channel axis of a single anchor, N
$V_{r,y}$	lowest factored steel resistance from all appropriate failure modes under shear perpendicular to the channel axis, N
$V_{r,x}$	lowest factored steel resistance from all appropriate failure modes under shear loading in longitudinal channel axis, N
V_{rc}	factored shear resistance of one anchor from all concrete failure modes (lowest value of V_{cbr} (anchor channels with anchor reinforcement to take up shear loads) or V_{car} (anchor channels with anchor reinforcement to take up shear loads) and V_{cpr})
V_{rs}	factored steel resistance of anchor channel loaded in shear (lowest value of V_{sar}, V_{scr}, and V_{slr})

$V_{rs,a}$ factored shear resistance for steel failure of anchor or connection between anchor and channel (lowest value of V_{sar} and V_{scr})

$V_{sar,y}$ factored shear steel resistance perpendicular to the channel axis of a single anchor, N

$V_{sar,x}$ factored shear steel resistance in longitudinal channel axis of a single anchor, N

$V_{sar,y,seis}$ factored seismic shear steel resistance perpendicular to the channel axis of a single anchor, N

$V_{sar,x,seis}$ factored seismic shear steel resistance in longitudinal channel axis of a single anchor, N

$V_{scr,y}$ factored shear resistance perpendicular to the channel axis of connection between one anchor and the anchor channel, N

$V_{scr,x}$ factored shear resistance in longitudinal channel axis of connection between one anchor and the anchor channel, N

$V_{scr,y,seis}$ factored seismic shear resistance perpendicular to the channel axis of connection between one anchor bolt and the anchor channel, N

$V_{scr,x,seis}$ factored seismic shear resistance in longitudinal channel axis of connection between one anchor bolt and the anchor channel, N

$V_{slr,y}$ factored shear steel resistance perpendicular to the channel axis of the local bending of the channel lips, N

$V_{slr,x}$ factored shear steel resistance in longitudinal channel axis of connection between channel bolt and channel lips, N

$V_{slr,y,seis}$ factored seismic shear steel resistance perpendicular to the channel axis of the local bending of the channel lips, N

$V_{slr,x,seis}$ factored seismic shear steel resistance in longitudinal channel axis of connection between channel bolt and channel lips, N

V_{ssr} factored resistance of channel bolt in shear, N

$V_{ssr,M}$ factored resistance of channel bolt in case of shear with lever arm, N

V_{fa} factored shear load on anchor channel, N

$V_{fa,x}$ factored shear load on anchor channel in longitudinal channel axis, N

$V_{fa,y}$ factored shear load on anchor channel perpendicular to the channel axis, N

V^a_{fa} factored shear load on a single anchor of the anchor channel, N

$V^a_{fa,x}$ factored shear load on a single anchor of the anchor channel in longitudinal channel axis, N

$V^a_{fa,y}$ factored shear load on a single anchor of the anchor channel perpendicular to the channel axis, N

$V^a_{fa,i}$ factored shear load on anchor i of the anchor channel, N

$V^a_{fa,x,i}$ factored shear load on anchor i of the anchor channel in longitudinal channel axis, N

$V^a_{fa,y,i}$ factored shear load on anchor i of the anchor channel perpendicular to the channel axis, N

V^b_{fa} factored shear load on a channel bolt, N

$V^b_{fa,x}$ factored shear load on a channel bolt in longitudinal channel axis, N

$V^b_{fa,y}$ factored shear load on a channel bolt perpendicular to the channel axis, N

α exponent of interaction equation (see Section 3.11)

$\alpha_{ch,N}$ factor to account for the influence of channel size on concrete breakout resistance in tension

α_M factor to account for the influence of restraint of fixture on the flexural resistance of the channel bolt

$\alpha_{ch,V}$ factor to account for the influence of channel size and anchor diameter on concrete edge breakout resistance in shear $N^{1/2}/mm^{1/3}$

λ modification factor for lightweight concrete (λ = 1 for normal weight concrete)

$\Psi_{c,N}$ modification factor to account for influence of cracked or uncracked concrete on concrete breakout resistance

$\Psi_{c,Nb}$ modification factor to account for influence of cracked or uncracked concrete on concrete blowout resistance

$\Psi_{c,V}$ modification factor to account for influence of cracked or uncracked concrete for concrete edge breakout resistance

$\Psi_{co,N}$ modification factor for corner effects on concrete breakout resistance for anchors loaded in tension

$\Psi_{co,Nb}$ modification factor for corner effects on concrete blowout resistance for anchors loaded in tension

$\Psi_{co,V}$ modification factor for corner effects on concrete edge breakout resistance for anchor channels loaded in shear

$\psi_{cp,N}$ modification factor for anchor channels to control splitting

$\psi_{ed,N}$ modification factor for edge effect on concrete breakout resistance for anchors loaded in tension

$\psi_{g,Nb}$ modification factor to account for influence of bearing area of neighboring anchors on concrete blowout resistance for anchors loaded in tension

$\psi_{h,Nb}$ modification factor to account for influence of member thickness on concrete blowout resistance for anchors loaded in tension

$\psi_{h,V}$ modification factor to account for influence of member thickness on concrete edge breakout resistance for anchors channels loaded in shear

$\psi_{s,N}$ modification factor to account for influence of location and loading of neighboring anchors on concrete breakout resistance for anchor channels loaded in tension

$\psi_{s,Nb}$ modification factor to account for influence of location and loading of neighboring anchors on concrete blowout resistance for anchor channels loaded in tension

$\psi_{s,V}$ modification factor to account for influence of location and loading of neighboring anchors on concrete edge breakout resistance for anchor channels loaded in shear

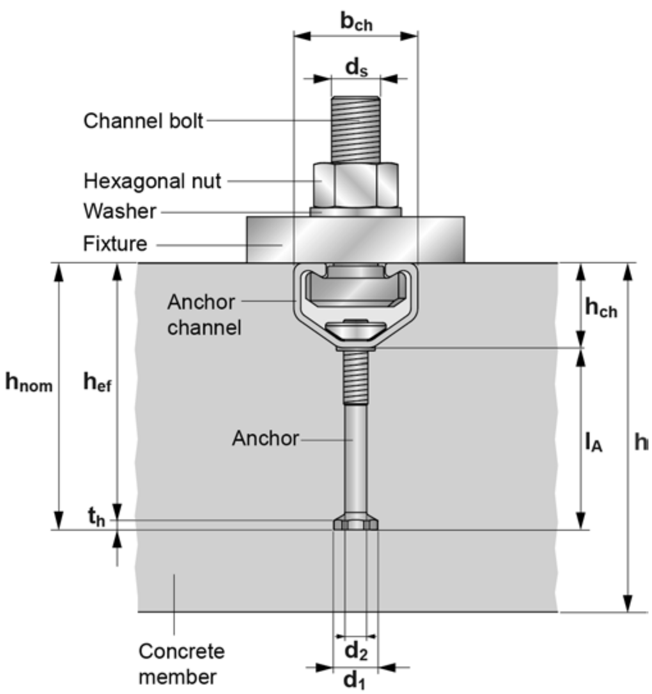


Figure 19: Dimensions of anchor channel system

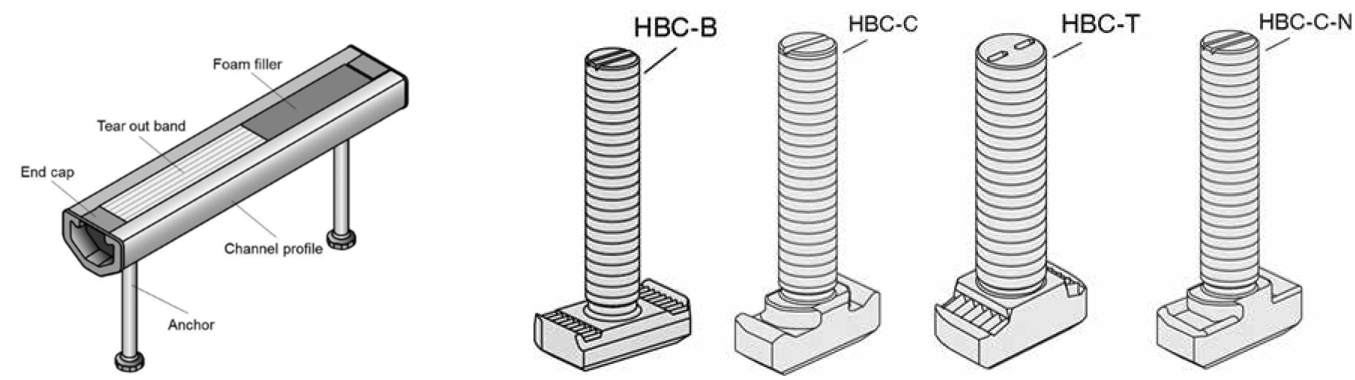


Figure 20: Hilti Anchor Channel HAC and Channel Bolts HBC-B, HBC-C, HBC-T, and HBC-C-N

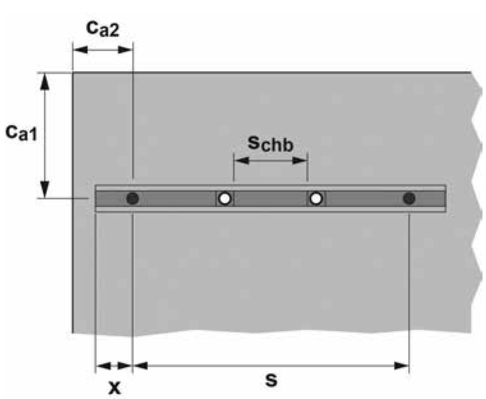


Figure 21: Position of anchor channel and channel bolts

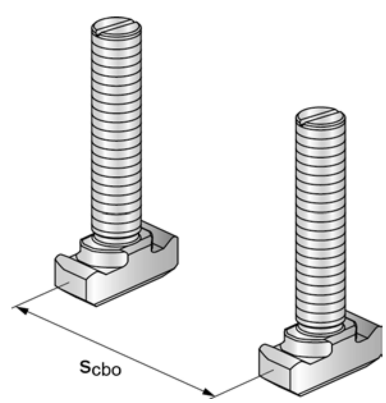


Figure 22: Channel bolt spacing s_{chb}

Table 1 - Geometric parameters for Hilti Anchor Channels (HAC and HAC-T)[1]

Criteria	Symbol	Units	Anchor channel sizes						
			HAC-30	HAC-40	HAC-50	HAC-T50	HAC-60	HAC-70	HAC-T70
Channel height	h_{ch}	mm	25.6	28.0	31.0		35.5	40.0	
Channel width	b_{ch}	mm	41.3	40.9	41.9		43.4	45.4	
Moment of inertia	I_y	mm^4	15.349	21.463	33.125	32.049	57.093	95.457	92.192
Minimum anchor spacing	s_{min}	mm	50	100					
Maximum anchor spacing	s_{max}	mm	250						
Minimum effective embedment depth	$h_{ef,min}$	mm	68	91	106		148	175	
Nominal embedment depth	h_{nom}	mm	$h_{ef} + t_h$						
Thickness of the anchor head	t_h	mm	2.0	3.0	3.5		4.5	5.0	
Minimum edge distance for normal-weight and sand-lightweight concrete	$c_{a,min}$	mm	50	50	50		75	75	
Minimum edge distance for all-lightweight concrete			75	75	75		75	75	
Minimum end spacing	x_{min}	mm	25	25	25		25	25	
Anchor shaft diameter	d_2	mm	5.35	7.19	9.03		9.03	10.86	
Head diameter[2]	d_1	mm	11.5	17.5	19.5		19.5	23.0	
Net bearing area of the anchor head	A_{brg}	mm^2	89	209	258		258	356	
Minimum concrete member thickness	h_{min}	mm	80	105	125		168	196	

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-1.
2 The head diameter is the inner diameter of the hexagonal shaped head, and does not fully reflect the cross sectional area of the anchor head.

Table 2 - Installation torque for Hilti Channel Bolts (HBC-B, HBC-C, HBC-T and HBC-C-N)[1]

Bolt type	Units	Installation torque T_{inst} (Installation type A)[2]							Installation torque T_{inst} (Installation type B)[3]						
		HAC-30	HAC-40	HAC-50	HAC-T50	HAC-60	HAC-70	HAC-T70	HAC-30	HAC-40	HAC-50	HAC-T50	HAC-60	HAC-70	HAC-T70
HBC-B M10 4.6	Nm	15	-						15	-					
HBC-B M12 4.6	Nm	25							25						
HBC-C M12 8.8	Nm		25		-	25		-		75		-	75		-
HBC-T M12 8.8	Nm		-		75	-		75				75			75
HBC-C-N M12 8.8	Nm		75			75		-		75			75		-
HBC-C M16 4.6	Nm		60		-	60				60		-	60		
HBC-C M16 50 R	Nm		60			60				60			60		
HBC-C M16 8.8	Nm	-	60			60				185			185		
HBC-T M16 8.8	Nm		-		100	-		100		-		185	-		185
HBC-C-N M16 8.8	Nm		185		-	185		-		185			185		
HBC-C M20 8.8	Nm		70	105		120				320			320		
HBC-T M20 8.8	Nm		-		120	-		120		-		320	-		320
HBC-C-N M20 8.8	Nm		320		-	320		-		320		-	320		-

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-2.
2 Installation type A: The fixture is in contact with the channel profile and the concrete surface
3 Installation type B: The fixture is fastened to the anchor channel by suitable steel part (e.g. square plate washer), fixture is in contact with the channel profile only

Table 3 - Tension steel strength design information for Hilti Anchor Channels (HAC and HAC-T) with Hilti Channel Bolts (HBC-B, HBC-C, HBC-T and HBC-C-N)[1]

Criteria	Symbol	Units	Anchor channel sizes						
			HAC-30	HAC-40	HAC-50	HAC-T50	HAC-60	HAC-70	HAC-T70
Factored tensile steel resistance for local failure of channel lips	N_{slr}	kN	11.9	17.0	23.8		34.0	48.3	
Factored tensile steel resistance for local failure of channel lips for seismic design	$N_{slr,seis}$	kN	11.9	17.0	23.8		23.8	48.3	
Material resistance factor for local failure of channel lips	Φ_s	-	0.85						
Resistance modification factor for tension. local failure of channel lips	R	-	0.8						
Factored tensile steel resistance of a single anchor	N_{sar}	kN	11.8	18.7	34.0		34.0	49.4	
Factored tensile steel resistance of a single anchor for seismic design	$N_{sar,seis}$	kN	11.8	18.7	34.0		34.0	49.4	
Material resistance factor for anchor failure	Φ_s	-	0.85						
Resistance modification factor for tension. anchor failure	R	-	0.8	0.70	0.80				
Factored tensile steel resistance of connection between anchor and channel	N_{scr}	kN	11.9	17.0	23.8		34.0	48.3	
Factored tensile steel resistance of connection between anchor and channel for seismic design	$N_{scr,seis}$	kN	11.9	17.0	23.8		23.8	48.3	
Material resistance factor for failure of connection between anchor and channel	Φ_s	-	0.85						
Resistance modification factor for tension. failure of connection between anchor and channel	R	-	0.8						
Factored bending resistance of the anchor channel with HBC-B	$M_{s,flexr}$	Nm	515	-	-	-	-	-	-
Factored bending resistance of the anchor channel with HBC-C			-	869	1,221	-	1,673	2,420	-
Factored bending resistance of the anchor channel with HBC-T			-	-	-	1,221	-	-	2,276
Factored bending resistance of the anchor channel with HBC-C-N			-	750	1,029	-	1,649	2,299	-
Factored bending resistance of the anchor channel for seismic design with HBC-B	$M_{s,flexr,seis}$	Nm	515	-	-	-	-	-	-
Factored bending resistance of the anchor channel for seismic design with HBC-C			-	869	1,221	-	1,221	2,420	-
Factored bending resistance of the anchor channel for seismic design with HBC-T			-	-	-	1,221	-	-	2,276
Factored bending resistance of the anchor channel for seismic design with HBC-C-N			-	750	1,029	-	1,029	2,299	-
Material resistance factor for bending failure	Φ_s	-		0.85					
Resistance modification factor for tension. bending failure	R	-		0.90					

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-3, and converted for use with CSA A23.3-14.

Table 4 - Tension concrete strength design information for Hilti Anchor Channels (HAC and HAC-T)[1]

Criteria	Symbol	Units	Anchor channel sizes				
			HAC-30	HAC-40	HAC-50 HAC-T50	HAC-60	HAC-70 HAC-T70
Edge distance required to develop full concrete capacity in absence of anchor reinforcement	c_{ac}	mm	204	273	318	444	525
Material resistance factor for tension, concrete failure modes	Φ_c	-	0.65				
Resistance modification factor for tension. concrete failure modes. Condition B[2]	R	-	1.00				

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-4.

2 For use with the load combinations of CSA A23.3-14 Annex C or CSA A23.3-04 Annex C, as applicable. Condition B applies where supplementary reinforcement in conformance with CSA A23.3-14 D.5.3(c) or CSA A23.3-04 D.5.4(c), as applicable, is not provided. For installations where complying supplementary reinforcement can be verified, the strength reduction factors associated with Condition A may be used.

Table 5 - Shear steel strength design information for Hilti Anchor Channels (HAC and HAC-T) with Hilti Channel Bolts (HBC-B, HBC-C, HBC-T and HBC-C-N)[1]

Criteria	Symbol	Units	Anchor channel sizes				
			HAC-30	HAC-40	HAC-50 HAC-T50	HAC-60	HAC-70 HAC-T70
Factored shear steel resistance for local failure of channel lips	$V_{slr,y}$	kN	18.1	25.1	34.2	52.0	69.2
Factored shear steel resistance for local failure of the channel lips for seismic design	$V_{slr,y,seis}$	kN	18.1	25.1	34.2	34.2	69.2
Material resistance factor for local failure of channel lips	$Φ_s$	-	0.85				
Resistance modification factor for local failure of channel lips	R	-	0.85				
Factored shear steel resistance of a single anchor	$V_{sar,y}$	kN	18.1	23.7	38.7	55.8	82.9
Factored shear steel resistance of a single anchor for seismic design	$V_{sar,y,seis}$	kN	18.1	23.7	34.2	34.2	69.2
Material resistance factor anchor failure	$Φ_s$	-	0.85				
Resistance modification factor anchor failure	R	-	0.85	0.7	0.85		
Factored shear steel resistance of connection between anchor and channel	$V_{scr,y}$	kN	18.1	28.6	38.7	55.8	82.9
Factored shear steel resistance of connection between anchor and channel for seismic design	$V_{scr,y,seis}$	kN	18.1	28.6	34.2	34.2	69.2
Material resistance factor for failure of connection between anchor and channel	$Φ_s$	-	0.85				
Resistance modification factor for failure of connection between anchor and channel	R	-	0.85				
Factored shear steel resistance of connection between anchor and channel	$V_{scr,x}$	kN	7.6	11.4	16.8	21.6	30.8
Factored shear steel resistance of connection between anchor and channel for seismic design	$V_{scr,x,seis}$	kN	7.6	11.4	16.8	16.8	30.8
Material resistance factor for failure of connection between anchor and channel	$Φ_s$	-	0.85				
Resistance modification factor for failure of connection between anchor and channel	R	-	0.85				
Factored shear steel resistance of a single anchor	$V_{sar,x}$	kN	7.5	13.7	21.7	21.7	31.5
Factored shear steel resistance of a single anchor for seismic design	$V_{sar,x,seis}$	kN	7.5	13.7	21.7	21.7	31.5
Material resistance factor anchor failure	$Φ_s$	-	0.85				
Resistance modification factor anchor failure	R	-	0.85				

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-5, and converted for use with CSA A23.3-14.

Table 6 - Steel strength design information for shear acting in longitudinal direction of the channel axis for hilti anchor channels (HAC-T) with Hilti Channel Bolts (HBC-T)[1]

Criteria	Symbol	Bolt type HBC-T	Units	Anchor channel sizes	
				HAC-T50	HAC-T70
Factored shear steel resistance of connection between channel lips and channel bolts	$V_{slr,x}$	M12	kN	9.6	
		M16	kN	12.8	
		M20	kN	12.8	
Factored shear steel resistance of connection between channel lips and channel bolts for seismic design	$V_{slr,x,seis}$	M12	kN	9.6	
		M16	kN	12.8	
		M20	kN	12.8	
Material resistance factor for failure of connection between channel lips and channel bolts	Φ_s	M12	-	0.85	
		M16			
		M20			
Resistance modification factor for failure of connection between channel lips and channel bolts	R	M12	-	0.75	
		M16			
		M20			

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-6, and converted for use with CSA A23.3-14.

Table 7 - Steel strength design information for shear acting in longitudinal direction of the channel axis for Hilti Anchor Channels (HAC) with Hilti Channel Bolts (HBC-B)[1]

Criteria	Symbol	Bolt type HBC-B	Units	Anchor channel sizes HAC-30
Factored shear steel resistance of connection between channel lips and channel bolts	$V_{slr,x}$	M12	kN	1.8
Factored shear steel resistance of connection between channel lips and channel bolts for seismic design	$V_{slr,x,seis}$	M12	kN	1.8
Material resistance factor for failure of connection between channel lips and channel bolts	Φ_s	M12	-	0.85
Resistance modification factor for failure of connection between channel lips and channel bolts	R	M12	-	0.6

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-7, and converted for use with CSA A23.3-14.

Table 8 - Steel strength design information for shear acting in longitudinal direction of the channel axis for Hilti Anchor Channels (HAC) with Hilti Channel Bolts (HBC-C-N)[1]

Criteria	Symbol	Bolt type HBC-C-N	Units	Anchor channel sizes			
				HAC-40	HAC-50	HAC-60	HAC-70
Factored shear steel resistance of connection between channel lips and channel bolts	$V_{slr,x}$	M12	kN	4.3	4.3	4.3	4.3
		M16	kN	10.0	10.0	10.0	10.0
		M20	kN	-	12.3	12.3	12.3
Factored shear steel resistance of connection between channel lips and channel bolts for seismic design	$V_{slr,x,seis}$	M12	kN	4.3	4.3	4.3	4.3
		M16	kN	10.0	10.0	10.0	10.0
		M20	kN	-	12.3	12.3	12.3
Material resistance factor for failure of connection between channel lips and channel bolts	Φ_s	M12	-	0.85			
		M16					
		M20					
Resistance modification factor for failure of connection between channel lips and channel bolts	R	M12	-	0.60			
		M16					
		M20					

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-8, and converted for use with CSA A23.3-14.

Table 9 - Steel strength design information for shear acting in longitudinal direction of the channel axis for Hilti Anchor Channels (HAC) with Hilti Channel Bolts (HBC-C) in combination with HIT HY-100 Adhesive[1]

Criteria	Symbol	Units	Anchor channel sizes			
			HAC-40	HAC-50	HAC-60	HAC-70
Factored shear steel resistance of connection between channel lips and channel bolts	$V_{slr,x}$	kN	-	24.0	24.0	30.9
Factored shear steel resistance of connection between channel lips and channel bolts for seismic design	$V_{slr,x,seis}$	kN	-	24.0	24.0	30.9
Material resistance factor for failure of connection between channel lips and channel bolts	Φ_s	-	-	0.85		
Resistance modification factor for failure of connection between channel lips and channel bolts	R	-	-	0.85		

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-9, and converted for use with CSA A23.3-14.

Table 10 - Shear concrete strength design information for Hilti Anchor Channels (HAC and HAC-T) with Hilti Channel Bolts (HBC-B, HBC-C, HBC-T and HBC-C-N)[1]

Criteria	Symbol	Units	Anchor channel sizes				
			HAC-30	HAC-40	HAC-50 HAC-T50	HAC-60	HAC-70 HAC-T70
Factor to account for the influence of channel size and anchor diameter on concrete edge breakout resistance in shear	$\alpha_{ch.V}$	$(N^{1/2}/mm^{1/3})$	7.5				
Coefficient for pryout resistance	k_{cp}	-	2.0				
Material resistance factor for shear concrete failure modes	Φ_s	-	0.65				
Resistance modification factor for shear, concrete failure modes Condition B[2]	R	-	1.00				

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-10, and converted for use with CSA A23.3-14.

2 For use with the load combinations of CSA A23.3-14 Annex C or CSA A23.3-04 Annex C, as applicable. Condition B applies where supplementary reinforcement in conformance with CSA A23.3-14 D.5.3(c) or CSA A23.3-04 D.5.4(c), as applicable, is not provided. For installations where complying supplementary reinforcement can be verified, the strength reduction factors associated with Condition A may be used.

Table 11 - Tension steel strength design information for Hilti Channel Bolts (HBC-B, HBC-C, HBC-T and HBC-C-N)[1]

Criteria	Symbol	Bolt type	Units	Channel bolt sizes			
				M10	M12	M16	M20
Factored tensile resistance of a channel bolt	N_{ssr}	HBC-B 4.6	kN	13.8	20.1	-	-
		HBC-C 4.6	kN	-	-	37.4	-
		HBC-C 50R	kN	-	-	37.2	-
		HBC-C 8.8	kN	-	40.1	74.7	103.7
		HBC-T 8.8	kN	-	40.1	74.7	103.8
		HBC-C-N 8.8	kN	-	40.1	74.7	120.5
Factored tensile resistance of a channel bolt for seismic design	$N_{ssr,seis}$	HBC-B 4.6	kN	-	20.1	-	-
		HBC-C 8.8	kN	-	40.1	74.7	103.7
		HBC-T 8.8	kN	-	40.1	74.7	103.8
		HBC-C-N 8.8	kN	-	40.1	74.7	120.5
Material resistance factor for tension. steel failure modes	Φ_s	-	-	0.85			
Resistance modification factor for tension. steel failure modes	R	-	-	0.70			

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-11, and converted for use with CSA A23.3-14.

Table 12 - Shear steel strength design information for Hilti Channel Bolts (HBC-B, HBC-C, HBC-T and HBC-C-N)[1]

Criteria	Symbol	Bolt type	Units	Channel bolt sizes			
				M10	M12	M16	M20
Factored shear resistance of a channel bolt	V_{ssr}	HBC-B 4.6	kN	7.7	11.2	-	-
		HBC-C 4.6	kN	-	-	20.8	-
		HBC-C 50R	kN	-	-	20.7	-
		HBC-C(-N) and HBC-T 8.8	kN	-	22.3	41.6	67.4
Factored shear resistance of a channel bolt for seismic design	$V_{ssr,seis}$	HBC-B 4.6	kN	-	11.2	-	-
		HBC-C(-N) and HBC-T 8.8	kN	-	22.3	41.6	67.4
Factored flexural resistance of the channel bolt	M^0_{ssr}	HBC-B 4.6	Nm	16.5	29	-	-
		HBC-C 4.6	Nm	-	-	73.5	-
		HBC-C 50R	Nm	-	-	73.4	-
		HBC-C(-N) and HBC-T 8.8	Nm	-	57.9	147.1	297.6
Factored flexural strength of the channel bolt for seismic design	$M^0_{ssr,seis}$	HBC-B 4.6	Nm	-	29	-	-
		HBC-C(-N) and HBC-T 8.8	Nm	-	57.9	147.1	297.6
Material resistance factor for shear. steel failure modes	Φ_s	-	-	0.85			
Resistance modification factor for shear. steel failure modes	R	-	-	0.65			

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-12, and converted for use with CSA A23.3-14.

Table 13 - Material specifications and properties for Hilti Anchor Channels (HAC and HAC-T) and Hilti Channel Bolts (HBC-B, HBC-C, HBC-T and HBC-C-N)[1]

Component	Carbon steel	Surface	Stainless steel
Channel Profile	Carbon steel	Hot dip galvanized (F) ≥ 55 µm[2] Hot dip galvanized (F) ≥ 70 µm[3]	-
Rivet		Hot dip galvanized (F) ≥ 45 µm	-
Anchor		Hot dip galvanized (F) ≥ 45 µm	-
Channel bolt	Grade 4.6 and 8.8 according to DIN EN ISO 898-1:2009-8	Hot dip galvanized (F) ≥ 45 µm, or electroplated (G) ≥ 8 µm	Grade 50 according to DIN EN ISO 3506-1:2010-4, passivation according ASTM A380
Plain washer[4] ISO 7089 and ISO 7093-1	Hardness A, 200 HV	Hot dip galvanized (F), or electroplated (G)	Hardness A, 200 HV according to ISO 3506-1
Hexagonal nut ISO 4032 or DIN 934[5]	Property class 8 according to ISO 898-2, or property class 5 according to DIN 267-4	Hot dip galvanized (F) ≥ 45 µm, or electroplated (G) ≥ 8 µm	Property class 70 according to DIN 267-11

1 Design information in this table is taken from ICC-ES ESR-3520, dated April 2019, table 8-13
2 For HAC-30F, HAC-40F and HAC(-T)50
3 For HAC-60F and HAC(-T)70
4 Not in scope of delivery
5 Hexagonal nuts DIN 934 for channel bolts made from carbon steel grade 4.6 and stainless steel bolts

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