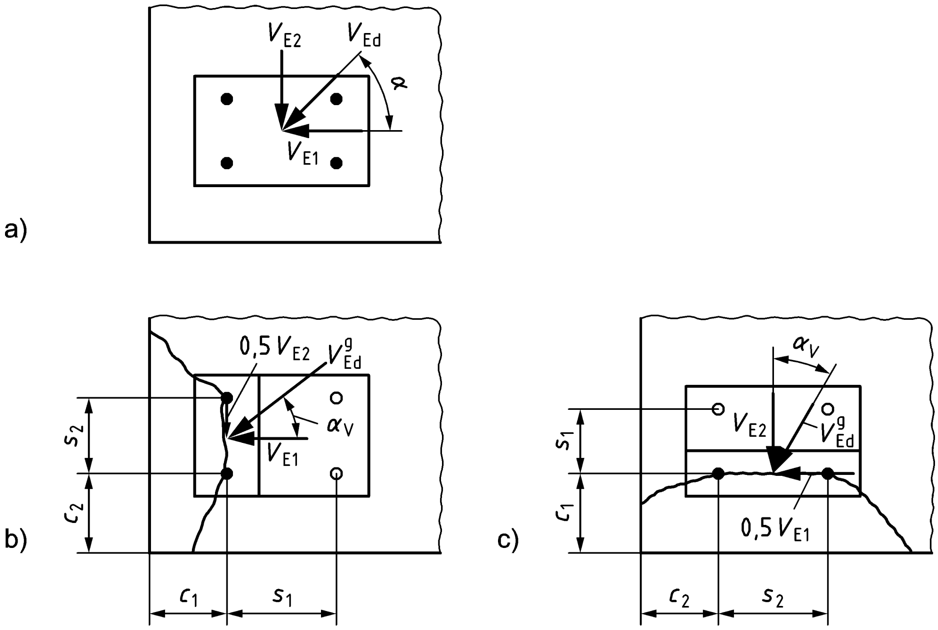


Key

$V_{\mathrm{E1}} = V_{\mathrm{Ed}}\ \cos\alpha$

$V_{\mathrm{E2}} = V_{\mathrm{Ed}}\ \sin\alpha$

a) applied action
b) verification for the left edge
c) verification for the bottom edge
● fastener in a); loaded fastener in b) and c)
○ unloaded fastener in b) and c)

Figure 7.12 — Verification for a quadruple fastening with hole clearance at a corner – Example

(5) The characteristic resistance $V_{\mathrm{Rk,c}}$ of a fastener or a group of fasteners loaded towards the edge is:

$$V_{\mathrm{Rk,c}} = V^{0}_{\mathrm{Rk,c}} \cdot \frac{A_{\mathrm{c,V}}}{A^{0}_{\mathrm{c,V}}} \cdot \psi_{\mathrm{s,V}} \cdot \psi_{\mathrm{h,V}} \cdot \psi_{\mathrm{ec,V}} \cdot \psi_{\alpha,\mathrm{V}} \cdot \psi_{\mathrm{re,V}} \qquad (7.40)$$

The different factors of Formula (7.40) are given below.

(6) The initial value of the characteristic resistance of a fastener loaded perpendicular to the edge is calculated as:

$$V^{0}_{\mathrm{Rk,c}} = k_9 \cdot d^{\alpha}_{\mathrm{nom}} \cdot l^{\beta}_{\mathrm{f}} \cdot \sqrt{f_{\mathrm{ck}}} \cdot c_1^{1{,}5} \qquad (7.41)$$

with

k_9 = 1,7 for cracked concrete
= 2,4 for uncracked concrete

$$\alpha = 0{,}1 \cdot \left(\frac{l_{\mathrm{f}}}{c_1}\right)^{0{,}5} \qquad (7.42)$$

$$\beta = 0,1 \cdot \left(\frac{d_{\text{nom}}}{c_1} \right)^{0,2} \tag{7.43}$$

l_f = h_ef in case of a uniform diameter of the shank of the headed fastener and a uniform diameter of the post-installed fastener

$\leq 12\ d_{\text{nom}}$ in case of $d_{\text{nom}} \leq 24$ mm

$\leq \max\left\{8\ d_{\text{nom}};\ 300\ \text{mm}\right\}$ in case of $d_{\text{nom}} > 24$ mm

The values d_nom and l_f are given in the relevant European Technical Product Specification.

(7) The ratio $A_{\text{c,V}} / A_{\text{c,V}}^0$ takes into account the geometrical effect of spacing as well as of further edge distances and the effect of thickness of the concrete member on the characteristic resistance.

$A_{\text{c,V}}^0$ is the reference projected area, see Figure 7.13

$$= 4,5\ c_1^2 \tag{7.44}$$

$A_\text{c,V}$ is the area of the idealized concrete break-out body, limited by the overlapping concrete cones of adjacent fasteners $\left(s \leq 3\ c_1\right)$ as well as by edges parallel to the assumed loading direction $\left(c_2 \leq 1,5\ c_1\right)$ and by member thickness $\left(h < 1,5\ c_1\right)$. Examples for the calculation of $A_\text{c,V}$ are given in Figure 7.14.

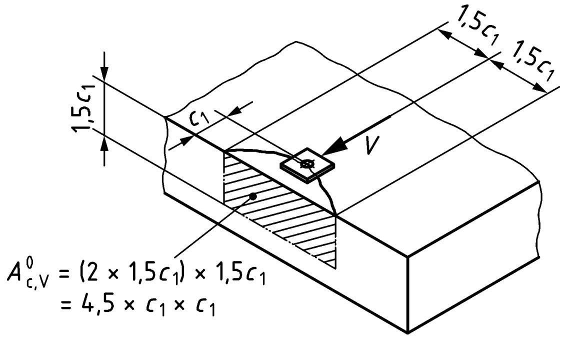
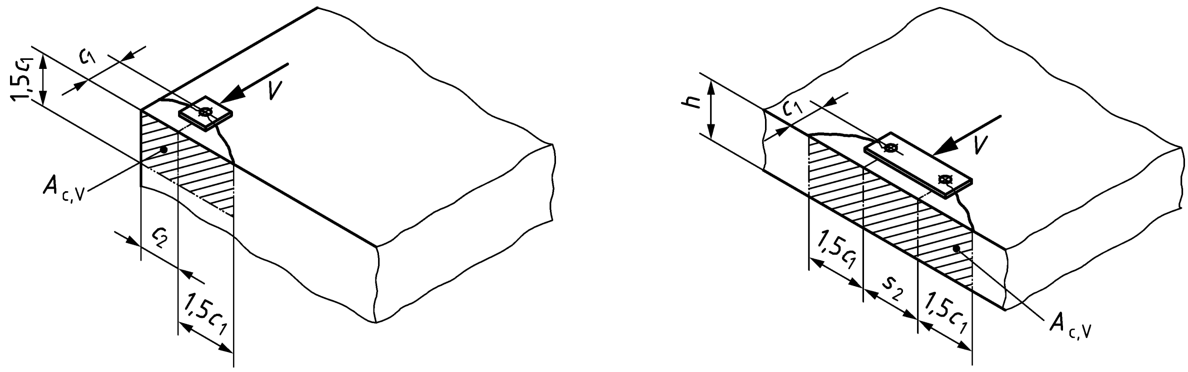


Figure 7.13 — Idealized concrete break-out body and area $A_{\text{c,V}}^0$ for a single fastener



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

$h \geq 1,5\, c_1$

$c_2 \leq 1,5\, c_1$

a) Single fastener at a corner

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

$h < 1,5 c_1$

$s_2 \leq 3\, c_1$

b) Group of fasteners at an edge in a thin concrete member

Figure 7.14 — Examples of actual projected areas $A_{c,V}$ of the idealized concrete break-out bodies for different fastener arrangements under shear loading

(8) Resistance calculated in accordance with Formula (7.40) may be unconservative for concrete edge failure in cases where the fastenings comprising two fasteners are subject to torsion resulting in shear in opposite directions in the fasteners due to overlapping of the concrete breakout bodies. If the ratio between the concrete edge breakout resistance (verified edge) to the concrete breakout resistance of the second fastener (pry-out or edge failure) is larger than 0,7 and $s_2 \leq s_{crit}$, $V_{Rk,c}$ according to Formula (7.40) should be multiplied by a factor of 0,8 which is assumed to be conservative. Herein, s_{crit} is defined as follows:

— $s_{crit} = 1,5h_{ef} + 1,5c_1$, if the second fastener is governed by pry-out failure;

— $s_{crit} = 1,5c_1$, if the second fastener is governed by concrete edge failure with respect to a second edge (perpendicular to the verified edge).

(9) The factor $\psi_{s,V}$ takes account of the disturbance of the distribution of stresses in the concrete due to further edges of the concrete member on the shear resistance. For fastenings with two edges parallel to the direction of loading (e.g. in a narrow concrete member) the smaller value of these edge distances shall be used for c_2 in Formula (7.45).

$$\psi_{s,V} = 0,7 + 0,3 \cdot \frac{c_2}{1,5\, c_1} \leq 1 \qquad (7.45)$$

(10) The factor $\psi_{h,V}$ takes account of the fact that the concrete edge resistance does not decrease proportionally to the member thickness as assumed by the ratio $A_{c,V} \,/\, A^0_{c,V}$ (Figure 7.14 b)).

$$\psi_{h,V} = \left(\frac{1,5c_1}{h} \right)^{0,5} \geq 1 \qquad (7.46)$$

(11) The factor $\psi_{\text{ec,V}}$ takes into account a group effect when different shear loads are acting on the individual fasteners of a group (see Figure 7.15).

$$\psi_{\text{ec,V}} = \frac{1}{1 + 2 \cdot e_{\text{V}} / (3c_1)} \leq 1 \qquad (7.47)$$

where

e_{V} is the eccentricity of the resulting shear load acting on the fasteners relative to the centre of gravity of the fasteners loaded in shear

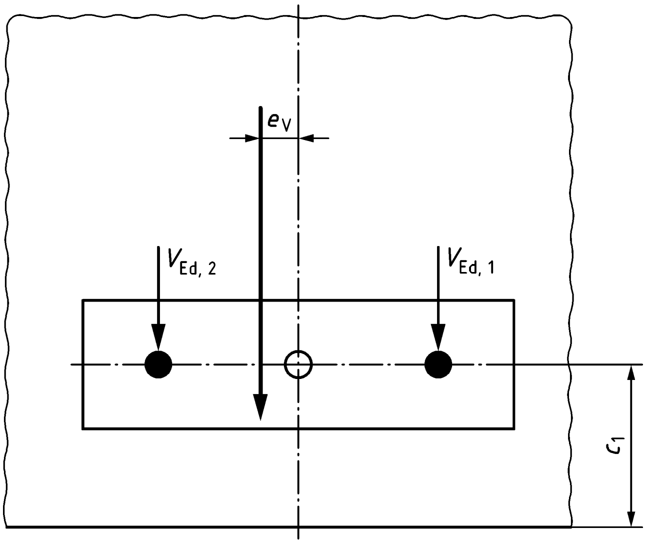


Figure 7.15 — Resolving unequal shear components into an eccentric shear load resultant – Example

(12) The factor $\psi_{\alpha,\text{V}}$ takes account of the influence of a shear load inclined to the edge under consideration on the concrete edge resistance.

$$\psi_{\alpha,\text{V}} = \sqrt{\frac{1}{(\cos \alpha_{\text{V}})^2 + (0{,}5 \cdot \sin \alpha_{\text{V}})^2}} \geq 1 \qquad (7.48)$$

where

α_{V} is the angle between design shear load V_{Ed} (single fastener) or V_{Ed}^{g} (group of fasteners) and a line perpendicular to the verified edge, $0° \leq \alpha_{\text{V}} \leq 90°$, see Figure 7.12.

(13) The factor $\psi_{\text{re,V}}$ takes account of the effect of the reinforcement located on the edge.

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

$\psi_{\text{re,V}} = 1{,}4$ fastening in cracked concrete with edge reinforcement (see Figure 7.10) and closely spaced stirrups or wire mesh with a spacing $a \leq 100$ mm and $a \leq 2c_1$.