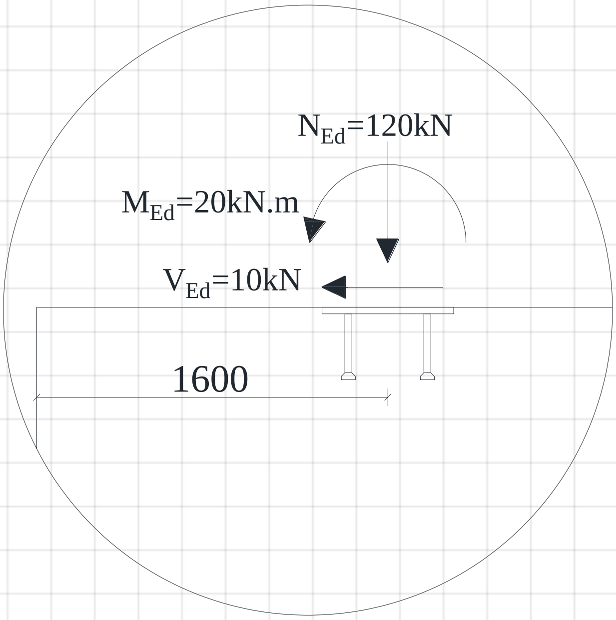
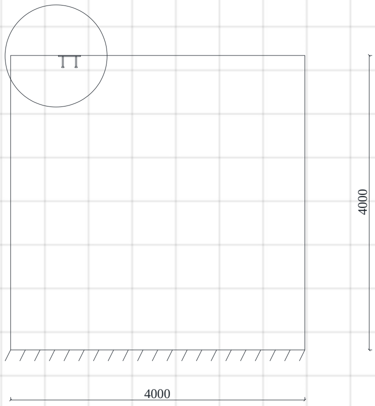
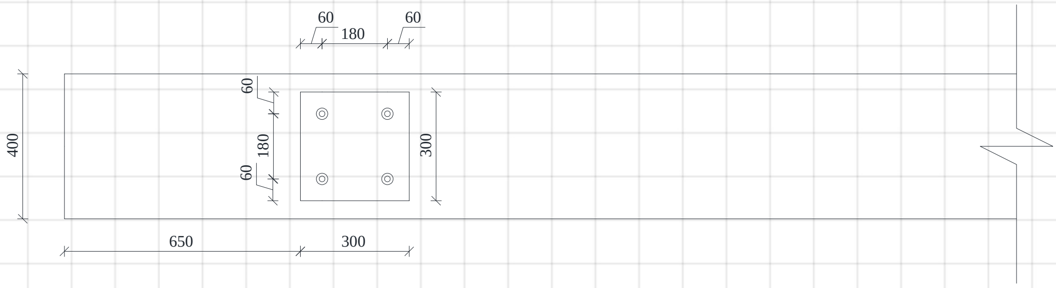
In the previous video, the embedded plates under the given loads have been verified for shear. In this video, the concrete edge failure will be verified according to Eurocode1992-4.

The wall thickness is 400mm made of C30/37 concrete class. The loads applied to the plate are given in design format (Ed), as shown in the figure. Dimensions are provided in mm.



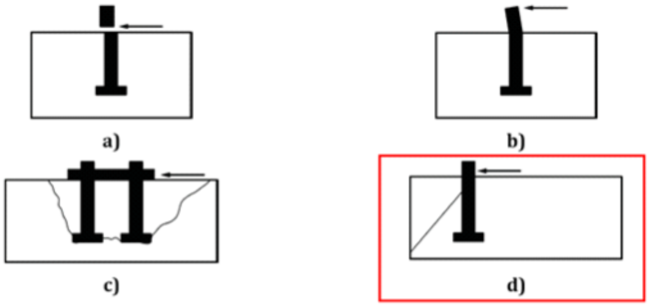




7.2.2 Shear load

7.2.2.1 Required verifications

The verifications of Table 7.2 apply. The failure modes addressed are given in Figure 7.9:



Key

a) steel failure without lever arm

b) steel failure with lever arm

c) concrete pry-out failure

d) concrete edge failure

Figure 7.9 — Failure modes of headed and post-installed fasteners under shear load

Table 7.2 — Required verifications for headed and post-installed fasteners in shear

	Failure mode	Single fastener	Group of fasteners	
			most loaded fastener	group
4	Concrete edge failure	$V_{Ed} \le V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$		$V_{Ed}^{g} \le V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$

6.2.2 Shear loads

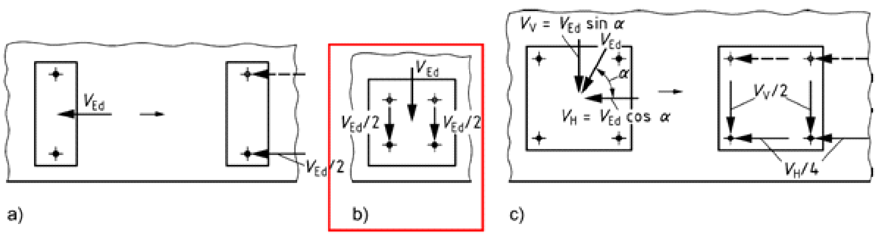
6.2.2.1 General

Only fastenings with no hole clearances or clearances in the direction of the shear load complying with Table 6.1 are covered by this EN.

6.2.2.2 Distribution of loads

(1) The load distribution depends on the effectiveness of fasteners to resist shear loads which is, e.g. influenced by the hole clearance and the edge distance. The following cases are distinguished.

b) Only fasteners closest to the edge loaded in shear are assumed to be effective for the verification of concrete edge failure if the fastening is located close to the edge $\left(c < \max\left\{10h_{ef}\,;60d_{nom}\right\}\right)$ and loaded perpendicular to the edge (see Figure 6.5 b)).



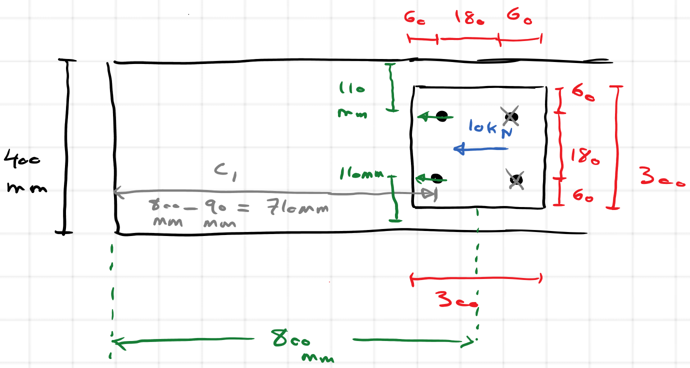
Key

a) group with two fasteners close to an edge loaded parallel to the edge

b) group with four fasteners close to an edge loaded perpendicular to the edge

c) quadruple fastening close to an edge loaded by an inclined shear load

Figure 6.5 — Determination of shear loads for verification of concrete edge failure; only the forces in the fasteners closest to the edge (solid lines) are considered in the verification – Examples



7.2.2.5 Concrete edge failure

(1) For embedded base plates with an edge distance in direction of the shear load $c \leq \max\{10\, h_{ef}\,;\, 60\, d\}$ the provisions are valid only if the thickness t of the base plate in contact with the concrete is smaller than 0,25 h_{ef}. For fastenings where the shear load acts with lever arm, the provisions are valid if $c > \max\{10\, h_{ef}\,;\, 60\, d\}$.

NOTE In case of fastenings located close to an edge and loaded by a shear load with lever arm the effect of an overturning moment on the concrete edge resistance is not considered in the following provisions.

(2) Only the fasteners located closest to the edge are used for the verification of concrete edge failure (see Figure 7.12). For load distribution see 6.2.2.2.

(3) For fastenings with more than one edge (see Figure 7.12), the verification shall be carried out for all edges.

(4) The minimum spacing of fasteners in a group should be $s_{min} \geq 4 d_{nom}$.

$c_1 = 710$ mm $h_{ef} = 157$ mm, $d = 16$ mm

$$710\ \text{mm} = c_1 \leq \max\{\underbrace{10 \times 157\ \text{mm}}_{1570\ \text{mm}},\ \underbrace{60 \times 16\ \text{mm}}_{960\ \text{mm}}\} \quad (\text{OK})$$

7.2.2.5 Concrete edge failure

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

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

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:

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

with

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

$$\alpha = 0,1 \cdot \left(\frac{l_f}{c_1}\right)^{0,5} \quad (7.42)$$

$c_1 = 710$ mm

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

$d_{nom} = 16$ mm

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

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

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

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

$l_f = \min\{h_{ef}, 12\, d_{nom}\}$ if $d_{nom} \leq 24$ mm

h_{ef} → 157 mm ; d_{nom} → 16 mm

$l_f = 157$ mm

$\alpha = 0.1\left(\frac{157\text{ mm}}{710\text{ mm}}\right)^{0.5} = 0.047$

$\beta = 0.1\left(\frac{16\text{ mm}}{710\text{ mm}}\right)^{0.2} = 0.047$

$V^0_{Rk,c} = k_9 \cdot d_{nom}^{\alpha} \cdot l_f^{\beta} \cdot \sqrt{f_{ck}} \cdot c_1^{1.5}$

k_9 → 1.7 ; d_{nom} → 16 mm ; α = 0.047 ; l_f → 157 mm ; β = 0.047 ; f_{ck} → 30 MPa ; c_1 → 710 mm

⇒ $V^0_{Rk,c} = 254$ kN

(7) The ratio $A_{c,V}/A^0_{c,V}$ 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.

$A^0_{c,V}$ is the reference projected area, see Figure 7.13

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

$A^0_{cv} = 4.5\, c_1^2 = 2268450\ mm^2$ (c_1 = 710 mm)

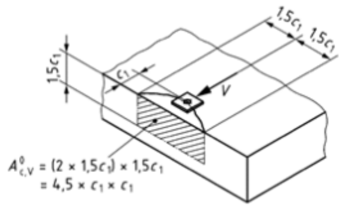
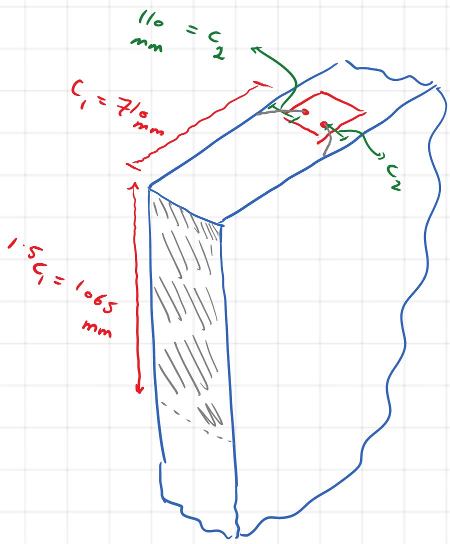
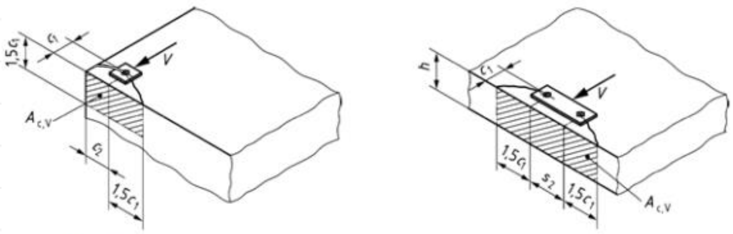


Figure 7.13 — Idealized concrete break-out body and area $A^0_{c,V}$ for a single fastener

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





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

$h \ge 1{,}5\, c_1$

$c_2 \le 1{,}5\, c_1$

a) Single fastener at a corner

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

$h < 1{,}5 c_1$

$s_2 \le 3\, c_1$

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

$A_{cv} = 1065\,mm \times 400\,mm = 426000\ mm^2$

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

7.2.2.5 Concrete edge failure

(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).

$$\psi_{s,V} = 0{,}7 + 0{,}3 \cdot \frac{c_2}{1{,}5\, c_1} \le 1 \tag{7.45}$$

$\psi_{sv} = 0.7 + 0.3 \left(\frac{110\,mm}{1.5 \times 710\,mm} \right) \le 1$

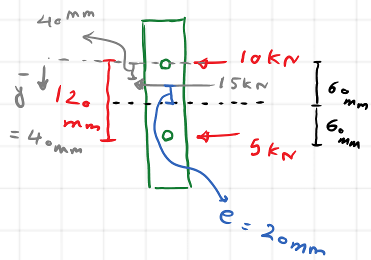
$\psi_{sv} = 0.73$

(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_{cv} / A^0_{cv} (Figure 7.14 b)).

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

$\psi_{hv} = 1$

$\bar{y} = \frac{5\,kN \times 120\,mm}{10\,kN + 5\,kN} = 40\,mm$



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

$$\psi_{ec,V} = \frac{1}{1 + 2 \cdot e_V / (3c_1)} \le 1 \tag{7.47}$$

$e_v = 0 \Rightarrow \psi_{ec,V} = \frac{1}{1 + 2 \times \frac{0}{3c_1}} = 1$

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

7.2.2.5 Concrete edge failure

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

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

$\psi_{\alpha,V} = 1$

where

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

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

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

$\psi_{re,V} = 1$

$\psi_{re,V} = 1{,}4$ 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 $a \leq 2c_1$.

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

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

$A_{c,V} \to 426000$; $\psi_{h,V} \cdot \psi_{ec,V} \cdot \psi_{\alpha,V} \cdot \psi_{re,V} \to 1$; $V^0_{Rk,c} \to 254$ kN; $A^0_{c,V} \to 226845$; $\psi_{s,V} \to 0.73$

$V_{Rk,c} = 34.8$ kN

$V_{Ed} \leq \frac{V_{Rk,c}}{\gamma_{Mc}}$ ($V_{Ed} \to 10$ kN; $V_{Rk,c} \to 34.8$ kN; $\gamma_{Mc} \to 1.5$)

$\Rightarrow 10\text{ kN} \leq \frac{34.8\text{ kN}}{1.5} = 23.2\text{ kN}$

$UR = \frac{10\text{ kN}}{23.2\text{ kN}} = 43\%$