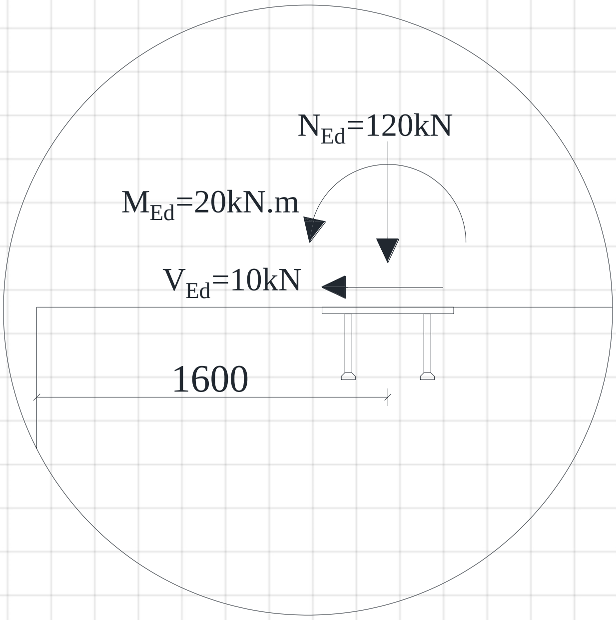
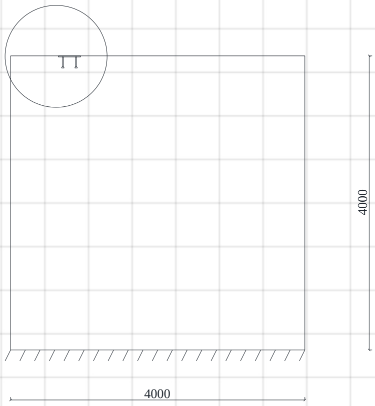
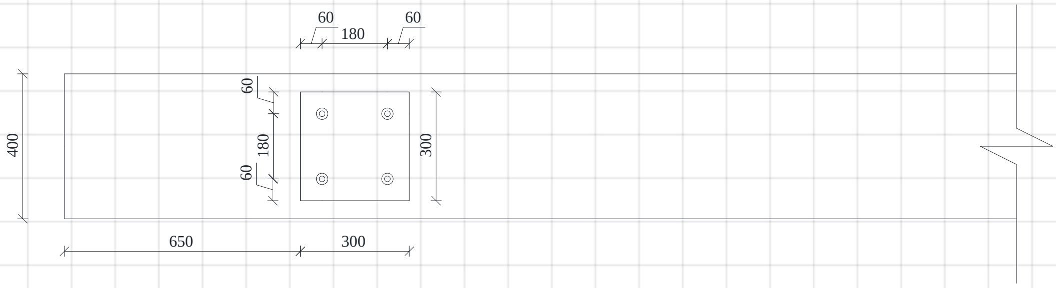
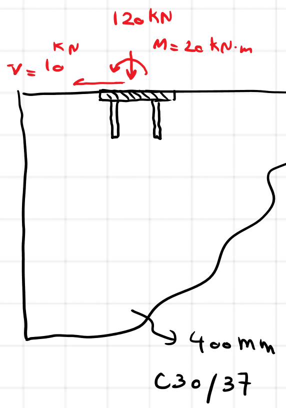
In the previous video, the embedded plates under the given loads have been verified for tension. In this video, the shear force calculation and how shear force needs to be verified is explained according to Eurocode1992-4.

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.









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.

a) All fasteners are considered to be effective for each of the following cases:

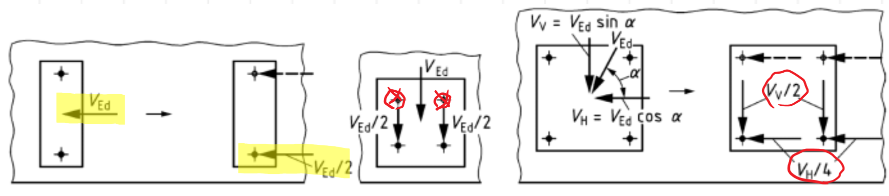
1) if the fastening is located far from an edge $\left(c_i \geq \max\left\{10h_{ef}; 60d_{nom}\right\}\right)$;

2) for verification of steel failure and pry-out failure;

3) if the fastening is loaded by a torsion moment (see Figure 6.4), or by a shear load parallel to the edge (see Figure 6.5 a)).

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)).

(2) A fastener is not considered to resist shear loads if the hole is slotted in the direction of the shear force.



a) b) c)

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

6.2.2.3 Shear loads with and without lever arm

(1) Shear loads acting on fastenings may be assumed to act without a lever arm if all of the following conditions are satisfied.

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

b) The fixture is fixed:

1) either directly to the concrete without an intermediate layer; or

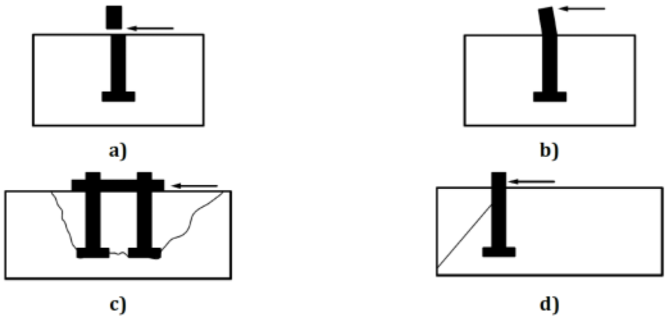
2) using a levelling mortar with a thickness $t_{grout} \leq 0{,}5d$ under at least the full dimensions of the fixture on a rough concrete surface (see EN 1992-1-1:2004, 6.2.5) as intermediate layer; the strength of the mortar shall be at least that of the base concrete but not less than 30 N/mm².

When the above conditions are not satisfied, shear force on fastenings should be assumed to act with lever arm.

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
1	Steel failure of fastener without lever arm	$V_{Ed} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	$V^h_{Ed} \leq V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms}}$	
2	Steel failure of fastener with lever arm	$V_{Ed} \leq V_{Rd,s,M} = \frac{V_{Rk,s,M}}{\gamma_{Ms}}$	$V^h_{Ed} \leq V_{Rd,s,M} = \frac{V_{Rk,s,M}}{\gamma_{Ms}}$	
3	Concrete pry-out failure	$V_{Ed} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$		$V^g_{Ed} \leq V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$ [a]
4	Concrete edge failure	$V_{Ed} \leq V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$		$V^g_{Ed} \leq V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}}$
5	Steel failure of supplementary reinforcement [b]	$N_{Ed,re} \leq N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$	$N^h_{Ed,re} \leq N_{Rd,re} = \frac{N_{Rk,re}}{\gamma_{Ms,re}}$	
6	Anchorage failure of supplementary reinforcement [b]	$N_{Ed,re} \leq N_{Rd,a}$	$N^h_{Ed,re} \leq N_{Rd,a}$	

[a] Exception see 7.2.2.4 (4).
[b] The tension force acting on the reinforcement is calculated from V_{Ed} according to Formula (6.6).

7.2.2.3 Steel failure of fastener

7.2.2.3.1 Shear load without lever arm

(1) The characteristic resistance of a single fastener in case of steel failure $V^0_{\mathrm{Rk,s}}$ is given in the relevant European Technical Product Specification.

NOTE For a single fastener made out of carbon steel without sleeve in the sheared section (threaded rod) and without significant reduction in cross-section along its total length $V^0_{\mathrm{Rk,s}}$ can be calculated as follows:

$$V^0_{\mathrm{Rk,s}} = k_6 \cdot A_s \cdot f_{\mathrm{uk}} \qquad (7.34)$$

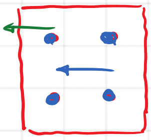
where

k_6 = 0,6 for $f_{\mathrm{uk}} \leq 500\ \mathrm{N/mm^2}$

= 0,5 for $500\ \mathrm{N/mm^2} < f_{\mathrm{uk}} \leq 1\,000\ \mathrm{N/mm^2}$

For fasteners with a ratio $h_{\mathrm{ef}} / d < 5$ and a concrete compressive strength class < C20/25 the characteristic resistance $V^0_{\mathrm{Rk,s}}$ should be multiplied by a factor of 0,8.

$\frac{1}{4} \times V_{Ed} = 2.5$ kN



$V_{Ed} = 10$ kN

$\frac{h_{ef}}{d} = \frac{157\,mm}{16\,mm} = 9.8 \nless 5$

C30/37 ≮ C20/25

$f_{uk} = 450$ MPa

$A_s = \frac{\pi \times (16mm)^2}{4} = 201\ mm^2$

$k_6 = 0.6$

$\rightarrow V^0_{Rk,s} = 0.6 \times 201\ mm^2 \times 450\ MPa = 54.3$ kN

(2) The characteristic resistance of a fastener $V_{\mathrm{Rk,s}}$ accounting for ductility of the fastener in a group and including a possible grout layer with a thickness $t_{\mathrm{grout}} \leq d / 2$ is:

$$V_{\mathrm{Rk,s}} = k_7 \cdot V^0_{\mathrm{Rk,s}} \qquad (7.35)$$

where

for single fasteners $k_7 = 1$;

for fasteners in a group k_7 is given in the relevant European Technical Product Specification.

NOTE For fasteners in a group the factor k_7 for ductile steel can be assumed as $k_7 = 1$, for steel with a rupture elongation $A_5 \leq 8\%$ a value $k_7 = 0{,}8$ can be used.

$V_{Rk,s} = 1 \times 54.3\,kN = 54.3\,kN$

Table 4.1 — Recommended values of partial factors

Failure modes	Partial factor		
		Permanent and transient design situations	Accidental design situation
Steel failure – fasteners			
Tension	γ_{Ms}	$= 1,2 \cdot f_{uk}/f_{yk} \geq 1,4$	$= 1,05 \cdot f_{uk}/f_{yk} \geq 1,25$
Shear with and without lever arm		$= 1,0 \cdot f_{uk}/f_{yk} \geq 1,25$ when $f_{uk} \leq 800$ N/mm² and $f_{yk}/f_{uk} \leq 0,8$	$= 1,0 \cdot f_{uk}/f_{yk} \geq 1,25$ when $f_{uk} \leq 800$ N/mm² and $f_{yk}/f_{uk} \leq 0,8$
		$= 1,5$ when $f_{uk} > 800$ N/mm² or $f_{yk}/f_{uk} > 0,8$	$= 1,3$ when $f_{uk} > 800$ N/mm² or $f_{yk}/f_{uk} > 0,8$

$$\begin{cases} f_{uk} = 450\,MPa < 800\,MPa \\ \dfrac{f_{yk}}{f_{uk}} = \dfrac{350}{450} = 0.78 < 0.8 \end{cases} \rightarrow \gamma_{Ms} = \max\left\{1 \cdot \frac{f_{uk}}{f_{yk}} = 1.28,\ 1.25\right\} = 1.28$$

$$V_{Ed} = 2.5\,kN$$

$$V_{Rd} = \frac{V_{Rk,s}}{\gamma_{Ms}} = \frac{54.3\,kN}{1.28} = 42.4\,kN$$

$$UR = \frac{V_{Ed}}{V_{Rd}} = \frac{2.5\,kN}{42.4\,kN} = 5.9\,\%$$