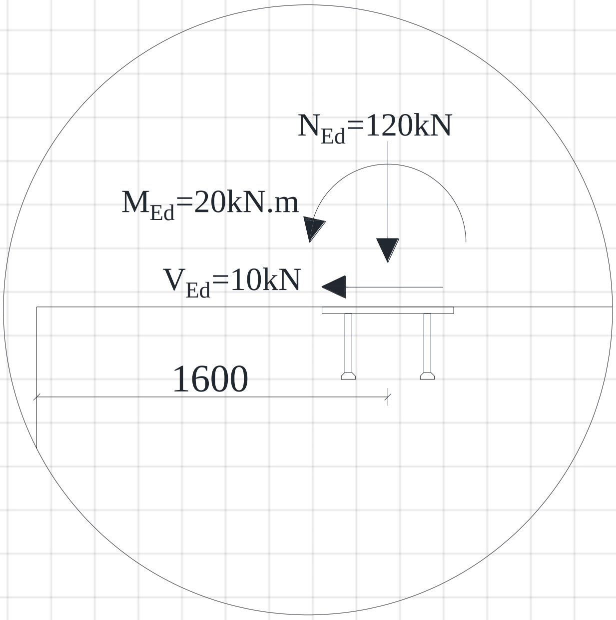
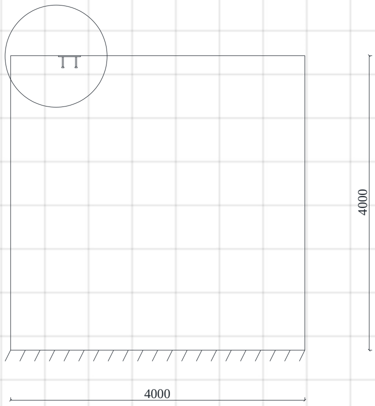
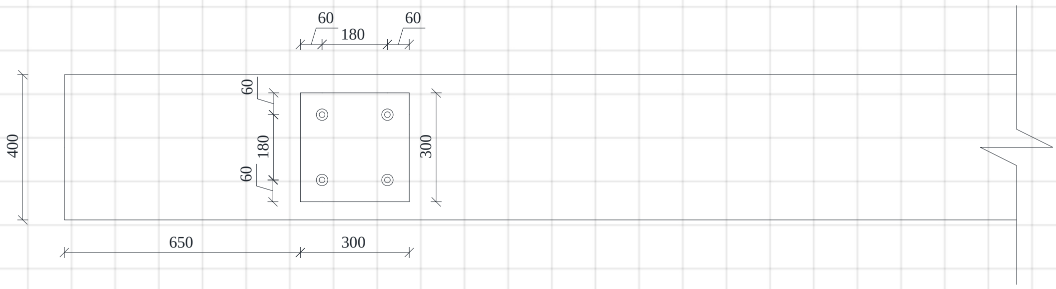
In the previous video, we went through the concrete edge failure. In this video, the concrete pry-out failure and combined tension and shear force will be verified according to Eurocode1992-4.

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.



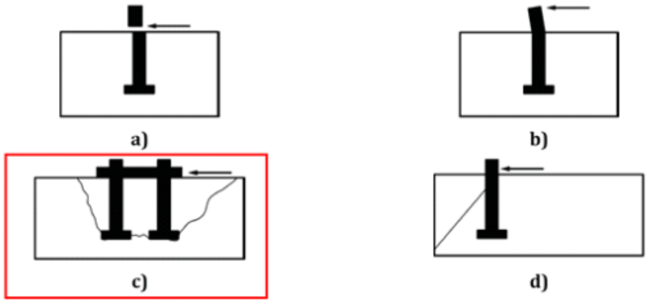




7.2.2 Shear load

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	
3	Concrete pry-out failure	$V_{Ed} \le V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$		$V_{Ed}^{g} \le V_{Rd,cp} = \frac{V_{Rk,cp}}{\gamma_{Mc}}$	a

[a] Exception see 7.2.2.4 (4).

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

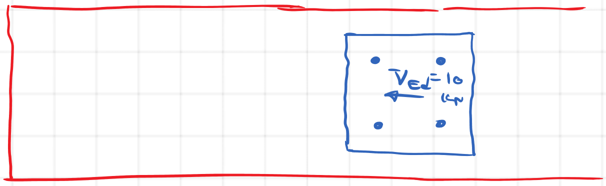
(1) The load distribution depends on the effectiveness of fasteners to resist shear loads which is, e.g. influenced by the hole clearance and the edge distance. The following cases are distinguished.

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

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

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)).



7.2.2.4 Concrete pry-out failure

(1) Fastenings may fail due to a concrete pry-out failure at the side opposite to load direction. Pull-out failure may also occur due to a tension force introduced in the fasteners by the shear load. For reason of simplicity this effect is not verified explicitly, but implicitly accounted for in the verification for pry-out failure, where relevant.

NOTE The tension force is caused by the eccentricity between the applied shear force and the resultant of the resistance in the concrete.

(2) The corresponding characteristic resistance $V_{Rk,cp}$ shall be calculated for fastenings with headed or mechanical post-installed fasteners as follows:

— for fastenings without supplementary reinforcement

$$V_{Rk,cp} = k_8 \cdot N_{Rk,c} \tag{7.39a}$$

$k_8 = 2$

— for fastenings with supplementary reinforcement

$$V_{Rk,cp} = 0{,}75 \cdot k_8 \cdot N_{Rk,c} \tag{7.39b}$$

where

k_8 is a factor to be taken from the relevant European Technical Product Specification

$N_{Rk,c}$ is determined according to 7.2.1.4 for a single fastener or all fasteners in a group loaded in shear.

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English translation prepared by CSTB

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Table 5: Characteristic values for shear loads in case of static and quasi static loading for design method A

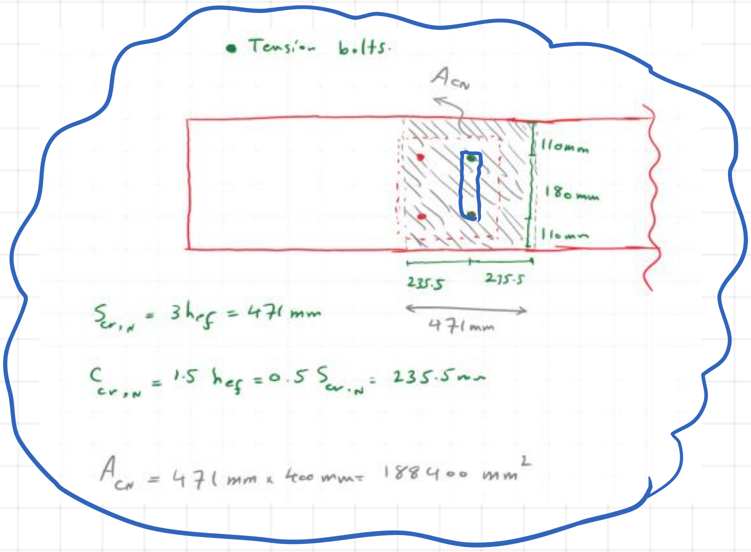
			M8	M10	M12	M16
Steel failure without lever arm						
Char. resistance	$V_{Rk,s}$	[kN]	8,1	17,6	24,7	45,9
Partial safety factor	γ_{Ms} [1]	[-]	1,25			
Steel failure with lever arm						
Char. bending resistance	$M^0_{Rk,s}$	[Nm]	22,8	45,5	76,6	194,8
Partial safety factor	γ_{Ms} [1]	[-]	1,25			
Concrete pry-out failure						
Factor for determination of resistance to pry-out failure	$k_3=k_8$	[-]	1,0	2,0	2,0	2,0
Partial safety factor	$\gamma_2 = \gamma_{inst}$ [1]	[-]	1,0			

7.2.1.4 Concrete cone failure

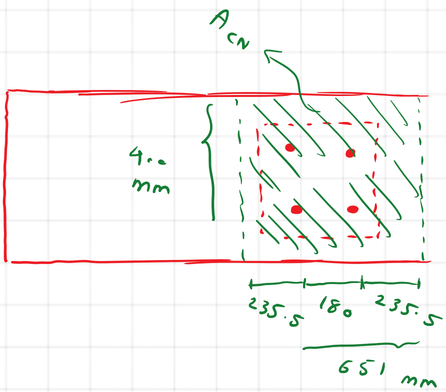
(1) The characteristic resistance of a fastener, a group of fasteners and the tensioned fasteners of a group of fasteners in case of concrete cone failure shall be obtained as given in Formula (7.1):

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N} \quad (7.1)$$

$N^0_{Rk,c}$ → 95.9 kN; $A^0_{c,N}$ → 221841 mm²; $\psi_{s,N}$ → 0.84; $\psi_{re,N}$ → 1; $\psi_{ec,N}$ → 1; $\psi_{M,N}$ → 1



Concrete Cone failure



$A_{cN} = 651\ mm \times 400\ mm = 260400\ mm^2$

$N_{Rk,c} = 95.9\ kN \times \frac{260400\ mm^2}{221841\ mm^2} \times 0.84 \times 1 \times 1 \times 1 = 94.6\ kN$

$V_{Rk,cp} = k_8 \cdot N_{Rk,c} = 2 \times 94.6\ kN = 189.11\ kN$

$V^g_{Ed} \leq \frac{V_{Rk,cp}}{\gamma_{Mc}} \Rightarrow 10\ kN \leq \frac{189.11\ kN}{1.5} = 126\ kN$

$UR = \frac{10\ kN}{126\ kN} = 7.9\ \%$

(UR)

	Tension	Shear
Steel	26%	5.9%
Concrete	67%, 17% 48%, NA	43% 7.9%

7.2.3 Combined tension and shear loads

7.2.3.1 Fastenings without supplementary reinforcement

The required verifications are given in Table 7.3. Verifications for steel and concrete failure modes are carried out separately. Both verifications shall be fulfilled.

Table 7.3 — Required verifications for headed and post-installed fasteners without supplementary reinforcement subjected to a combined tension and shear load

	Failure mode	Verification
1	Steel failure of fastener [a]	$\left(\frac{N_{Ed}}{N_{Rd,s}}\right)^2 + \left(\frac{V_{Ed}}{V_{Rd,s}}\right)^2 \leq 1$ (7.54) If N_{Ed} and V_{Ed} are different for the individual fasteners of the group, the interaction shall be verified for all fasteners.
2	Failure modes other than steel failure	$\left(\frac{N_{Ed}}{N_{Rd,i}}\right)^{1,5} + \left(\frac{V_{Ed}}{V_{Rd,i}}\right)^{1,5} \leq 1$ (7.55) or $\left(\frac{N_{Ed}}{N_{Rd,i}}\right) + \left(\frac{V_{Ed}}{V_{Rd,i}}\right) \leq 1,2$ (7.56) with $N_{Ed} / N_{Rd,i} \leq 1$ and $V_{Ed} / V_{Rd,i} \leq 1$ The largest value of $N_{Ed} / N_{Rd,i}$ and $V_{Ed} / V_{Rd,i}$ for the different failure modes shall be taken.

[a] This verification is not required in case of shear load with lever arm as Formula (7.37) accounts for the interaction.

26%   5.9%

→ 7.54)

$0.26^2 + 0.06^2 = 0.07$ → 7% (OK)

7.55 → $0.67^{1.5} + 0.43^{1.5} = 0.83$ 83% ≤ 100% (OK)   UR = 83%

7.56 → $0.67 + 0.43 = 1.1 \leq 1.2$ → $UR = \frac{1.1}{1.2} = 92\%$