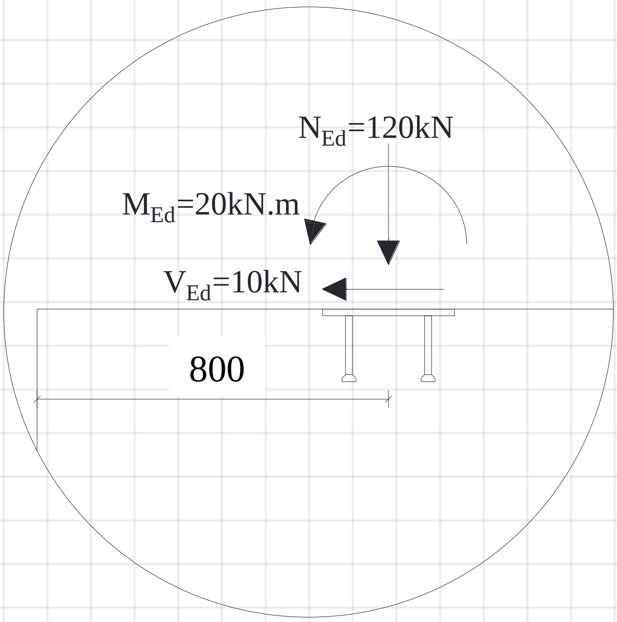
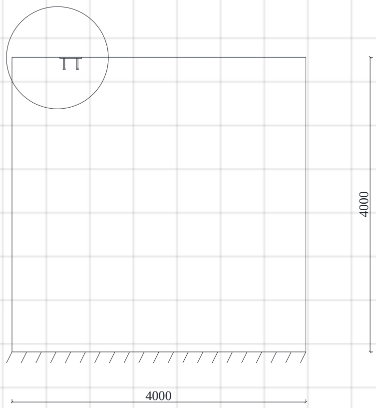
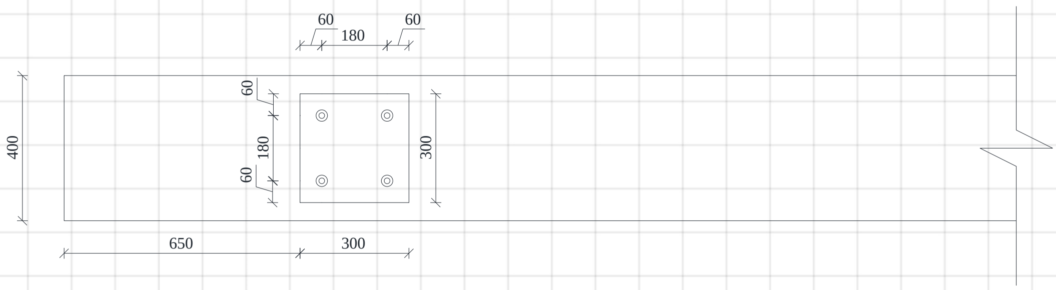
In the previous video, the tension force in the anchor bolts has been calculated. According to Eurocode1992-4, verify the anchor bolts for the following criteria:

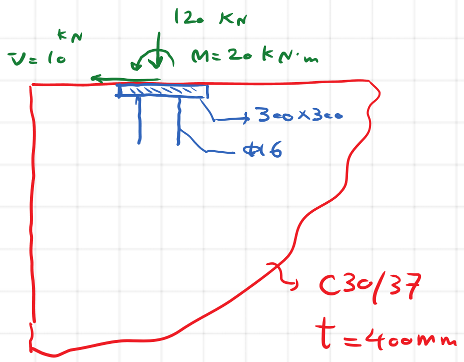
a) Steel failure
b) Concrete cone failure

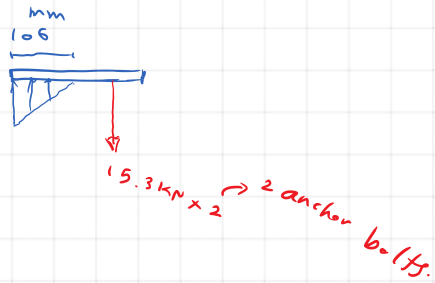
The wall thickness is 400mm made of C30/37 concrete class. The loads applied to the plate are given in design format (Ed), as shown in the figure. Dimensions are provided in mm.











7.2.1.3 Steel failure of fastener

The characteristic resistance of a fastener in case of steel failure $N_{Rk,s}$ is given in the relevant European Technical Product Specification. The characteristic resistance is based on f_{uk}.

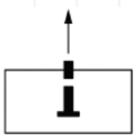
$f_{uk} = 450\ MPa$

$f_{yk} = 350\ MPa$

$$\rightarrow \gamma_{MS} = \max\left\{1.2\frac{f_{uk}}{f_{yk}} = 1.54,\ 1.4\right\} = 1.54$$

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 $f_{yk}/f_{uk} > 0{,}8$



a)

Table 7.1 — Required verifications for headed and post-installed fasteners in tension

Failure mode	Single fastener	Group of fasteners	
		most loaded fastener	group
Steel failure of fastener	$N_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$	$N^h_{Ed} \leq N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}}$	

$N_{Ed} = T_{Ed} = 15.3\ kN$

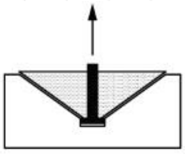
$$N_{Rd,s} = \frac{N_{Rk,s}}{\gamma_{Ms}} = \frac{f_{uk} \cdot A_s}{\gamma_{Ms}}$$

$f_{uk} = 450\ MPa$

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

$\rightarrow N_{Rd,s} = 58.75\ kN$

$$UR = \frac{N_{Ed}}{N_{Rd,s}} = \frac{15.3\ kN}{58.75\ kN} = 26\%$$



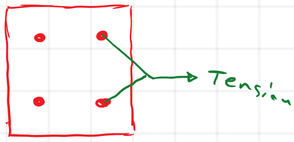


Table 7.1 — Required verifications for headed and post-installed fasteners in tension

	Failure mode	Single fastener	Group of fasteners	
			most loaded fastener	group
2	Concrete cone failure	$N_{Ed} \le N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$		$N^{g}_{Ed} \le N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$

$N^{g}_{Ed} = 2 \times 15.3 kN = 30.6 kN$

Table 4.1 — Recommended values of partial factors

Failure modes	Partial factor		
		Permanent and transient design situations	Accidental design situation
Concrete related failure			
Concrete cone failure, concrete edge failure, concrete blow-out failure, concrete pry-out failure	γ_{Mc}	$= \gamma_c \cdot \gamma_{inst}$	$= \gamma_c \cdot \gamma_{inst}$
	γ_c	= 1,5[a] for seismic repair and strengthening of existing structures see the EN 1998 series	= 1,2[a] for seismic repair and strengthening of existing structures see the EN 1998 series
	γ_{inst}	= 1,0 for headed fasteners and anchor channels satisfying the requirements of 4.6 (in tension and shear) ≥ 1,0 for post-installed fasteners in tension, see relevant European Technical Product Specification = 1,0 for post-installed fasteners in shear	

$\gamma_{Mc} = 1.5 \times 1 = 1.5$

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):

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

The different factors of Formula (7.1) are given below.

(2) The characteristic resistance of a single fastener placed in concrete and not influenced by adjacent fasteners or edges of the concrete member is obtained as follows:

$$N^{0}_{Rk,c} = k_1 \cdot \sqrt{f_{ck}} \cdot h_{ef}^{1,5} \qquad (7.2)$$

h_{ef} → 157mm

f_{ck} → 30 MPa

with

k_1 $= k_{cr,N}$ for cracked concrete

$= k_{ucr,N}$ for uncracked concrete

$k_{cr,N}$ and $k_{ucr,N}$ are given in the corresponding European Technical Product Specification.

NOTE Indicative values for $k_{cr,N}$ and $k_{ucr,N}$ are $k_{cr,N}$ = 7,7 and $k_{ucr,N}$ = 11,0 for post-installed fasteners and $k_{cr,N}$ = 8,9 and $k_{ucr,N}$ = 12,7 for cast-in headed fasteners.

$N^{0}_{Rk,c} = 8.9 \cdot \sqrt{30MPa} \cdot (157mm)^{1.5} = 95.9 kN$

(3) The geometric effect of axial spacing and edge distance on the characteristic resistance is taken into account by the value $A_{c,N} / A^0_{c,N}$

where

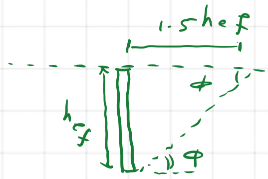
$$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N} \quad (7.3)$$

is the reference projected area, see Figure 7.3.

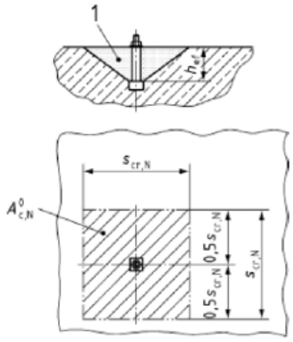
$A_{c,N}$ is the actual projected area, limited by overlapping concrete cones of adjacent fasteners $(s \le s_{cr,N})$ as well as by edges of the concrete member $(c \le c_{cr,N})$. An example for the calculation of $A_{c,N}$ is given in Figure 7.4.

$c_{cr,N}$ is given in the corresponding European Technical Product Specification and $s_{cr,N} = 2\ c_{cr,N}$.

NOTE For headed and post-installed fasteners according to current experience $s_{cr,N} = 2\ c_{cr,N} = 3\ h_{ef}$.



$\phi = \operatorname{atan}\left(\frac{h_{ef}}{1.5 h_{ef}}\right) = 33.7 \simeq 34°$



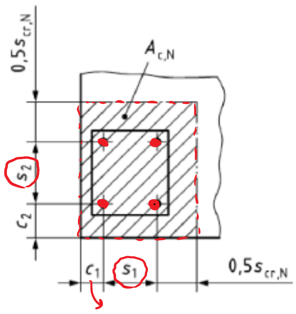
Key
1 concrete cone

Figure 7.3 — Idealized concrete cone and area $A^0_{c,N}$ of concrete cone of an individual fastener

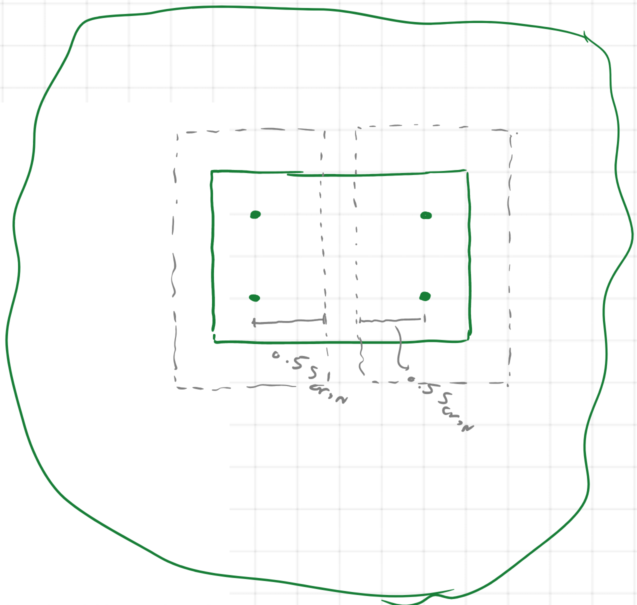
$h_{ef} = 157\ mm$

$s_{cr,N} = 3 h_{ef} = 471\ mm$

$A^0_{c,N} = s_{cr,N} \cdot s_{cr,N} = 221841\ mm^2$



$c_1 < 0.5 s_{cr,N} = c_{cr,N}$



Key

$A_{c,N} = (c_1 + s_1 + 0{,}5 s_{cr,N}) \cdot (c_2 + s_2 + 0{,}5 s_{cr,N})$

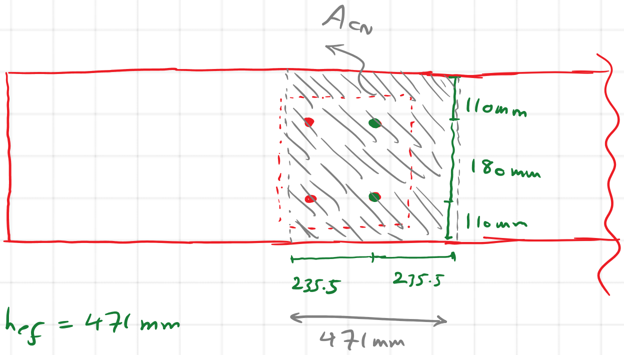
if c_1 and $c_2 \le c_{cr,N}$

s_1 and $s_2 \le s_{cr,N}$

When the fastening is close to one edge only, the value of c_1 (or c_2) parallel to the edge should be replaced by 0,5 $s_{cr,N}$ and the expression for $A_{c,N}$ should be modified accordingly.

Figure 7.4 — Actual area $A_{c,N}$ of the idealized concrete cone for a group of four fasteners – Example

- Tension bolts.



$S_{cr,N} = 3h_{ef} = 471\ mm$

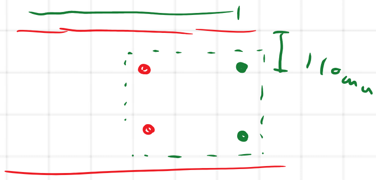
$C_{cr,N} = 1.5\ h_{ef} = 0.5\ S_{cr,N} = 235.5\ mm$

$A_{cN} = 471\ mm \times 400\ mm = 188400\ mm^2$

(4) The factor $\psi_{s,N}$ takes account of the disturbance of the distribution of stresses in the concrete due to the proximity of an edge of the concrete member. For fastenings with several edge distances (e.g. fastening in a corner of the concrete member or in a narrow member), the smallest edge distance c shall be inserted in Formula (7.4).

$$\psi_{s,N} = 0,7 + 0,3 \cdot \frac{c}{c_{cr,N}} \leq 1 \qquad (7.4)$$

$c \rightarrow 110\ mm$, $c_{cr,N} \rightarrow 235.5\ mm$ → $\psi_{s,N} = 0.84$



(5) The shell spalling factor $\psi_{re,N}$ applies when $h_{ef} < 100$ mm and accounts for the effect of dense reinforcement between which the fastener is installed:

$$\psi_{re,N} = 0,5 + \frac{h_{ef}}{200} \leq 1 \qquad (7.5)$$

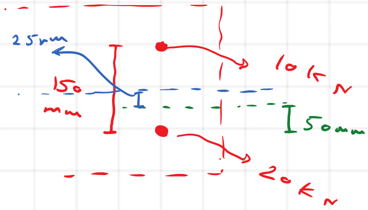
The factor $\psi_{re,N}$ may be taken as 1,0 in the following cases:

$h_{ef} = 157\ mm \nless 100\ mm$ → $\psi_{re,N} = 1$

(6) The factor $\psi_{ec,N}$ takes account of a group effect when different tension loads are acting on the individual fasteners of a group.

$$\psi_{ec,N} = \frac{1}{1+2\cdot\left(e_N / s_{cr,N}\right)} \le 1 \quad \Rightarrow \psi_{ec,N} = 1 \qquad (7.6)$$

$e_N \to 0$



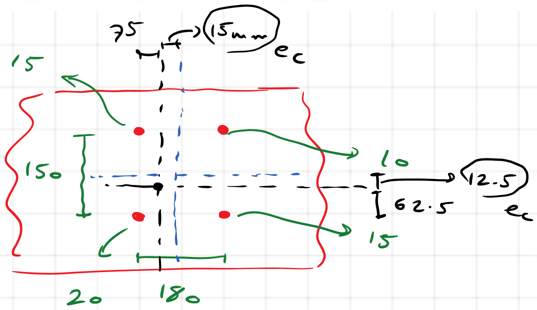
Where there is an eccentricity in two directions, $\psi_{ec,N}$ shall be determined separately for each direction and the product of both factors shall be inserted in Formula (7.1).

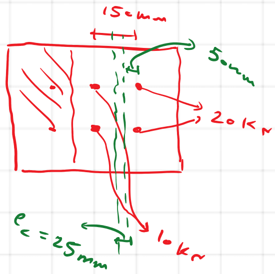
(7) The factor $\psi_{M,N}$ takes into account the effect of a compression force between fixture and concrete in cases of bending moments with or without axial force.

$$y = \frac{10\,kN \times 150\,mm + 20\,kN \times 0}{10\,kN + 20\,kN} = 50\,mm$$

$\psi_{M,N}$ = 1 for the following cases:

— fastenings with an edge distance $c < 1{,}5\ h_{ef}$; (110 mm → 235.5 mm)





$$X = \frac{(20+15)\times 0 + (10+15)\times 180}{20+15+10+15} = 75\,mm$$

$$Y = \frac{(20+15)\times 0 + (15+10)\times 150}{20+15+15+10} = 62.5\,mm$$

$$N_{Rk,c} = N^0_{Rk,c} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N} = 68.4\ kN \qquad (7.1)$$

$N^0_{Rk,c}$ → 95.9 kN; $A_{c,N}$ → 1884..; $A^0_{c,N}$ → 221841 mm²; $\psi_{s,N}$ → 0.84; $\psi_{re,N}$ → 1; $\psi_{ec,N}$ → 1; $\psi_{M,N}$ → 1

$$N^g_{Ed} \le N_{Rd,c} = \frac{N_{Rk,c}}{\gamma_{Mc}}$$

N_{Ed} = 30.6 kN

$$N_{Rd,c} = \frac{68.4\,kN}{1.5} = 45.6\,kN \rightarrow UR = \frac{30.6\,kN}{45.6\,kN} = 67\%$$