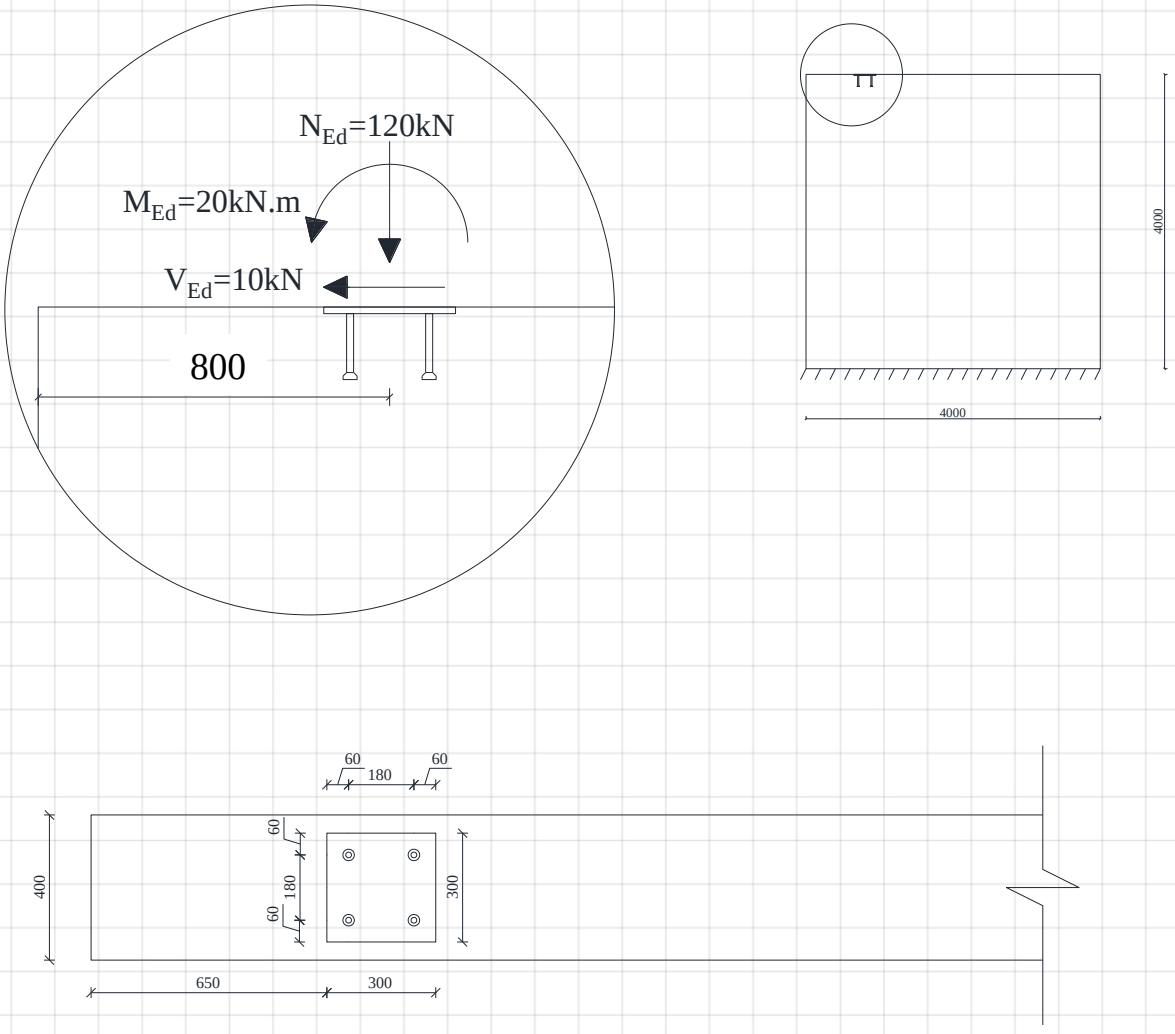
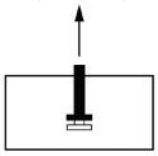
In the previous videos, the first two criteria of tension in anchor bolts have been verified. According to Eurocode1992-4, verify the anchor bolts for the following criteria:

a) Pull-Out failure
b) Concrete splitting 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.





c)

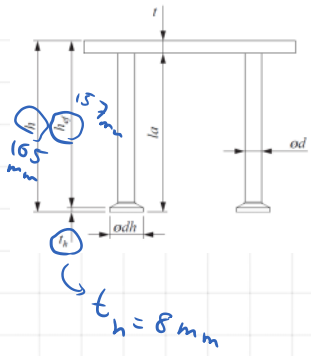
Table 7.1 — Required verifications for headed and post-installed fasteners in tension

	Failure mode	Single fastener	Group of fasteners	
			most loaded fastener	group
3	Pull-out failure of fastener [a]	$N_{Ed} \le N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	$N_{Ed}^{h} < N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$	

[a] Not required for post-installed bonded fasteners.

15.3 kN

7.2.1.5 Pull-out failure of fastener



The characteristic resistance in case of pull-out failure $N_{Rk,p}$ of post-installed mechanical and headed fasteners is given in the relevant European Technical Product Specification.

For headed fasteners the characteristic resistance $N_{Rk,p}$ is limited by the concrete pressure under the head of the fastener according to Formula (7.11):

$$N_{Rk,p} = k_2 \cdot A_h \cdot f_{ck} \quad (7.11)$$

7.5 → 30 MPa

where

A_h is the load bearing area of the head of the fastener

$$= \frac{\pi}{4}\left(d_h^2 - d_a^2\right) \text{ for circular shaped heads} \quad (7.12)$$

16 mm

$d_h = 32$ mm

$d_a = 16$ mm

* k_2 = 7,5 for fasteners in cracked concrete

= 10,5 for fasteners in uncracked concrete

In Formula (7.12) d_h should not be taken larger than $6\,t_h + d$.

$d_h = 32\text{mm} \le 6 \times t_h + d = 64$ mm

(t_h = 8 mm, d = 16 mm)

$$A_h = \frac{\pi}{4}\left((32\text{mm})^2 - (16\text{mm})^2\right) = 603.2\ \text{mm}^2$$

$$N_{Rk,p} = k_2 \cdot A_h \cdot f_{ck} = 7.5 \times 603.2\ \text{mm}^2 \times 30\ \text{MPa} = 136\ \text{kN}$$

Table 4.1 — Recommended values of partial factors

Failure modes	Partial factor	
	Permanent and transient design situations	Accidental design situation
Pull-out and combined pull-out and concrete failure	$\gamma_{Mp} = \gamma_{Mc} = 1.5$	

$N_{Ed} = 15.3$ kN

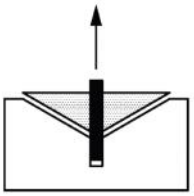
$N_{Rd} = \frac{N_{Rk}}{\gamma_M} = \frac{136\ \text{kN}}{1.5} = 90.7$ kN

$\rightarrow UR = \frac{15.3\text{kN}}{90.7\text{kN}} = 17\,\%$

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

	Failure mode	Single fastener	Group of fasteners	
			most loaded fastener	group
4	Combined pull-out and concrete failure [b]	$N_{Ed} \le N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$		$N_{Ed}^{g} \le N_{Rd,p} = \frac{N_{Rk,p}}{\gamma_{Mp}}$

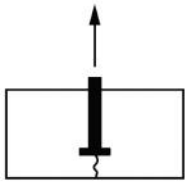
[b] Not required for headed and post-installed mechanical fasteners.



d)

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

	Failure mode	Single fastener	Group of fasteners	
			most loaded fastener	group
5	Concrete splitting failure	$N_{Ed} \le N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$		$N_{Ed}^{g} \le N_{Rd,sp} = \frac{N_{Rk,sp}}{\gamma_{Msp}}$



e)

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

$\gamma_{Msp} = 1.5$

Table 4.1 — Recommended values of partial factors

Failure modes	Partial factor	
	Permanent and transient design situations	Accidental design situation
Concrete splitting failure	$\gamma_{Msp} = \gamma_{Mc}$ = 1.5	

7.2.1.7 Concrete splitting failure

(1) Concrete splitting failure during installation (e.g. when applying the installation torque on a fastener) is avoided by complying with minimum values for edge distances c_{min}, spacing s_{min}, member thickness h_{min} and requirements for reinforcement as given in the relevant European Technical Product Specification.

(2) Concrete splitting failure due to loading shall be taken into account according to the following rules.

a) The characteristic edge distance in the case of splitting under load, $c_{cr,sp}$, is given in the relevant European Technical Product Specification. The characteristic spacing is defined as $s_{cr,sp} = 2\ c_{cr,sp}$.

b) No verification is required if at least one of the following conditions is fulfilled.

1) The edge distance in all directions is $c \ge 1,0\ c_{cr,sp}$ for single fasteners and $c \ge 1,2\ c_{cr,sp}$ for groups of fasteners and the member thickness is $h \ge h_{min}$ in both cases, with h_{min} corresponding to $c_{cr,sp}$.

2) The characteristic resistances for concrete cone failure and pull-out failure (headed and post-installed mechanical fasteners) or combined pull-out and concrete failure (bonded fasteners) are calculated for cracked concrete and reinforcement resists the splitting forces and limits the crack width to $w_k \le 0,3$ mm.

c) If neither condition b) 1) or b) 2) is fulfilled, the characteristic resistance of a fastener or a group of fasteners in case of concrete splitting failure shall be calculated according to Formula (7.23).

$$N_{Rk,sp} = N^0_{Rk,sp} \cdot \frac{A_{c,N}}{A^0_{c,N}} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{h,sp} \quad (7.23)$$

$\Rightarrow N_{Rk,sp} = 95.9\ kN$

$\frac{A_{c,N}}{A^0_{c,N}} = 1$

where

$N^0_{Rk,sp}$ is given in the relevant European Technical Product Specification

$A_{c,N}$, $A^0_{c,N}$, $\psi_{s,N}$, $\psi_{re,N}$, $\psi_{ec,N}$ according to 7.2.1.4, however the values $c_{cr,N}$ and $s_{cr,N}$ shall be replaced by $c_{cr,sp}$ and $s_{cr,sp}$, respectively, which correspond to the minimum member thickness h_{min}.

$\psi_{h,sp}$ takes into account the influence of the actual member thickness h on the splitting resistance (see Formula (7.24))

$$\psi_{h,sp} = \left(\frac{h}{h_{min}}\right)^{2/3} \le \max\left\{1; \left(\frac{h_{ef} + 1{,}5c_1}{h_{min}}\right)^{2/3}\right\} \le 2 \quad (7.24)$$

d) If in the relevant European Technical Product Specification $c_{cr,sp}$ is given for more than one minimum member thickness h_{min}, the minimum member thickness corresponding to $c_{cr,sp}$ used in Formula (7.23) shall be inserted in Formula (7.24).

NOTE If $N^0_{Rk,sp}$ is not available in the relevant European Technical Product Specification, this value can be conservatively calculated as $N^0_{Rk,sp} = \min\left\{N_{Rk,p}; N^0_{Rk,c}\right\}$, with $N_{Rk,p}$ according to 7.2.1.5 in case of post-installed mechanical and cast-in fasteners or replaced by $N^0_{Rk,p}$ according to 7.2.1.6 in case of bonded fasteners. $N^0_{Rk,c}$ is calculated according to Formula (7.2).

$N_{Rk,p} = 136\ kN$

$N^0_{Rk,c} = 95.9\ kN$

$N^0_{Rk,sp} = \min\{95.9\ kN; 136\ kN\} = 95.9\ kN$

$N_{Rd,sp} = \frac{95.9\ kN}{1.5} = 64\ kN$

$N_{Ed} = 30.6\ kN$

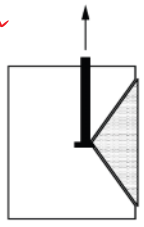
$\rightarrow UR = \frac{30.6\ kN}{64\ kN} = 48\ \%$

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

	Failure mode	Single fastener	Group of fasteners: most loaded fastener	Group of fasteners: group
6	Concrete blow-out failure [c]	$N_{Ed} \le N_{Rd,cb} = \frac{N_{Rk,cb}}{\gamma_{Mc}}$		$N^g_{Ed} \le N_{Rd,cb} = \frac{N_{Rk,cb}}{\gamma_{Mc}}$

[c] For cases which require verification see 7.2.1.8 (1).

$30.6\ kN$



f)

7.2.1.8 Concrete blow-out failure

(1) Verification of concrete blow-out failure is required in case of headed fasteners and for post-installed mechanical undercut fasteners acting as headed fasteners if the edge distance $c \le 0.5\, h_{ef}$. Each edge shall be considered in turn. The characteristic resistance in case of concrete blow-out failure is calculated as follows:

$$N_{Rk,cb} = N^{0}_{Rk,cb} \cdot \frac{A_{c,Nb}}{A^{0}_{c,Nb}} \cdot \psi_{s,Nb} \cdot \psi_{g,Nb} \cdot \psi_{ec,Nb} \qquad (7.25)$$

$C = 110\,mm \not< 0.5 h_{ef} = 78.5\,mm \rightarrow (N.A)$

- Steel: 26 %
- Concrete cone: 67 %
- pull out: 17 %
- Splitting: 48 %
- Blow out: N.A