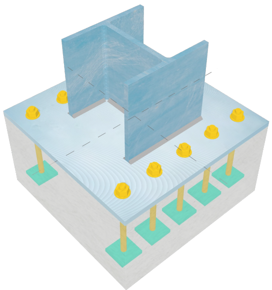
REFERENCES	CALCULATIONS	RESULTS

SkyCiv Base Plate and Anchor Rod Design

Shear and Compression - EN

Project Information:
Design Code: EN 1993-1-8-2005, EN 1993-1-1-2005 and EN 1992-1-1-2004
Anchoring Code: EN 1992-4:2018

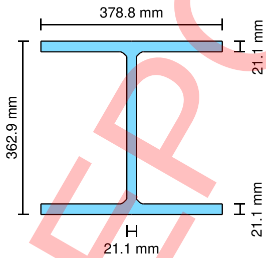


Load Combinations:

Load Combination	Axial Load, Nx (kN)	Strong-axis Shear, Vy (kN)	Weak-axis Shear, Vz (kN)
1	1500.00	25.00	12.00

Note(s):
1. Positive Nx (+) indicates compression; negative Nx (-) indicates tension.

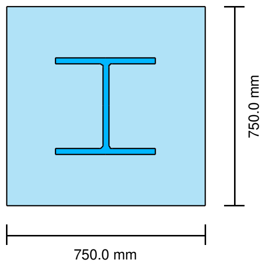
Column Properties:



Symbol	Description	Value
$Section$	Column section	HP 360x180
d_{col}	Column depth	362.9 mm
t_w	Column web thickness	21.1 mm
b_f	Column flange width	378.8 mm
t_f	Column flange thickness	21.1 mm
A_{col}	Column area	23000.0 mm^2
r_{col}	Column root radius	15.2 mm
f_{y_col}	Column yield strength (S275N)	265.0 MPa
f_{u_col}	Column ultimate tensile strength (S275N)	370.0 MPa

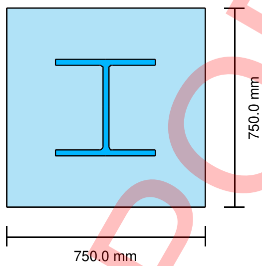
REFERENCES	CALCULATIONS	RESULTS

Base Plate Properties:



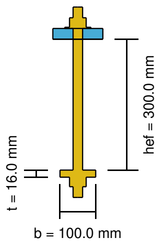
Symbol	Description	Value
B_{bp}	Base plate width	750.0 mm
L_{bp}	Base plate length	750.0 mm
t_{bp}	Base plate thickness	25.0 mm
A_{bp}	Base plate plan area	562500.0 mm^2
f_{y_bp}	Base plate yield strength (S235)	225.0 MPa
f_{u_bp}	Base plate ultimate tensile strength (S235)	360.0 MPa
t_{grout}	Grout thickness	0.0 mm
$Material$	Grout material	≥ 30 MPa

Concrete Properties:



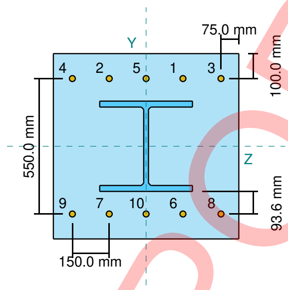
Symbol	Description	Value
B_{conc}	Concrete width	750.0 mm
L_{conc}	Concrete length	750.0 mm
t_{conc}	Concrete thickness	380.0 mm
A_{conc}	Concrete plan area	562500.0 mm^2
f_{ck}	Concrete compressive strength (C20/25)	20.0 MPa
–	Concrete assumption: cracked or uncracked	Cracked

REFERENCES	CALCULATIONS	RESULTS
	Anchor Information:	



Symbol	Description	Value
d_{anc}	Anchor rod diameter	24.0 mm
h_{ef}	Anchor rod embedment length	300.0 mm
b_{embed_plate}	Anchor embed plate side dimension	100.0 mm
t_{embed_plate}	Anchor embed plate thickness	16.0 mm
F_{y_anc}	Anchor rod yield strength (8.8)	640.0 MPa
F_{u_anc}	Anchor rod ultimate tensile strength (8.8)	800.0 MPa
d_{hole}	Anchor rod clearance hole diameter	26.0 mm

Anchor Layout:



Symbol	Description	Value
n_{anc}	Total number of anchor rods	10.0
s_z	Spacing of anchor rods along Z-axis	150.0 mm
s_y	Spacing of anchor rods along Y-axis	550.0 mm
$l_{edge,z}$	Base Plate edge distance along Z-axis	75.0 mm
$l_{edge,y}$	Base Plate edge distance along Y-axis	100.0 mm

REFERENCES	CALCULATIONS	RESULTS

Anchor Data Summary:

ID	Z (mm)	Y (mm)
1	150.000	275.000
2	-150.000	275.000
3	300.000	275.000
4	-300.000	275.000
5	0.000	275.000
6	150.000	-275.000
7	-150.000	-275.000
8	300.000	-275.000
9	-300.000	-275.000
10	0.000	-275.000

ID	Anchor in Tension Zone	Breakout (Tension)	Side-Face Blowout (Y-direction)	Side-Face Blowout (Z-direction)
1	✓	BO Group 1	-	SFz Group 1
2	✓	BO Group 1	-	SFz Group 1
3	✓	BO Group 1	Single	SFz Group 1
4	✓	BO Group 1	Single	SFz Group 1
5	✓	BO Group 1	-	SFz Group 1
6	✓	BO Group 1	-	SFz Group 2
7	✓	BO Group 1	-	SFz Group 2
8	✓	BO Group 1	Single	SFz Group 2
9	✓	BO Group 1	Single	SFz Group 2
10	✓	BO Group 1	-	SFz Group 2

ID	Shear Direction Resisted	Breakout (Vy Shear)	Breakout (Vz Shear)	Pryout (Vy Shear)	Pryout (Vz Shear)
1	+Vy	BO Vy Group 1	-	PO Vy All Load Directions	PO Vz Group 1
2	+Vy	BO Vy Group 1	-	PO Vy All Load Directions	PO Vz Group 1
3	+Vz +Vy	BO Vy Group 1	Single	PO Vy All Load Directions	PO Vz Group 1
4	-Vz +Vy	BO Vy Group 1	Single	PO Vy All Load Directions	PO Vz Group 1
5	+Vy	BO Vy Group 1	-	PO Vy All Load Directions	PO Vz Group 1
6	-Vy	BO Vy Group 2	-	PO Vy All Load Directions	PO Vz Group 1
7	-Vy	BO Vy Group 2	-	PO Vy All Load Directions	PO Vz Group 1
8	+Vz -Vy	BO Vy Group 2	Single	PO Vy All Load Directions	PO Vz Group 1
9	-Vz -Vy	BO Vy Group 2	Single	PO Vy All Load Directions	PO Vz Group 1
10	-Vy	BO Vy Group 2	-	PO Vy All Load Directions	PO Vz Group 1

Weld Properties:

Symbol	Description	Value
$Type$	Weld Type	Fillet
z_{top_flange}	Fillet weld leg size at Top Flange	12.000 mm
z_{bottom_flange}	Fillet weld leg size at Bottom Flange	12.000 mm
z_{web}	Fillet weld leg size at Web	12.000 mm
a_{top_flange}	Weld throat thickness at Top Flange	8.485 mm
a_{bottom_flange}	Weld throat thickness at Bottom Flange	8.485 mm
a_{web}	Weld throat thickness at Web	8.485 mm
f_{uw}	Filler metal ultimate tensile strength (E38)	470.000 MPa

REFERENCES	CALCULATIONS	RESULTS

Summary of Detailing Checks

Check Name	Dimensions (Min/Max/Actual)	Status	Reference
Weld Size Requirement (Flange)	Min: 4.24 mm, Max: 19.00 mm, Actual: 12.00 mm	**PASS**	EN 1993-1-8:2005 Clause 4.5.2-2
Weld Size Requirement (Web)	Min: 4.24 mm, Max: 19.00 mm, Actual: 12.00 mm	**PASS**	EN 1993-1-8:2005 Clause 4.5.2-2
Anchor Clearance	Min: 34.92 mm, Actual: 81.55 mm	**PASS**	SkyCiv Recommendation
Base Plate Edge Distance	Min: 36.00 mm, Actual: 75.00 mm	**PASS**	EN 1993-1-8:2005 Table 3.3
Minimum Number of Anchors	Min: 4.00, Actual: 10.00	**PASS**	SCI P358 Clause 7.3
Embedded Plate Dimension	Min: 96.00 mm, Actual: 100.00 mm	**PASS**	SkyCiv Recommendation
Min. Anchor Spacing to Prevent Concrete Splitting	Min: 24.00 mm, Actual: 150.00 mm	**PASS**	EN 1992-4-2018: Clause 7.2.1.7(1)
Min. Concrete Cover to Prevent Concrete Splitting	Min: 40.00 mm, Actual: 75.00 mm	**PASS**	EN 1992-4-2018: Clause 7.2.1.7(1)

✔ All Detailing Checks Passed

The design geometry meets requirements.

Summary of Design Checks

Design Check	Governing LC	Demand	Capacity	DCR	Result
Weld Capacity	1	125.76	360.00	0.35	**PASS**
Concrete Bearing Capacity and Base Plate Yield Capacity (Compression Load)	1	1500.00	1811.26	0.83	**PASS**
Base Plate Bearing Capacity (Vy Shear)	1	2.50	432.00	0.01	**PASS**
Base Plate Bearing Capacity (Vz Shear)	1	1.20	415.38	0.00	**PASS**
Concrete Breakout Capacity (Vy Shear)	1	25.71	28.87	0.89	**PASS**
Concrete Breakout Capacity (Vz Shear)	1	6.50	9.33	0.70	**PASS**
Concrete Pryout Capacity	1	27.73	191.52	0.14	**PASS**
Anchor Rod Shear Capacity	1	2.77	144.76	0.02	**PASS**

✔ All Design Checks Passed

The design is adequate.

REFERENCES | CALCULATIONS | RESULTS

Load Combination No. 1: Compression Load and Shear Load

Check No. 1: Weld Capacity

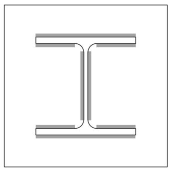


Fig. Welds on column to base plate.

Notes:
Assume the Vz shear load is taken by the flange welds only.
Assume the Vy shear load is taken by the web welds only.

Calculate total weld length

L_{weld} - Total length of weld

$$L_{weld} = 2b_f + 2\left(d_{col} - 2t_f - 2r_{col}\right) + 2\left(b_f - t_w - 2r_{col}\right)$$

$$L_{weld} = 2 \times 378.8 \text{ mm} + 2 \times (362.9 \text{ mm} - 2 \times 21.1 \text{ mm} - 2 \times 15.2 \text{ mm}) + 2 \times (378.8 \text{ mm} - 21.1 \text{ mm} - 2 \times 15.2 \text{ mm})$$

$$L_{weld} = 1992.8 \text{ mm}$$

Calculate total weld length on flanges

$b_f = 378.8 \text{ mm}$ - Column flange width

$t_w = 21.1 \text{ mm}$ - Column web thickness

$r_{col} = 15.2 \text{ mm}$ - Column root radius

L_{w_flg} - Total length of weld at flange

$$L_{w\_flg} = 2b_f + 2\left(b_f - t_w - 2r_{col}\right) = 2 \times 378.8 \text{ mm} + 2 \times (378.8 \text{ mm} - 21.1 \text{ mm} - 2 \times 15.2 \text{ mm}) = 1412.2 \text{ mm}$$

Calculate normal and shear stresses

$N_x = 1500 \text{ kN}$ - Compression load

$a_{flg} = 8.485 \text{ mm}$ - Design weld throat thickness at flange

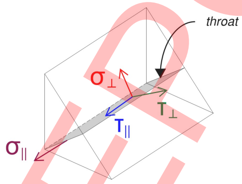


Fig. Weld stresses.

EN 1993-1-8:2005 Clause 4.5.3.2

$\sigma_{\perp}$ - Normal stress perpendicular to the throat

$$\sigma_{\perp} = \frac{N_x}{L_{weld} a_{flg} \sqrt{2}} = \frac{1500 \text{ kN}}{1992.8 \text{ mm} \times 8.485 \text{ mm} \times \sqrt{2}} = 62.728 \text{ MPa}$$

EN 1993-1-8:2005 Clause 4.5.3.2

$\tau_{\perp}$ - Shear stress in the plane of the throat perpendicular to the axis of the weld

$$\tau_{\perp} = \frac{N_x}{L_{weld} a_{flg} \sqrt{2}} = \frac{1500 \text{ kN}}{1992.8 \text{ mm} \times 8.485 \text{ mm} \times \sqrt{2}} = 62.728 \text{ MPa}$$

EN 1993-1-8:2005 Clause 4.5.3.2

$\tau_{\parallel}$ - Shear stress in the plane of the throat parallel to the axis of the weld

$$\tau_{\parallel} = \frac{V_z}{L_{w\_flg} a_{flg}} = \frac{12 \text{ kN}}{1412.2 \text{ mm} \times 8.485 \text{ mm}} = 1.0015 \text{ MPa}$$

Calculate design weld stress using directional method

EN 1993-1-8:2005 Eq. 4.1

$F_{w,Ed1}$ - Design weld stress using directional method

$$F_{w,Ed1} = \sqrt{\left((\sigma_{\perp})^2\right) + 3\left(\left((\tau_{\perp})^2\right) + \left((\tau_{\parallel})^2\right)\right)}$$

$$F_{w,Ed1} = \sqrt{\left((62.728 \text{ MPa})^2\right) + 3 \times \left(\left((62.728 \text{ MPa})^2\right) + \left((1.0015 \text{ MPa})^2\right)\right)}$$

$$F_{w,Ed1} = 125.47 \text{ MPa}$$

Calculate design perpendicular stress on base metal

EN 1993-1-8:2005 Clause 4.5.3.2

$\sigma_{\perp} = 62.728 \text{ MPa}$

EN 1993-1-8-2005 Eq. 4.1

$F_{w,Ed2}$ - Design normal stress for base metal check using directional method

$$F_{w,Ed2} = \sigma_{\perp} = 62.728 \text{ MPa}$$

Calculate total weld length on web

$d_{col} = 362.9 \text{ mm}$ - Column depth

$t_f = 21.1 \text{ mm}$ - Column flange thickness

$r_{col} = 15.2 \text{ mm}$ - Column root radius

L_{w_web} - Total length of weld at web

$$L_{w\_web} = 2\left(d_{col} - 2t_f - 2r_{col}\right) = 2 \times (362.9\ \mathrm{mm} - 2 \times 21.1\ \mathrm{mm} - 2 \times 15.2\ \mathrm{mm}) = 580.6\ \mathrm{mm}$$

Calculate normal and shear stresses

$N_x = 1500\ \mathrm{kN}$ - Compression load

$a_{web} = 8.485\ \mathrm{mm}$ - Weld throat thickness at Web

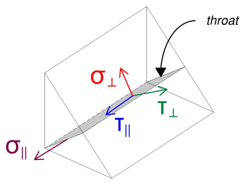


Fig. Weld stresses.

EN 1993-1-8:2005 Clause 4.5.3.2

$\sigma_{\perp}$ - Normal stress perpendicular to the throat

$$\sigma_{\perp} = \frac{N_x}{L_{weld} a_{web} \sqrt{2}} = \frac{1500\ \mathrm{kN}}{1992.8\ \mathrm{mm} \times 8.485\ \mathrm{mm} \times \sqrt{2}} = 62.728\ \mathrm{MPa}$$

EN 1993-1-8:2005 Clause 4.5.3.2

$\tau_{\perp}$ - Shear stress in the plane of the throat perpendicular to the axis of the weld

$$\tau_{\perp} = \frac{N_x}{L_{weld} a_{web} \sqrt{2}} = \frac{1500\ \mathrm{kN}}{1992.8\ \mathrm{mm} \times 8.485\ \mathrm{mm} \times \sqrt{2}} = 62.728\ \mathrm{MPa}$$

EN 1993-1-8:2005 Clause 4.5.3.2

$\tau_{\parallel}$ - Shear stress in the plane of the throat parallel to the axis of the weld

$$\tau_{\parallel} = \frac{V_y}{L_{w\_web} a_{web}} = \frac{25\ \mathrm{kN}}{580.6\ \mathrm{mm} \times 8.485\ \mathrm{mm}} = 5.0747\ \mathrm{MPa}$$

Calculate design weld stress using directional method

EN 1993-1-8:2005 Eq. 4.1

$F_{w,Ed1}$ - Design weld stress using directional method

$$F_{w,Ed1} = \sqrt{\left((\sigma_{\perp})^2\right) + 3\left(\left((\tau_{\perp})^2\right) + \left((\tau_{\parallel})^2\right)\right)}$$

$$F_{w,Ed1} = \sqrt{\left((62.728\ \mathrm{MPa})^2\right) + 3 \times \left(\left((62.728\ \mathrm{MPa})^2\right) + \left((5.0747\ \mathrm{MPa})^2\right)\right)}$$

$$F_{w,Ed1} = 125.76\ \mathrm{MPa}$$

Calculate design perpendicular stress on base metal

EN 1993-1-8:2005 Clause 4.5.3.2

$\sigma_{\perp} = 62.728\ \mathrm{MPa}$

EN 1993-1-8-2005 Eq. 4.1

$F_{w,Ed2}$ - Design normal stress for base metal check using directional method

$$F_{w,Ed2} = \sigma_{\perp} = 62.728\ \mathrm{MPa}$$

Determine governing weld stress

EN 1993-1-8:2005 Eq. 4.1

$F_{w,Ed1}$ - Governing design weld stress using directional method

$$F_{w,Ed1} = \max\left(\mathrm{F_{w,Ed1}},\ \mathrm{F_{w,Ed1}}\right) = \max\left(125.47\ \mathrm{MPa},\ 125.76\ \mathrm{MPa}\right) = 125.76\ \mathrm{MPa}$$

EN 1993-1-8:2005 Eq. 4.1

$F_{w,Ed2}$ - Governing design weld stress using directional method

$$F_{w,Ed2} = \max\left(\mathrm{F_{w,Ed2}},\ \mathrm{F_{w,Ed2}}\right) = \max\left(62.728\ \mathrm{MPa},\ 62.728\ \mathrm{MPa}\right) = 62.728\ \mathrm{MPa}$$

Determine the ultimate tensile strength of the weakest material

$f_{u\_col} = 370\ \mathrm{MPa}$ - Column ultimate tensile strength (S275N)

$f_{u\_bp} = 360\ \mathrm{MPa}$ - Base plate ultimate tensile strength (S235)

$f_{uw} = 470\ \mathrm{MPa}$ - Filler metal ultimate tensile strength (E38)

EN 1993-1-8:2005

f_u - Nominal tensile strength of the weaker part joined

$$f_u = \min\left(\mathrm{f_{u\_col}},\ \mathrm{f_{u\_bp}},\ \mathrm{f_{uw}}\right) = \min\left(370\ \mathrm{MPa},\ 360\ \mathrm{MPa},\ 470\ \mathrm{MPa}\right) = 360\ \mathrm{MPa}$$

Calculate fillet weld strength

EN 1993-1-8:2005

$f_u = 360\ \mathrm{MPa}$

EN 1993-1-8:2005 Clause 4.5.3.2 (6)

$\beta_w = 0.8$ - Weld correlation factor

EN 1993-1-8:2005

$\gamma_{M2,weld} = 1.25$ - Partial safety factor for resistance of welds

EN 1993-1-8-2005 Eq. 4.1

$F_{w,Rd1}$ - Design resistance of fillet weld using directional method

$$F_{w,Rd1} = \frac{f_u}{\beta_w\left(\gamma_{M2,weld}\right)} = \frac{360\ \mathrm{MPa}}{0.8 \times (1.25)} = 360\ \mathrm{MPa}$$

Calculate design resistance of base metal

EN 1993-1-8:2005

$f_u = 360\ \mathrm{MPa}$

EN 1993-1-8:2005

$\gamma_{M2,weld} = 1.25$ - Partial safety factor for resistance of welds

EN 1993-1-8-2005 Eq. 4.1

$F_{w,Rd2}$ - Design resistance of base metal using directional method

$$F_{w,Rd2} = \frac{0.9 f_u}{\gamma_{M2,weld}} = \frac{0.9 \times 360\ \mathrm{MPa}}{1.25} = 259.2\ \mathrm{MPa}$$

Result:

PASS = 0.35

DCR - Demand over capacity ratio, comparing two conditions:

$$DCR = \max\left(\frac{F_{w,Ed1}}{F_{w,Rd1}}, \frac{F_{w,Ed2}}{F_{w,Rd2}}\right) = \max\left(\frac{125.76\text{ MPa}}{360\text{ MPa}}, \frac{62.728\text{ MPa}}{259.2\text{ MPa}}\right) = 0.34934$$

Go back to summary results table.

Check No. 2: Concrete Bearing Capacity and Base Plate Yield Capacity (Compression Load)

Calculate bearing load on concrete

$N_x = 1500\text{ kN}$ - Compression load

N_{Ed} - Design bearing force

$$N_{Ed} = N_x = 1500\text{ kN}$$

Calculate base plate area

$L_{bp} = 750\text{ mm}$ - Base plate length

$B_{bp} = 750\text{ mm}$ - Base plate width

A_{c0} - Loaded area of base plate

$$A_{c0} = B_{bp}L_{bp} = 750\text{ mm} \times 750\text{ mm} = 562500\text{ mm}^2$$

Calculate alpha coefficient

$L_{conc} = 750\text{ mm}$ - Concrete length

$B_{conc} = 750\text{ mm}$ - Concrete width

$t_{conc} = 380\text{ mm}$ - Concrete thickness

e_h - Additional length outside of base plate in calculating alpha coefficient

$$e_h = \frac{L_{conc} - L_{bp}}{2} = \frac{750\text{ mm} - 750\text{ mm}}{2} = 0$$

e_b - Additional width outside of base plate in calculating alpha coefficient

$$e_b = \frac{B_{conc} - B_{bp}}{2} = \frac{750\text{ mm} - 750\text{ mm}}{2} = 0$$

Design Guide "Multi-Storey Steel Buildings" by Arcelor Mittal, Peiner Trager and Corus, Part 5, Section 6.1

α - Alpha coefficient which accounts for diffusion of the concentrated force within the foundation

$$\alpha = \min\left(1 + \frac{t_{conc}}{\max(L_{bp}, B_{bp})}, 1 + 2\left(\frac{e_h}{L_{bp}}\right), 1 + 2\left(\frac{e_b}{B_{bp}}\right), 3\right)$$

$$\alpha = \min\left(1 + \frac{380\text{ mm}}{\max(750\text{ mm}, 750\text{ mm})}, 1 + 2 \times \left(\frac{0}{750\text{ mm}}\right), 1 + 2 \times \left(\frac{0}{750\text{ mm}}\right), 3\right)$$

$$\alpha = 1$$

Calculate design compressive strength of concrete

EN 1992-1-1:2004 Clause 3.1.6

$a_{cc} = 1$ - Coefficient for compressive strength long term effects

$f_{ck} = 20\text{ MPa}$ - Concrete compressive strength (C20/25)

EN 1992-1-1:2004 Table 2.1N

$\gamma_C = 1.5$ - Partial safety factor for resistance of concrete

EN 1992-1-1:2004 Eq. 3.15

f_{cd} - Design compressive strength of concrete

$$f_{cd} = \frac{a_{cc}f_{ck}}{\gamma_C} = \frac{1 \times 20\text{ MPa}}{1.5} = 13.333\text{ MPa}$$

Calculate design bearing strength of the joint

Design Guide "Multi-Storey Steel Buildings" by Arcelor Mittal, Peiner Trager and Corus, Part 5, Section 6.1

$\alpha = 1$

$\beta = 0.66667$ - Foundation joint material coefficient

EN 1992-1-1:2004 Eq. 3.15

$f_{cd} = 13.333\text{ MPa}$

EN 1993-1-8:2005 Eq 6.6 and EN 1992-1-1:2004 Eq. 6.63

f_{jd} - Design bearing strength of the joint

$$f_{jd} = \beta\alpha f_{cd} = 0.66667 \times 1 \times 13.333\text{ MPa} = 8.8889\text{ MPa}$$

Calculate cantilever 'c' dimension on base plate effective area

EN 1993-1-8:2005 Eq 6.6 and EN 1992-1-1:2004 Eq. 6.63

$f_{jd} = 8.8889\text{ MPa}$

$f_{y\_bp} = 225\text{ MPa}$ - Base plate yield strength (S235)

$t_{bp} = 25\text{ mm}$ - Base plate thickness

EN 1993-1-1:2005 Clause 6.1

$\gamma_{M0} = 1$ - Partial safety factor for resistance of steel cross-sections

SCI P358 pg. 243, EN 1993-1-1:2005 Clause 6.2.5

c - Cantilever length from base plate bending resistance

$$c = t_{bp}\sqrt{\frac{f_{y\_bp}}{3f_{jd}\gamma_{M0}}} = 25\text{ mm} \times \sqrt{\frac{225\text{ MPa}}{3 \times 8.8889\text{ MPa} \times 1}} = 72.618\text{ mm}$$

Calculate effective area

$b_f = 378.8\text{ mm}$ - Column flange width

$d_{col} = 362.9\text{ mm}$ - Column depth

$t_w = 21.1\text{ mm}$ - Column web thickness

$A_{col} = 23000\text{ mm}^2$ - Column area

SCI P358 pg. 243, EN 1993-1-1:2005 Clause 6.2.5

$c = 72.618\ \mathrm{mm}$

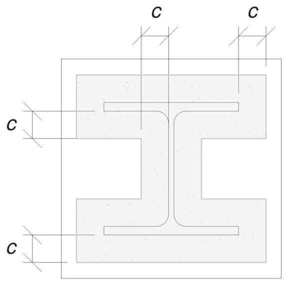


Fig. Effective area on base plate.

The dimension 'c' is not overlapping within the column profile

SCI P358 pg. 242

P_{col} - Perimeter of column

$$P_{col} = 2b_f + 2d_{col} + 2\left(b_f - t_w\right) = 2 \times 378.8\ \mathrm{mm} + 2 \times 362.9\ \mathrm{mm} + 2 \times (378.8\ \mathrm{mm} - 21.1\ \mathrm{mm}) = 2198.8\ \mathrm{mm}$$

SCI P358 pg. 242

A_e - Effective area of base plate

$$A_e = 4c^2 + P_{col}c + A_{col} = 4 \times 72.618\ \mathrm{mm}^2 + 2198.8\ \mathrm{mm} \times 72.618\ \mathrm{mm} + 23000\ \mathrm{mm}^2 = 203770\ \mathrm{mm}^2$$

Calculate design bearing resistance

EN 1993-1-8:2005 Eq 6.6 and EN 1992-1-1:2004 Eq. 6.63

$f_{jd} = 8.8889\ \mathrm{MPa}$

SCI P358 pg. 242

$A_e = 203770\ \mathrm{mm}^2$

$A_{c0} = 562500\ \mathrm{mm}^2$

EN 1993-1-8:2005 Eq 6.6 and EN 1992-1-1:2004 Eq. 6.63

N_{Rd} - Design concrete bearing resistance on base plate effective area

$$N_{Rd} = \left(\min\left(\mathrm{A_e},\ \mathrm{A_{c0}}\right)\right) f_{jd} = \left(\min\left(203770\ \mathrm{mm}^2,\ 562500\ \mathrm{mm}^2\right)\right) \times 8.8889\ \mathrm{MPa} = 1811.3\ \mathrm{kN}$$

Result:

PASS = 0.83

DCR - Demand-to-Capacity Ratio

$$DCR = \frac{N_{Ed}}{N_{Rd}} = \frac{1500\ \mathrm{kN}}{1811.3\ \mathrm{kN}} = 0.82815$$

Go back to summary results table.

Check No. 3: Base Plate Bearing Capacity (Vy Shear)

Calculate shear load per anchor

$V_y = 25\ \mathrm{kN}$ - Vy shear load

$n_{anc} = 10$ - Total number of anchor rods

$F_{b,Ed}$ - Design shear force per anchor

$$F_{b,Ed} = \frac{V_y}{n_{anc}} = \frac{25\ \mathrm{kN}}{10} = 2.5\ \mathrm{kN}$$

Symbol	Description	Value
d_{hole}	Anchor rod clearance hole diameter	26.0 mm
$l_{edge,y}$	Base Plate edge distance along Y-axis	100.0 mm
$l_{edge,z}$	Base Plate edge distance along Z-axis	75.0 mm
s_y	Spacing of anchor rods along Y-axis	550.0 mm
s_z	Spacing of anchor rods along Z-axis	150.0 mm

Calculate alpha d factor for end and inner bolts

EN 1993-1-8:2005 Table 3.4

$\alpha_{d,end}$ - Alpha d factor for end bolts

$$\alpha_{d,end} = \frac{l_{edge,y}}{3d_{hole}} = \frac{100\ \mathrm{mm}}{3 \times 26\ \mathrm{mm}} = 1.2821$$

EN 1993-1-8:2005 Table 3.4

$\alpha_{d,inner}$ - Alpha d factor for inner bolts

$$\alpha_{d,inner} = \frac{s_y}{3d_{hole}} - \frac{1}{4} = \frac{550\ \mathrm{mm}}{3 \times 26\ \mathrm{mm}} - \frac{1}{4} = 6.8013$$

Calculate governing alpha b factor

EN 1993-1-8:2005 Table 3.4

α_b - Alpha b factor

$$\alpha_b = \min\left(\alpha_{\mathrm{d,end}},\ \alpha_{\mathrm{d,inner}},\ \frac{\mathrm{f_{u\_anc}}}{\mathrm{f_{u\_bp}}},\ 1.0\right) = \min\left(1.2821,\ 6.8013,\ \frac{800\ \mathrm{MPa}}{360\ \mathrm{MPa}},\ 1\right) = 1$$

Calculate k1 factor for edge and inner bolts

EN 1993-1-8:2005 Table 3.4

$k_{1,edge}$ - k1 factor for edge bolts

$$k_{1,edge} = \min\left(2.8\left(\frac{\mathrm{l_{edge,z}}}{\mathrm{d_{hole}}}\right) - 1.7,\ 1.4\left(\frac{\mathrm{s_z}}{\mathrm{d_{hole}}}\right) - 1.7,\ 2.5\right)$$

$$k_{1,edge} = \min\left(2.8 \times \left(\frac{75\ \mathrm{mm}}{26\ \mathrm{mm}}\right) - 1.7,\ 1.4 \times \left(\frac{150\ \mathrm{mm}}{26\ \mathrm{mm}}\right) - 1.7,\ 2.5\right) = 2.5$$

EN 1993-1-8:2005 Table 3.4

$k_{1,inner}$ - k1 factor for inner bolts

	$$k_{1,inner} = \min\left(1.4\left(\frac{\mathrm{s_z}}{\mathrm{d_{hole}}}\right) - 1.7,\ 2.5\right) = \min\left(1.4 \times \left(\frac{150\ \mathrm{mm}}{26\ \mathrm{mm}}\right) - 1.7,\ 2.5\right) = 2.5$$	
EN 1993-1-8:2005 Table 3.4	**Calculate governing k1 factor** k_1 - k1 factor $$k_1 = \min\left(\mathrm{k_{1,edge}},\ \mathrm{k_{1,inner}}\right) = \min\left(2.5,\ 2.5\right) = 2.5$$	
	Calculate design bearing resistance of base plate $f_{u\_bp} = 360\ \mathrm{MPa}$ - Base plate ultimate tensile strength (S235) $d_{anc} = 24\ \mathrm{mm}$ - Anchor rod diameter $t_{bp} = 25\ \mathrm{mm}$ - Base plate thickness	
EN 1993-1-8:2005	$\gamma_{M2,anchor} = 1.25$ - Partial safety factor for resistance of bolts/anchors	
EN 1993-1-8:2005 Table 3.4	$F_{b,Rd}$ - Design bearing resistance of anchor rod on base plate $$F_{b,Rd} = \frac{k_1 \alpha_b f_{u\_bp} d_{anc} t_{bp}}{\gamma_{M2,anchor}} = \frac{2.5 \times 1 \times 360\ \mathrm{MPa} \times 24\ \mathrm{mm} \times 25\ \mathrm{mm}}{1.25} = 432\ \mathrm{kN}$$	
	Result: DCR - Demand-to-Capacity Ratio $$DCR = \frac{F_{b,Ed}}{F_{b,Rd}} = \frac{2.5\ \mathrm{kN}}{432\ \mathrm{kN}} = 0.005787$$	**PASS = 0.01** Go back to summary results table.

	Check No. 4: Base Plate Bearing Capacity (Vz Shear) **Calculate shear load per anchor** $V_z = 12\ \mathrm{kN}$ - Vz shear load $n_{anc} = 10$ - Total number of anchor rods $F_{b,Ed}$ - Design shear force per anchor $$F_{b,Ed} = \frac{V_z}{n_{anc}} = \frac{12\ \mathrm{kN}}{10} = 1.2\ \mathrm{kN}$$	

Symbol	Description	Value
d_{hole}	Anchor rod clearance hole diameter	26.0 mm
$l_{edge,y}$	Base Plate edge distance along Y-axis	100.0 mm
$l_{edge,z}$	Base Plate edge distance along Z-axis	75.0 mm
s_y	Spacing of anchor rods along Y-axis	550.0 mm
s_z	Spacing of anchor rods along Z-axis	150.0 mm

Calculate alpha d factor for end and inner bolts

EN 1993-1-8:2005 Table 3.4

$\alpha_{d,end}$ - Alpha d factor for end bolts

$$\alpha_{d,end} = \frac{l_{edge,z}}{3 d_{hole}} = \frac{75\ \mathrm{mm}}{3 \times 26\ \mathrm{mm}} = 0.96154$$

EN 1993-1-8:2005 Table 3.4

$\alpha_{d,inner}$ - Alpha d factor for inner bolts

$$\alpha_{d,inner} = \frac{s_z}{3 d_{hole}} - \frac{1}{4} = \frac{150\ \mathrm{mm}}{3 \times 26\ \mathrm{mm}} - \frac{1}{4} = 1.6731$$

Calculate governing alpha b factor

EN 1993-1-8:2005 Table 3.4

α_b - Alpha b factor

$$\alpha_b = \min\left(\alpha_{\mathrm{d,end}},\ \alpha_{\mathrm{d,inner}},\ \frac{\mathrm{F_{u\_anc}}}{\mathrm{f_{u\_bp}}},\ 1.0\right) = \min\left(0.96154,\ 1.6731,\ \frac{800\ \mathrm{MPa}}{360\ \mathrm{MPa}},\ 1\right) = 0.96154$$

Calculate k1 factor for edge and inner bolts

EN 1993-1-8:2005 Table 3.4

$k_{1,edge}$ - k1 factor for edge bolts

$$k_{1,edge} = \min\left(2.8\left(\frac{\mathrm{l_{edge,y}}}{\mathrm{d_{hole}}}\right) - 1.7,\ 1.4\left(\frac{\mathrm{s_y}}{\mathrm{d_{hole}}}\right) - 1.7,\ 2.5\right)$$

$$k_{1,edge} = \min\left(2.8 \times \left(\frac{100\ \mathrm{mm}}{26\ \mathrm{mm}}\right) - 1.7,\ 1.4 \times \left(\frac{550\ \mathrm{mm}}{26\ \mathrm{mm}}\right) - 1.7,\ 2.5\right) = 2.5$$

EN 1993-1-8:2005 Table 3.4

$k_{1,inner}$ - k1 factor for inner bolts

$$k_{1,inner} = \min\left(1.4\left(\frac{\mathrm{s_y}}{\mathrm{d_{hole}}}\right) - 1.7,\ 2.5\right) = \min\left(1.4 \times \left(\frac{550\ \mathrm{mm}}{26\ \mathrm{mm}}\right) - 1.7,\ 2.5\right) = 2.5$$

Calculate governing k1 factor

EN 1993-1-8:2005 Table 3.4

k_1 - k1 factor

$$k_1 = \min\left(\mathrm{k_{1,edge}},\ \mathrm{k_{1,inner}}\right) = \min\left(2.5,\ 2.5\right) = 2.5$$

Calculate design bearing resistance of base plate

$f_{u\_bp} = 360\ \mathrm{MPa}$ - Base plate ultimate tensile strength (S235)

$d_{anc} = 24\ \mathrm{mm}$ - Anchor rod diameter

$t_{bp} = 25\ \mathrm{mm}$ - Base plate thickness

EN 1993-1-8:2005

$\gamma_{M2,anchor} = 1.25$ - Partial safety factor for resistance of bolts/anchors

EN 1993-1-8:2005 Table 3.4

$F_{b,Rd}$ - Design bearing resistance of anchor rod on base plate

$$F_{b,Rd} = \frac{k_1 \alpha_b f_{u\_bp} d_{anc} t_{bp}}{\gamma_{M2,anchor}} = \frac{2.5 \times 0.96154 \times 360\ \text{MPa} \times 24\ \text{mm} \times 25\ \text{mm}}{1.25} = 415.38\ \text{kN}$$

Result:

DCR - Demand-to-Capacity Ratio

$$DCR = \frac{F_{b,Ed}}{F_{b,Rd}} = \frac{1.2\ \text{kN}}{415.38\ \text{kN}} = 0.0028889$$

PASS = 0.00

Go back to summary results table.

Check No. 5: Concrete Breakout Capacity (Vy Shear)

$V_y = 25\ \text{kN}$ - Vy shear load

$n_{a,vy} = 5$ - Number of anchors resisting +Vy shear

$n_{a,g1} = 5$ - Number of anchors in anchor group BO Vy 1

$V_{\perp}$ - Required concrete breakout shear strength of anchor group with failure edge perpendicular to load

$$V_{\perp} = V_y \left(\frac{n_{a,g1}}{n_{a,vy}}\right) = 25\ \text{kN} \times \left(\frac{5}{5}\right) = 25\ \text{kN}$$

$V_z = 12\ \text{kN}$ - Vz shear load

$n_{anc} = 10$ - Total number of anchor rods

$n_{a,g1} = 5$ - Number of anchors in anchor group BO Vy 1

$V_{\parallel}$ - Required concrete breakout shear strength of anchor group with failure edge parallel to load

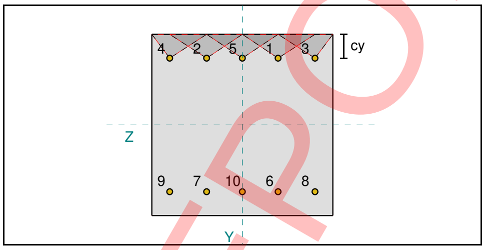
$$V_{\parallel} = V_z \left(\frac{n_{a,g1}}{n_{anc}}\right) = 12\ \text{kN} \times \left(\frac{5}{10}\right) = 6\ \text{kN}$$

Calculate total shear load per anchor group

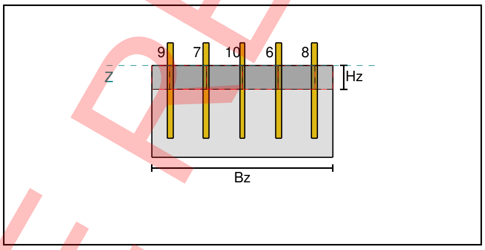
V_{Ed} - Total required load on assumed concrete edge failure

$$V_{Ed} = \sqrt{\left((V_{\perp})^2\right) + \left((V_{\parallel})^2\right)} = \sqrt{\left((25\ \text{kN})^2\right) + \left((6\ \text{kN})^2\right)} = 25.71\ \text{kN}$$

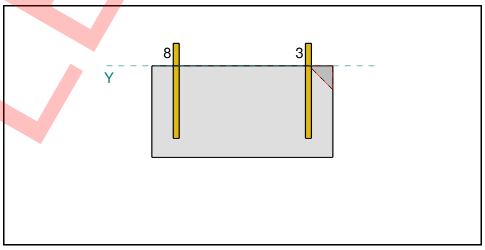
Only the anchors nearest to the failure edge are assumed to resist the shear load.



PLAN VIEW



FRONT VIEW



SIDE VIEW

EN 1992-4:2018 Clause 7.2.2.5(14)

Determine if the support is a narrow concrete member

The support is not a narrow member.

Symbol	Description	Value
$c_{left,g1}$	Anchor group BO Vy 1 concrete edge distance (left)	75.0 mm
$c_{right,g1}$	Anchor group BO Vy 1 concrete edge distance (right)	75.0 mm
$c_{top,g1}$	Anchor group BO Vy 1 concrete edge distance (top)	100.0 mm
$c_{bottom,g1}$	Anchor group BO Vy 1 concrete edge distance (bottom)	650.0 mm
t_{conc}	Concrete thickness	380.0 mm
s_z	Spacing of anchor rods along Z-axis	150.0 mm
$c_{1,g1}$	Anchor group distance to failure edge (+Vy shear)	100.0 mm
	Narrow Member	FALSE

Calculation for critical anchor group: Anchor Group BO Vy 1.

Calculate alpha and beta factors

ACI 318-19 Clause 17.7.2.1.2

$c_{1,g1} = 100 \text{ mm}$ - Anchor group distance to failure edge (+Vy shear)

$h_{ef} = 300 \text{ mm}$ - Anchor rod embedment length

$d_{anc} = 24 \text{ mm}$ - Anchor rod diameter

EN 1992-4:2018 Clause 7.2.2.5

l_f - Length of fastener

$$l_f = \min(\mathrm{h_{ef}},\ 12\mathrm{d_{anc}}) = \min(300 \text{ mm},\ 12 \times 24 \text{ mm}) = 288 \text{ mm}$$

EN 1992-4:2018 Eq. 7.42

α - Alpha factor

$$\alpha = 0.1\left(\frac{l_f}{c_{1,g1}}\right)^{0.5} = 0.1 \times \left(\frac{288 \text{ mm}}{100 \text{ mm}}\right)^{0.5} = 0.16971$$

EN 1992-4:2018 Eq. 7.43

β - Beta factor

$$\beta = 0.1\left(\frac{d_{anc}}{c_{1,g1}}\right)^{0.2} = 0.1 \times \left(\frac{24 \text{ mm}}{100 \text{ mm}}\right)^{0.2} = 0.07517$$

Calculate initial value of the characteristic resistance of a fastener

EN 1992-4:2018 Clause 7.2.2.5

$k_9 = 1.7$ - Breakout factor under shear loading

$f_{ck} = 20 \text{ MPa}$ - Concrete compressive strength (C20/25)

ACI 318-19 Clause 17.7.2.1.2

$c_{1,g1} = 100 \text{ mm}$ - Anchor group distance to failure edge (+Vy shear)

EN 1992-4-2018 Eq. 7.41

$V^0_{Rk,c}$ - Characteristic strength of a single fastener

$$V^0_{Rk,c} = k_9\left(\frac{d_{anc}}{mm}\right)^{\alpha}\left(\frac{l_f}{mm}\right)^{\beta}\sqrt{\frac{f_{ck}}{MPa}}\left(\frac{c_{1,g1}}{mm}\right)^{1.5} N$$

$$V^0_{Rk,c} = 1.7 \times \left(\frac{24 \text{ mm}}{1 \text{ mm}}\right)^{0.16971} \times \left(\frac{288 \text{ mm}}{1 \text{ mm}}\right)^{0.07517} \times \sqrt{\frac{20 \text{ MPa}}{1 \text{ MPa}}} \times \left(\frac{100 \text{ mm}}{1 \text{ mm}}\right)^{1.5} \times 0.001 \text{ kN}$$

$$V^0_{Rk,c} = 19.956 \text{ kN}$$

Calculate reference projected area of a single anchor

EN 1992-4:2018 Eq. 7.44

$A^0_{c,V}$ - Reference projected area of a single fastener

$$A^0_{c,V} = 4.5(c_{1,g1})^2 = 4.5 \times (100 \text{ mm})^2 = 45000 \text{ mm}^2$$

Calculate width of actual projected area on failure surface

$s_{sum,z,g1} = 600 \text{ mm}$ - Anchor group BO Vy 1 sum of spacing along Z-axis

$n_{z,g1} = 5$ - Number of anchors along Z-axis for anchor group BO Vy 1

EN 1992-4:2018 Clause 7.2.2.5

$B_{c,V}$ - Actual width of failure surface for an anchor group

$$B_{c,V} = \min(\mathrm{c_{left,g1}},\ 1.5\mathrm{c_{1,g1}}) + (\min(\mathrm{s_{sum,z,g1}},\ 3\mathrm{c_{1,g1}}(\mathrm{n_{z,g1}} - 1))) + \min(\mathrm{c_{right,g1}},\ 1.5\mathrm{c_{1,g1}})$$

$$B_{c,V} = \min(75 \text{ mm},\ 1.5 \times 100 \text{ mm}) + (\min(600 \text{ mm},\ 3 \times 100 \text{ mm} \times (5-1))) + \min(75 \text{ mm},\ 1.5 \times 100 \text{ mm})$$

$$B_{c,V} = 750 \text{ mm}$$

Calculate height of actual projected area on failure surface

EN 1992-4:2018 Clause 7.2.2.5

$H_{c,V}$ - Actual height of projected area

$$H_{c,V} = \min(1.5\mathrm{c_{1,g1}},\ \mathrm{t_{conc}}) = \min(1.5 \times 100 \text{ mm},\ 380 \text{ mm}) = 150 \text{ mm}$$

Calculate actual projected area on failure surface

EN 1992-4:2018 Clause 7.2.2.5

$A_{c,V}$ - Actual projected area

$$A_{c,V} = H_{c,V}B_{c,V} = 150 \text{ mm} \times 750 \text{ mm} = 112500 \text{ mm}^2$$

Calculate parameters for breakout resistance

EN 1992-4:2018 Eq 7.4

$\Psi_{s,V}$ - Factor that takes account the disturbance of stress distribution

$$\Psi_{s,V} = \min\left(0.7 + 0.3\left(\frac{\mathrm{c_{2,g1}}}{1.5\mathrm{c_{1,g1}}}\right),\ 1.0\right) = \min\left(0.7 + 0.3 \times \left(\frac{75 \text{ mm}}{1.5 \times 100 \text{ mm}}\right),\ 1\right) = 0.85$$

EN 1992-4-2018 Eq. 7.46

$\Psi_{h,V}$ - Parameter that takes account the member thickness

$$\Psi_{h,V} = \max\left(\left(\frac{1.5c_{1,g1}}{t_{conc}}\right)^{0.5}, 1\right) = \max\left(\left(\frac{1.5 \times 100\ \text{mm}}{380\ \text{mm}}\right)^{0.5}, 1\right) = 1$$

Recall applied perpendicular and parallel loads:

$V_{\perp} = 25\ \text{kN}$

$V_{\parallel} = 6\ \text{kN}$

EN 1992-4-2018 Eq. 7.48

α_V - Angle between design shear load V and a line perpendicular to the verified edge

$$\alpha_V = \tan^{-1}\left(\frac{V_{\parallel}}{V_{\perp}}\right) = \tan^{-1}\left(\frac{6\ \text{kN}}{25\ \text{kN}}\right) = 0.23554\ \text{rad}$$

EN 1992-4-2018 Eq. 7.48

$\Psi_{\alpha,V}$ - Parameter that takes account the influence of a shear load inclined to edge

$$\Psi_{\alpha,V} = \max\left(\sqrt{\frac{1}{\left((\cos(\alpha_V))^2\right) + \left((0.5(\sin(\alpha_V)))^2\right)}}, 1\right)$$

$$\Psi_{\alpha,V} = \max\left(\sqrt{\frac{1}{\left((\cos(0.23554\ \text{rad}))^2\right) + \left((0.5 \times (\sin(0.23554\ \text{rad})))^2\right)}}, 1\right)$$

$$\Psi_{\alpha,V} = 1.0211$$

Calculate design concrete cone breakout resistance

EN 1992-4-2018 Eq. 7.47

$\Psi_{ec,V} = 1$ - Parameter accounting for the influence of eccentricity (no eccentricity)

EN 1992-4-2018 Clause 7.2.2.5 Note 13

$\Psi_{re,V} = 1$ - Parameter that takes account the effect of reinforcement (no reinforcement considered)

EN 1992-4:2018 Table 4.1

$\gamma_{Mc} = 1.5$ - Partial safety factor for concrete failure

EN 1992-4:2018 Eq. 7.1

$V_{Rk,c}$ - Design concrete cone breakout resistance

$$V_{Rk,c} = V^0_{Rk,c}\left(\frac{A_{c,V}}{A^0_{c,V}}\right)\Psi_{s,V}\Psi_{h,V}\Psi_{ec,V}\Psi_{\alpha,V}\Psi_{re,V}$$

$$V_{Rk,c} = 19.956\ \text{kN} \times \left(\frac{112500\ \text{mm}^2}{45000\ \text{mm}^2}\right) \times 0.85 \times 1 \times 1 \times 1.0211 \times 1 = 43.299\ \text{kN}$$

EN 1992-4:2018 Eq. 7.1

$V_{Rd,c}$ - Design shear breakout resistance

$$V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}} = \frac{43.299\ \text{kN}}{1.5} = 28.866\ \text{kN}$$

Result:

DCR - Demand-to-Capacity Ratio

$$DCR = \frac{V_{Ed}}{V_{Rd,c}} = \frac{25.71\ \text{kN}}{28.866\ \text{kN}} = 0.89066$$

PASS = 0.89

Go back to summary results table.

Check No. 6: Concrete Breakout Capacity (Vz Shear)

$V_z = 12\ \text{kN}$ - Vz shear load

$n_{a,s} = 2$ - Number of single anchors for Vz shear breakout

$V_{\perp}$ - Required concrete breakout shear strength of a single anchor with failure edge perpendicular to load

$$V_{\perp} = \frac{V_z}{n_{a,s}} = \frac{12\ \text{kN}}{2} = 6\ \text{kN}$$

$V_y = 25\ \text{kN}$ - Vy shear load

$n_{anc} = 10$ - Total number of anchor rods

$V_{\parallel}$ - Required concrete breakout shear strength of a single anchor with failure edge parallel to load

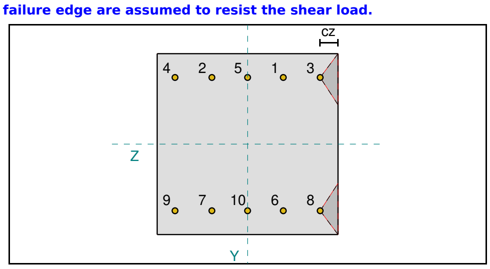
$$V_{\parallel} = \frac{V_y}{n_{anc}} = \frac{25\ \text{kN}}{10} = 2.5\ \text{kN}$$

Calculate total shear load per anchor group

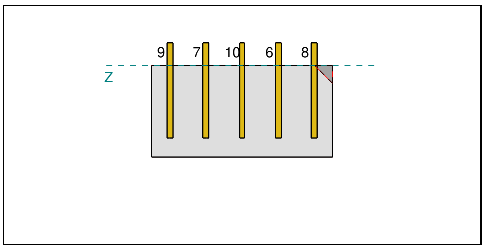
V_{Ed} - Total required load on assumed concrete edge failure

$$V_{Ed} = \sqrt{\left((V_{\perp})^2\right) + \left((V_{\parallel})^2\right)} = \sqrt{\left((6\ \text{kN})^2\right) + \left((2.5\ \text{kN})^2\right)} = 6.5\ \text{kN}$$

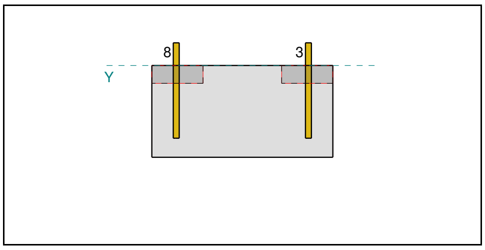
Only the anchors nearest to the failure edge are assumed to resist the shear load.



PLAN VIEW



FRONT VIEW



SIDE VIEW

Determine if the support is a narrow concrete member

EN 1992-4:2018 Clause 7.2.2.5(14)

The support is not a narrow member.

Symbol	Description	Value
$c_{left,s3}$	Single anchor concrete edge distance (left)	675.0 mm
$c_{right,s3}$	Single anchor concrete edge distance (right)	75.0 mm
$c_{top,s3}$	Single anchor concrete edge distance (top)	100.0 mm
$c_{bottom,s3}$	Single anchor concrete edge distance (bottom)	650.0 mm
t_{conc}	Concrete thickness	380.0 mm
$c_{1,s3}$	Single anchor distance to failure edge (+Vz shear)	75.0 mm
	Narrow Member	FALSE

Calculation for critical anchor: Anchor ID 3.

Calculate alpha and beta factors

EN 1992-4:2018 Clause 7.2.2.5(14)

$c_{1,s3} = 75\ \mathrm{mm}$ - Single anchor distance to failure edge (+Vz shear)

$h_{ef} = 300\ \mathrm{mm}$ - Anchor rod embedment length

$d_{anc} = 24\ \mathrm{mm}$ - Anchor rod diameter

EN 1992-4:2018 Clause 7.2.2.5

l_f - Length of fastener

$$l_f = \min\left(\mathrm{h_{ef}},\ 12\mathrm{d_{anc}}\right) = \min\left(300\ \mathrm{mm},\ 12 \times 24\ \mathrm{mm}\right) = 288\ \mathrm{mm}$$

EN 1992-4:2018 Eq. 7.42

α - Alpha factor

$$\alpha = 0.1\left(\frac{l_f}{c_{1,s3}}\right)^{0.5} = 0.1 \times \left(\frac{288\ \mathrm{mm}}{75\ \mathrm{mm}}\right)^{0.5} = 0.19596$$

EN 1992-4:2018 Eq. 7.43

β - Beta factor

$$\beta = 0.1\left(\frac{d_{anc}}{c_{1,s3}}\right)^{0.2} = 0.1 \times \left(\frac{24\ \mathrm{mm}}{75\ \mathrm{mm}}\right)^{0.2} = 0.079621$$

Calculate initial value of the characteristic resistance of a fastener

EN 1992-4:2018 Clause 7.2.2.5

$k_9 = 1.7$ - Breakout factor under shear loading

$f_{ck} = 20\ \mathrm{MPa}$ - Concrete compressive strength (C20/25)

EN 1992-4:2018 Clause 7.2.2.5(14)

$c_{1,s3} = 75\ \mathrm{mm}$ - Single anchor distance to failure edge (+Vz shear)

EN 1992-4-2018 Eq. 7.41

$V^0_{Rk,c}$ - Characteristic strength of a single fastener

$$V^0_{Rk,c} = k_9\left(\frac{d_{anc}}{mm}\right)^{\alpha}\left(\frac{l_f}{mm}\right)^{\beta}\sqrt{\frac{f_{ck}}{MPa}}\left(\frac{c_{1,s3}}{mm}\right)^{1.5} N$$

$$V^0_{Rk,c} = 1.7 \times \left(\frac{24\ \mathrm{mm}}{1\ \mathrm{mm}}\right)^{0.19596} \times \left(\frac{288\ \mathrm{mm}}{1\ \mathrm{mm}}\right)^{0.079621} \times \sqrt{\frac{20\ \mathrm{MPa}}{1\ \mathrm{MPa}}} \times \left(\frac{75\ \mathrm{mm}}{1\ \mathrm{mm}}\right)^{1.5} \times 0.001\ \mathrm{kN}$$

$$V^0_{Rk,c} = 14.449\ \mathrm{kN}$$

Calculate reference projected area of a single anchor

EN 1992-4:2018 Eq. 7.44

$A^0_{c,V}$ - Reference projected area of a single fastener

$$A^0_{c,V} = 4.5\left(c_{1,s3}\right)^2 = 4.5 \times \left(75\ \mathrm{mm}\right)^2 = 25313\ \mathrm{mm}^2$$

Calculate width of actual projected area on failure surface

EN 1992-4:2018 Clause 7.2.2.5

$B_{c,V}$ - Actual length of concrete cone for a single anchor

$$B_{c,V} = \min\left(\mathrm{c_{top,s3}},\ 1.5\mathrm{c_{1,s3}}\right) + \min\left(\mathrm{c_{bottom,s3}},\ 1.5\mathrm{c_{1,s3}}\right)$$

$$B_{c,V} = \min\left(100\ \mathrm{mm},\ 1.5 \times 75\ \mathrm{mm}\right) + \min\left(650\ \mathrm{mm},\ 1.5 \times 75\ \mathrm{mm}\right) = 212.5\ \mathrm{mm}$$

Calculate height of actual projected area on failure surface

EN 1992-4:2018 Clause 7.2.2.5

$H_{c,V}$ - Actual height of projected area

$$H_{c,V} = \min\left(1.5\mathrm{c_{1,s3}},\ \mathrm{t_{conc}}\right) = \min\left(1.5 \times 75\ \mathrm{mm},\ 380\ \mathrm{mm}\right) = 112.5\ \mathrm{mm}$$

Calculate actual projected area on failure surface

EN 1992-4:2018 Clause 7.2.2.5

$A_{c,V}$ - Actual projected area

$$A_{c,V} = H_{c,V}B_{c,V} = 112.5\ \mathrm{mm} \times 212.5\ \mathrm{mm} = 23906\ \mathrm{mm}^2$$

Calculate parameters for breakout resistance

EN 1992-4:2018 Eq 7.4

$\Psi_{s,V}$ - Factor that takes account the disturbance of stress distribution

$$\Psi_{s,V} = \min\left(0.7 + 0.3\left(\frac{\mathrm{c_{2,s3}}}{1.5\mathrm{c_{1,s3}}}\right),\ 1.0\right) = \min\left(0.7 + 0.3 \times \left(\frac{100\ \mathrm{mm}}{1.5 \times 75\ \mathrm{mm}}\right),\ 1\right) = 0.96667$$

EN 1992-4-2018 Eq. 7.46

$\Psi_{h,V}$ - Parameter that takes account the member thickness

$$\Psi_{h,V} = \max\left(\left(\frac{1.5\mathrm{c_{1,s3}}}{\mathrm{t_{conc}}}\right)^{0.5},\ 1\right) = \max\left(\left(\frac{1.5 \times 75\ \mathrm{mm}}{380\ \mathrm{mm}}\right)^{0.5},\ 1\right) = 1$$

Recall applied perpendicular and parallel loads:

$V_{\perp} = 6\ \mathrm{kN}$

$V_{\parallel} = 2.5\ \mathrm{kN}$

EN 1992-4-2018 Eq. 7.48

α_V - Angle between design shear load V and a line perpendicular to the verified edge

$$\alpha_V = \tan^{-1}\left(\frac{\mathrm{V_{\parallel}}}{\mathrm{V_{\perp}}}\right) = \tan^{-1}\left(\frac{2.5\ \mathrm{kN}}{6\ \mathrm{kN}}\right) = 0.39479\ \mathrm{rad}$$

EN 1992-4-2018 Eq. 7.48

$\Psi_{\alpha,V}$ - Parameter that takes account the influence of a shear load inclined to edge

$$\Psi_{\alpha,V} = \max\left(\sqrt{\frac{1}{\left(\left(\cos\left(\alpha_{\mathrm{V}}\right)\right)^2\right) + \left(\left(0.5\left(\sin\left(\alpha_{\mathrm{V}}\right)\right)\right)^2\right)}},\ 1\right)$$

$$\Psi_{\alpha,V} = \max\left(\sqrt{\frac{1}{\left(\left(\cos\left(0.39479\ \mathrm{rad}\right)\right)^2\right) + \left(\left(0.5 \times \left(\sin\left(0.39479\ \mathrm{rad}\right)\right)\right)^2\right)}},\ 1\right)$$

$$\Psi_{\alpha,V} = 1.0606$$

Calculate design concrete cone breakout resistance

EN 1992-4-2018 Eq. 7.47

$\Psi_{ec,V} = 1$ - Parameter accounting for the influence of eccentricity (no eccentricity)

EN 1992-4-2018 Clause 7.2.2.5 Note 13

$\Psi_{re,V} = 1$ - Parameter that takes account the effect of reinforcement (no reinforcement considered)

EN 1992-4:2018 Table 4.1

$\gamma_{Mc} = 1.5$ - Partial safety factor for concrete failure

EN 1992-4:2018 Eq. 7.1

$V_{Rk,c}$ - Design concrete cone breakout resistance

$$V_{Rk,c} = V^0_{Rk,c}\left(\frac{A_{c,V}}{A^0_{c,V}}\right)\Psi_{s,V}\Psi_{h,V}\Psi_{ec,V}\Psi_{\alpha,V}\Psi_{re,V}$$

$$V_{Rk,c} = 14.449\ \mathrm{kN} \times \left(\frac{23906\ \mathrm{mm}^2}{25313\ \mathrm{mm}^2}\right) \times 0.96667 \times 1 \times 1 \times 1.0606 \times 1 = 13.99\ \mathrm{kN}$$

EN 1992-4:2018 Eq. 7.1

$V_{Rd,c}$ - Design shear breakout resistance

$$V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}} = \frac{13.99\ \mathrm{kN}}{1.5} = 9.3269\ \mathrm{kN}$$

Result:

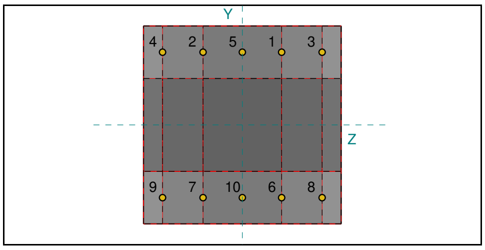
DCR - Demand-to-Capacity Ratio

$$DCR = \frac{V_{Ed}}{V_{Rd,c}} = \frac{6.5\ \mathrm{kN}}{9.3269\ \mathrm{kN}} = 0.69691$$

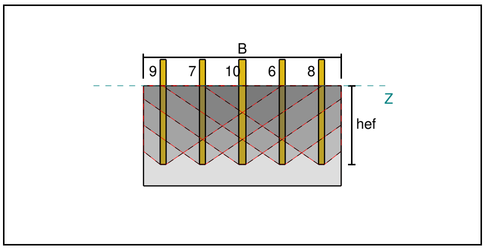
PASS = 0.70

Go back to summary results table.

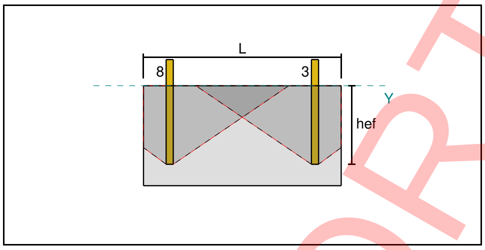
Check No. 7: Concrete Pryout Capacity



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate total shear load on anchor group

$V_y = 25 \text{ kN}$ - Vy shear load

$V_z = 12 \text{ kN}$ - Vz shear load

V_{res} - Resultant shear load

$$V_{res} = \sqrt{\left((V_y)^2\right) + \left((V_z)^2\right)} = \sqrt{\left((25 \text{ kN})^2\right) + \left((12 \text{ kN})^2\right)} = 27.731 \text{ kN}$$

$n_{anc} = 10$ - Total number of anchor rods

$n_{a,g1} = 10$ - Number of anchors in anchor group PO 1

V_{Ed} - Required concrete pryout strength of an anchor group

$$V_{Ed} = \left(\frac{V_{res}}{n_{anc}}\right) n_{a,g1} = \left(\frac{27.731 \text{ kN}}{10}\right) \times 10 = 27.731 \text{ kN}$$

Determine if the support is a narrow concrete member

EN 1992-4:2018 Clause 7.2.1.4(8)

The support is classified as a narrow member. The modified values below will be used throughout the calculations.

Symbol	Description	Value
$c_{left,g1}$	Anchor group PO 1 concrete edge distance (left)	75.0 mm
$c_{right,g1}$	Anchor group PO 1 concrete edge distance (right)	75.0 mm
$c_{top,g1}$	Anchor group PO 1 concrete edge distance (top)	100.0 mm
$c_{bottom,g1}$	Anchor group PO 1 concrete edge distance (bottom)	100.0 mm
h_{ef}	Anchor rod embedment length	300.0 mm
s_{cr}	Anchor rod characteristic spacing	900.0 mm
c_{cr}	Anchor rod characteristic edge distance	450.0 mm
$h'_{ef,g1}$	Anchor group PO 1 modified effective embedment length	183.3 mm
$s'_{cr,g1}$	Anchor group PO 1 modified characteristic spacing	550.0 mm
$c'_{cr,g1}$	Anchor group PO 1 modified characteristic edge distance	275.0 mm
	Narrow Member	TRUE

Calculation for critical anchor group: Anchor Group PO 1.

Calculate characteristic strength of a single anchor

$f_{ck} = 20 \text{ MPa}$ - Concrete compressive strength (C20/25)

EN 1992-4:2018 Clause 7.2.1.4(8) $h'_{ef,g1} = 183.33 \text{ mm}$ - Anchor group PO 1 modified effective embedment length

EN 1992-4:2018 Clause 7.2.1.4 $k_1 = 8.9$ - Breakout factor

EN 1992-4:2018 Eq. 7.2 $N^0_{Rk,c}$ - Characteristic strength of a single fastener

$$N^0_{Rk,c} = k_1 \sqrt{\frac{f_{ck}}{MPa}} \left(\frac{h'_{ef,g1}}{mm}\right)^{1.5} N$$

$$N^0_{Rk,c} = 8.9 \times \sqrt{\frac{20\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{183.33\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 0.001\ \text{kN} = 98.802\ \text{kN}$$

Calculate reference projected area of a single anchor

EN 1992-4:2018 Eq. 7.3

$A^0_{c,N}$ - Reference projected area of a single fastener

$$A^0_{c,N} = s'_{cr,g1} s'_{cr,g1} = 550\ \text{mm} \times 550\ \text{mm} = 302500\ \text{mm}^2$$

Calculate length of actual projected cone area (along Z-direction)

$s_{sum,z,g1} = 600\ \text{mm}$ - Anchor group PO 1 sum of spacing along Z-axis

$n_{z,g1} = 5$ - Number of anchors along Z-axis for anchor group PO 1

EN 1992-4:2018 Clause 7.2.1.4

L_{Nc} - Actual length of concrete cone for an anchor group

$$L_{Nc} = \min\left(\mathrm{c_{left,g1}},\ \mathrm{c'_{cr,g1}}\right) + \left(\min\left(\mathrm{s_{sum,z,g1}},\ \mathrm{s'_{cr,g1}}\left(\mathrm{n_{z,g1}} - 1\right)\right)\right) + \min\left(\mathrm{c_{right,g1}},\ \mathrm{c'_{cr,g1}}\right)$$

$$L_{Nc} = \min(75\ \text{mm},\ 275\ \text{mm}) + (\min(600\ \text{mm},\ 550\ \text{mm} \times (5-1))) + \min(75\ \text{mm},\ 275\ \text{mm})$$

$$L_{Nc} = 750\ \text{mm}$$

Calculate width of actual projected cone area (along Y-direction)

$s_{sum,y,g1} = 550\ \text{mm}$ - Anchor group PO 1 sum of spacing along Y-axis

$n_{y,g1} = 2$ - Number of anchors along Y-axis for anchor group PO 1

EN 1992-4:2018 Clause 7.2.1.4

B_{Nc} - Actual width of concrete cone for an anchor group

$$B_{Nc} = \min\left(\mathrm{c_{top,g1}},\ \mathrm{c'_{cr,g1}}\right) + \left(\min\left(\mathrm{s_{sum,y,g1}},\ \mathrm{s'_{cr,g1}}\left(\mathrm{n_{y,g1}} - 1\right)\right)\right) + \min\left(\mathrm{c_{bottom,g1}},\ \mathrm{c'_{cr,g1}}\right)$$

$$B_{Nc} = \min(100\ \text{mm},\ 275\ \text{mm}) + (\min(550\ \text{mm},\ 550\ \text{mm} \times (2-1))) + \min(100\ \text{mm},\ 275\ \text{mm})$$

$$B_{Nc} = 750\ \text{mm}$$

Calculate actual projected area of the anchor group

$n_{a,g1} = 10$ - Number of anchors in anchor group PO 1

EN 1992-4:2018 Clause 7.2.1.4

A_{Nc} - Actual projected area for an anchor group

$$A_{Nc} = L_{Nc} B_{Nc} = 750\ \text{mm} \times 750\ \text{mm} = 562500\ \text{mm}^2$$

Calculate shortest edge distance

$c_{min,N}$ - Shortest edge distance

$$c_{min,N} = \min\left(\mathrm{c_{left,g1}},\ \mathrm{c_{right,g1}},\ \mathrm{c_{top,g1}},\ \mathrm{c_{bottom,g1}}\right) = \min(75\ \text{mm},\ 75\ \text{mm},\ 100\ \text{mm},\ 100\ \text{mm}) = 75\ \text{mm}$$

Calculate parameters for breakout resistance

EN 1992-4:2018 Eq 7.4

$\Psi_{s,N}$ - Parameter accounting for distribution of stresses in concrete

$$\Psi_{s,N} = \min\left(0.7 + 0.3\left(\frac{\mathrm{c_{min,N}}}{\mathrm{c'_{cr,g1}}}\right),\ 1.0\right) = \min\left(0.7 + 0.3 \times \left(\frac{75\ \text{mm}}{275\ \text{mm}}\right),\ 1\right) = 0.78182$$

EN 1992-4:2018 Eq. 7.5

$\Psi_{re,N}$ - Parameter accounting for shell spalling effect

$$\Psi_{re,N} = \min\left(0.5 + \frac{\frac{\mathrm{h'_{ef,g1}}}{\mathrm{mm}}}{200},\ 1.0\right) = \min\left(0.5 + \frac{\frac{183.33\ \text{mm}}{1\ \text{mm}}}{200},\ 1\right) = 1$$

Calculate design concrete cone breakout resistance

EN 1992-4:2018 Eq. 7.6

$\Psi_{ec,N} = 1$ - Parameter accounting for the influence of eccentricity (no eccentricity)

EN 1992-4:2018 Eq. 7.7

$\Psi_{M,N} = 1$ - Parameter accounting for the influence of compression force

EN 1992-4:2018 Eq. 7.1

N_{cbg} - Nominal concrete breakout strength in shear of an anchor group

$$N_{cbg} = \left(\frac{A_{Nc}}{A^0_{c,N}}\right) \Psi_{s,N} \Psi_{re,N} \Psi_{ec,N} \Psi_{M,N} N^0_{Rk,c}$$

$$N_{cbg} = \left(\frac{562500\ \text{mm}^2}{302500\ \text{mm}^2}\right) \times 0.78182 \times 1 \times 1 \times 1 \times 98.802\ \text{kN} = 143.64\ \text{kN}$$

Calculate design characteristic resistance for concrete pryout failure

EN 1992-1-1:2004 Table 2.1N

$\gamma_C = 1.5$ - Partial safety factor for resistance of concrete

ETAG-001 Annex C Clause 5.2.3.3

$k_8 = 2$ - Concrete pryout factor

EN 1992-4:2018 Eq. 7.39a

$V_{Rd,cp}$ - Design characteristic resistance of anchor group for concrete pryout failure

$$V_{Rd,cp} = \frac{k_8 N_{cbg}}{\gamma_C} = \frac{2 \times 143.64\ \text{kN}}{1.5} = 191.52\ \text{kN}$$

Result:

PASS = 0.14

DCR - Demand-to-Capacity Ratio

$$DCR = \frac{V_{Ed}}{V_{Rd,cp}} = \frac{27.731\ \text{kN}}{191.52\ \text{kN}} = 0.1448$$

Go back to summary results

		[table](#).
	Check No. 8: Anchor Rod Shear Capacity	

Calculate shear load per anchor

$V_y = 25\ \mathrm{kN}$ - Vy shear load

$V_z = 12\ \mathrm{kN}$ - Vz shear load

$n_{anc} = 10$ - Total number of anchor rods

V_{Ed} - Design shear force on anchor rod

$$V_{Ed} = \frac{\sqrt{\left((V_y)^2\right) + \left((V_z)^2\right)}}{n_{anc}}$$

$$V_{Ed} = \frac{\sqrt{\left((25\ \mathrm{kN})^2\right) + \left((12\ \mathrm{kN})^2\right)}}{10} = 2.7731\ \mathrm{kN}$$

Determine whether the shear load is applied with a lever arm

EN 1992-4:2018 Clause 6.2.2.3(1)

The shear load may be applied without a lever arm because all of the following conditions are met.

Description	Value
Fixture is in contact with fastener	Yes
Base plate is in direct contact with concrete	Yes
Shear load is applied with lever arm	FALSE

Calculate anchor stress area

$d_{anc} = 24\ \mathrm{mm}$ - Anchor rod diameter

A_s - Tensile stress area of anchor

$$A_s = \frac{\pi}{4}(d_{anc})^2 = \frac{\pi}{4} \times (24\ \mathrm{mm})^2 = 452.39\ \mathrm{mm}^2$$

Calculate characteristic resistance of a single fastener in steel failure

$F_{u\_anc} = 800\ \mathrm{MPa}$ - Anchor rod ultimate tensile strength (8.8)

EN 1992-4:2018 Clause 7.2.2.3.1(1)

$k_6 = 0.5$ - Anchor steel factor for shear failure

EN 1992-4:2018 Eq. 7.34

$V^0_{Rk,s}$ - Characteristic resistance of a single fastener in steel failure

$$V^0_{Rk,s} = k_6 A_s F_{u\_anc} = 0.5 \times 452.39\ \mathrm{mm}^2 \times 800\ \mathrm{MPa} = 180.96\ \mathrm{kN}$$

Calculate characteristic resistance accounting ductility

EN 1992-4:2018 Clause 7.2.2.3.1(2)

$k_7 = 1$ - Factor for characteristic resistance of single/group fastener accouting ductility

EN 1992-4:2018 Eq. 7.35 and Eq. 7.36

$V_{Rk,s}$ - Characteristic resistance of a single fastener accounting for ductility

$$V_{Rk,s} = k_7 V^0_{Rk,s} = 1 \times 180.96\ \mathrm{kN} = 180.96\ \mathrm{kN}$$

Calculate partial factor for steel shear failure

$F_{u\_anc} = 800\ \mathrm{MPa}$ - Anchor rod ultimate tensile strength (8.8)

$F_{y\_anc} = 640\ \mathrm{MPa}$ - Anchor rod yield strength (8.8)

EN 1992-4:2018 Table 4.1

$\gamma_{Ms,shear}$ - Partial factor for steel shear failure

$$\gamma_{Ms,shear} = \max\left(1.0\left(\frac{\mathrm{F_{u\_anc}}}{\mathrm{F_{y\_anc}}}\right),\ 1.25\right) = \max\left(1 \times \left(\frac{800\ \mathrm{MPa}}{640\ \mathrm{MPa}}\right),\ 1.25\right) = 1.25$$

Calculate design resistance for steel shear failure for shear load without lever arm

EN 1992-4:2018 Eq. 7.35 or Eq. 7.36

$V_{Rd,s}$ - Design shear resistance of the anchor rod for shear load without lever arm

$$V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms,shear}} = \frac{180.96\ \mathrm{kN}}{1.25} = 144.76\ \mathrm{kN}$$

Result:

PASS = 0.02

DCR - Demand-to-Capacity Ratio

$$DCR = \frac{V_{Ed}}{V_{Rd,s}} = \frac{2.7731\ \mathrm{kN}}{144.76\ \mathrm{kN}} = 0.019156$$

[Go back to summary results table](#).