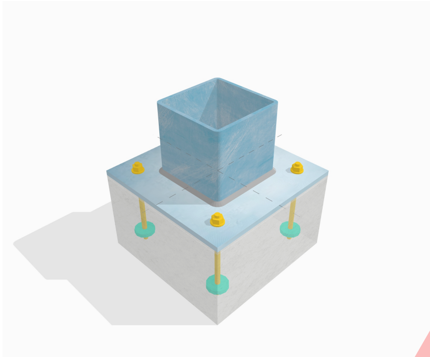
REFERENCES	CALCULATIONS	RESULTS

SkyCiv Base Plate and Anchor Rod Design

Shear Design Example for 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

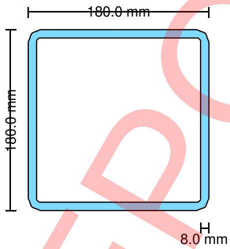


Load Combinations:

Load Combination	Axial Load, Nx (kN)	Strong-axis Shear, Vy (kN)	Weak-axis Shear, Vz (kN)
1	0.00	5.00	5.00

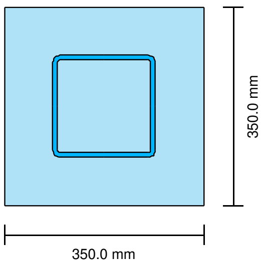
Note(s):
1. Positive Nx (+) indicates compression; negative Nx (-) indicates tension.

Column Properties:



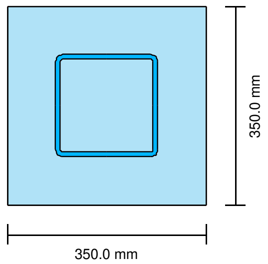
Symbol	Description	Value
$Section$	Column section	SHS180x180x8
d_{col}	Column depth	180.0 mm
t_{col}	Column thickness	8.0 mm
b_{col}	Column width	180.0 mm
A_{col}	Column area	5440.0 mm^2
r_{col}	Column root radius	4.0 mm
f_{y_col}	Column yield stress (S235)	235.0 MPa
f_{u_col}	Column tensile stress (S235)	360.0 MPa

Base Plate Properties:



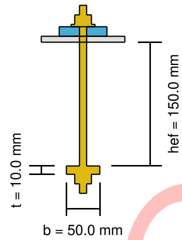
Symbol	Description	Value
B_{bp}	Base plate width	350.0 mm
L_{bp}	Base plate length	350.0 mm
t_{bp}	Base plate thickness	12.0 mm
A_{bp}	Base plate plan area	122500.0 mm^2
f_{y_bp}	Base plate yield strength (S235)	235.0 MPa
f_{u_bp}	Base plate ultimate tensile strength (S235)	360.0 MPa
t_{grout}	Grout thickness	6.0 mm
$Material$	Grout material	≥ 30 MPa

Concrete Properties:



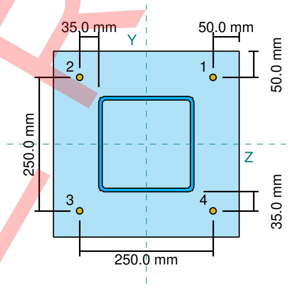
Symbol	Description	Value
B_{conc}	Concrete width	350.0 mm
L_{conc}	Concrete length	350.0 mm
t_{conc}	Concrete thickness	200.0 mm
A_{conc}	Concrete plan area	122500.0 mm^2
f_{ck}	Concrete compressive strength (C20/25)	20.0 MPa
–	Concrete assumption: cracked or uncracked	Cracked

Anchor Information:



Symbol	Description	Value
d_{anc}	Anchor rod diameter	12.0 mm
h_{ef}	Anchor rod embedment length	150.0 mm
b_{embed_plate}	Anchor embed plate diameter	50.0 mm
t_{embed_plate}	Anchor embed plate thickness	10.0 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

Anchor Layout:



Symbol	Description	Value
n_{anc}	Total number of anchor rods	4.0
s_z	Spacing of anchor rods along Z-axis	250.0 mm
s_y	Spacing of anchor rods along Y-axis	250.0 mm
$l_{edge,z}$	Base Plate edge distance along Z-axis	50.0 mm
$l_{edge,y}$	Base Plate edge distance along Y-axis	50.0 mm

Anchor Data Summary:

ID	Z (mm)	Y (mm)
1	125.000	125.000
2	-125.000	125.000
3	-125.000	-125.000
4	125.000	-125.000

ID	Shear Direction Resisted	Breakout (Vy Shear)	Breakout (Vz Shear)	Pryout (Vy Shear)	Pryout (Vz Shear)
1	+Vz +Vy	Single	Single	PO Vy All Load Directions	PO Vz Group 1
2	-Vz +Vy	Single	Single	PO Vy All Load Directions	PO Vz Group 1
3	-Vz -Vy	Single	Single	PO Vy All Load Directions	PO Vz Group 1
4	+Vz -Vy	Single	Single	PO Vy All Load Directions	PO Vz Group 1

Weld Properties:

Symbol	Description	Value
$Type$	Weld Type	Fillet
z	Fillet weld leg size	8.000 mm
a	Weld throat thickness	5.657 mm
f_{uw}	Filler metal ultimate tensile strength (E35)	440.000 MPa

Summary of Detailing Checks

Check Name	Dimensions (Min/Max/Actual)	Status	Reference
Weld Size Requirement	Min: 4.24 mm, Max: 19.00 mm, Actual: 8.00 mm	PASS	EN 1993-1-8:2005 Clause 4.5.2-2
Anchor Clearance	Min: 30.16 mm, Actual: 46.47 mm	PASS	SkyCiv Recommendation
Base Plate Edge Distance	Min: 18.00 mm, Actual: 50.00 mm	PASS	EN 1993-1-8:2005 Table 3.3
Minimum Number of Anchors	Min: 4.00, Actual: 4.00	PASS	SCI P358 Clause 7.3
Embedded Plate Dimension	Min: 48.00 mm, Actual: 50.00 mm	PASS	SkyCiv Recommendation
Min. Anchor Spacing to Prevent Concrete Splitting	Min: 20.00 mm, Actual: 250.00 mm	PASS	EN 1992-4-2018: Clause 7.2.1.7(1)
Min. Concrete Cover to Prevent Concrete Splitting	Min: 40.00 mm, Actual: 50.00 mm	PASS	EN 1992-4-2018: Clause 7.2.1.7(1)

The design geometry meets requirements!

REFERENCES	CALCULATIONS	RESULTS

Load Combination No. 1: Shear Load Only

Check No. 1: Weld Capacity

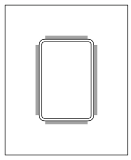


Fig. Welds on column to base plate.

Notes:
Assume the Vz shear load is taken by the top and bottom welds only.
Assume the Vy shear load is taken by the left and right welds only.

Calculate total weld length on top/bottom walls

$b_{col} = 180\ \mathrm{mm}$ - Column width

$t_{col} = 8\ \mathrm{mm}$ - Column thickness

$r_{col} = 4\ \mathrm{mm}$ - Column root radius

$L_{w,top\&bottom}$ - Total length of weld per side of hollow section

$$L_{w,top\&bottom} = 2\left(b_{col} - 2t_{col} - 2r_{col}\right) = 2 \times (180\ \mathrm{mm} - 2 \times 8\ \mathrm{mm} - 2 \times 4\ \mathrm{mm}) = 312\ \mathrm{mm}$$

Calculate normal and shear stresses

$N = 0\ \mathrm{kN}$ - Axial load

$a = 5.657\ \mathrm{mm}$ - Weld throat thickness

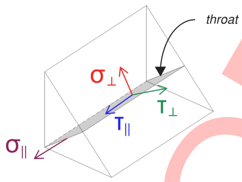


Fig. Weld stresses.

EN 1993-1-8:2005 Clause 4.5.3.2

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

$$\sigma_{\perp} = \frac{N}{\left(L_{w,top\&bottom}\right) a\sqrt{2}} = \frac{0\ \mathrm{kN}}{(312\ \mathrm{mm}) \times 5.657\ \mathrm{mm} \times \sqrt{2}} = 0$$

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

$$\tau_{\perp} = \frac{0}{\left(L_{w,top\&bottom}\right) a\sqrt{2}} = \frac{0\ \mathrm{kN}}{(312\ \mathrm{mm}) \times 5.657\ \mathrm{mm} \times \sqrt{2}} = 0$$

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

$$\tau_{\parallel} = \frac{V_z}{\left(L_{w,top\&bottom}\right) a} = \frac{5\ \mathrm{kN}}{(312\ \mathrm{mm}) \times 5.657\ \mathrm{mm}} = 2.8329\ \mathrm{MPa}$$

Calculate design weld stress using directional method

EN 1993-1-8:2005 Eq. 4.1

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

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

$$F_{w,Ed1} = \sqrt{\left((0)^2\right) + 3 \times \left(\left((0)^2\right) + \left((2.8329\ \mathrm{MPa})^2\right)\right)}$$

$$F_{w,Ed1} = 4.9067\ \mathrm{MPa}$$

Calculate design perpendicular stress on base metal

EN 1993-1-8:2005 Clause 4.5.3.2

$\sigma_{\perp} = 0$

EN 1993-1-8-2005 Eq. 4.1

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

$$F_{w,Ed2} = \sigma_{\perp} = 0$$

Calculate total weld length on left/right walls

$d_{col} = 180\ \mathrm{mm}$ - Column depth

$t_{col} = 8\ \mathrm{mm}$ - Column thickness

$r_{col} = 4\ \mathrm{mm}$ - Column root radius

$L_{w,left\&right}$ - Total length of weld per side of hollow section

$$L_{w,left\&right} = 2\left(d_{col} - 2t_{col} - 2r_{col}\right) = 2 \times (180\ \mathrm{mm} - 2 \times 8\ \mathrm{mm} - 2 \times 4\ \mathrm{mm}) = 312\ \mathrm{mm}$$

Calculate normal and shear stresses

$N = 0\ \mathrm{kN}$ - Axial load

$a = 5.657\ \mathrm{mm}$ - Weld throat thickness

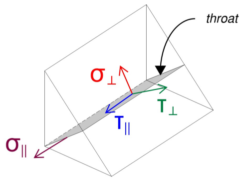


Fig. Weld stresses.

EN 1993-1-8:2005 Clause 4.5.3.2

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

$$\sigma_{\perp} = \frac{N}{(L_{w,left\&right})\, a\sqrt{2}} = \frac{0 \text{ kN}}{(312 \text{ mm}) \times 5.657 \text{ mm} \times \sqrt{2}} = 0$$

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

$$\tau_{\perp} = \frac{0}{(L_{w,left\&right})\, a\sqrt{2}} = \frac{0 \text{ kN}}{(312 \text{ mm}) \times 5.657 \text{ mm} \times \sqrt{2}} = 0$$

EN 1993-1-8:2005 Clause 4.5.3.2

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

$$\tau_{\|} = \frac{V_y}{(L_{w,left\&right})\, a} = \frac{5 \text{ kN}}{(312 \text{ mm}) \times 5.657 \text{ mm}} = 2.8329 \text{ MPa}$$

Calculate design weld stress using directional method

EN 1993-1-8:2005 Eq. 4.1

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

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

$$F_{w,Ed1} = \sqrt{\left((0)^2\right) + 3 \times \left(\left((0)^2\right) + \left((2.8329 \text{ MPa})^2\right)\right)}$$

$$F_{w,Ed1} = 4.9067 \text{ MPa}$$

Calculate design perpendicular stress on base metal

EN 1993-1-8:2005 Clause 4.5.3.2

$\sigma_{\perp} = 0$

EN 1993-1-8-2005 Eq. 4.1

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

$$F_{w,Ed2} = \sigma_{\perp} = 0$$

Determine governing weld stress

EN 1993-1-8:2005 Eq. 4.1

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

$$F_{w,Ed1} = \max\left(\mathrm{F_{w,Ed1}},\ \mathrm{F_{w,Ed1}}\right) = \max\left(4.9067 \text{ MPa},\ 4.9067 \text{ MPa}\right) = 4.9067 \text{ MPa}$$

EN 1993-1-8:2005 Eq. 4.1

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

$$F_{w,Ed2} = \max\left(\mathrm{F_{w,Ed2}},\ \mathrm{F_{w,Ed2}}\right) = \max\left(0,\ 0\right) = 0$$

Determine the ultimate tensile strength of the weakest material

$f_{u\_col} = 360 \text{ MPa}$ - Column tensile stress (S235)

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

$f_{uw} = 440 \text{ MPa}$ - Filler metal ultimate tensile strength (E35)

EN 1993-1-8:2005

f_u - Nominal tensile strength of the weaker part joined

$$f_u = \min\left(\mathrm{f_{u\_col}},\ \mathrm{f_{u\_bp}},\ \mathrm{f_{uw}}\right) = \min\left(360 \text{ MPa},\ 360 \text{ MPa},\ 440 \text{ MPa}\right) = 360 \text{ MPa}$$

Calculate fillet weld strength

EN 1993-1-8:2005

$f_u = 360 \text{ MPa}$

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

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

Calculate design resistance of base metal

EN 1993-1-8:2005

$f_u = 360 \text{ MPa}$

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

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

Result:

PASS = 0.01

DCR - Demand over capacity ratio, comparing two conditions:

$$DCR = \max\left(\frac{\mathrm{F_{w,Ed1}}}{\mathrm{F_{w,Rd1}}},\ \frac{\mathrm{F_{w,Ed2}}}{\mathrm{F_{w,Rd2}}}\right) = \max\left(\frac{4.9067 \text{ MPa}}{360 \text{ MPa}},\ \frac{0}{259.2 \text{ MPa}}\right) = 0.01363$$

Check No. 2: Concrete Breakout Capacity (Vy Shear)

$V_y = 5 \text{ kN}$ - Vy shear load

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

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

$$V_{\perp} = \frac{V_y}{n_{a,s}} = \frac{5\ \mathrm{kN}}{2} = 2.5\ \mathrm{kN}$$

$V_z = 5\ \mathrm{kN}$ - Vz shear load

$n_{anc} = 4$ - Total number of anchor rods

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

$$V_{\parallel} = \frac{V_z}{n_{anc}} = \frac{5\ \mathrm{kN}}{4} = 1.25\ \mathrm{kN}$$

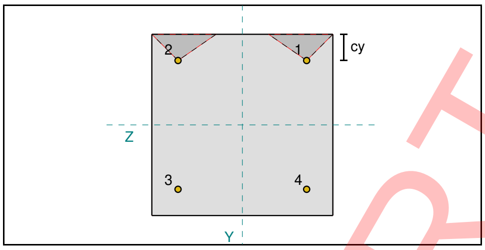
Calculate total shear load per anchor group

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

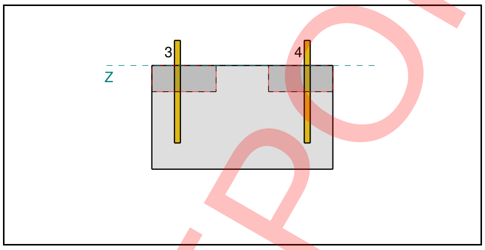
$$V_{Ed} = \sqrt{\left((V_{\perp})^2\right) + \left((V_{\parallel})^2\right)}$$

$$V_{Ed} = \sqrt{\left((2.5\ \mathrm{kN})^2\right) + \left((1.25\ \mathrm{kN})^2\right)} = 2.7951\ \mathrm{kN}$$

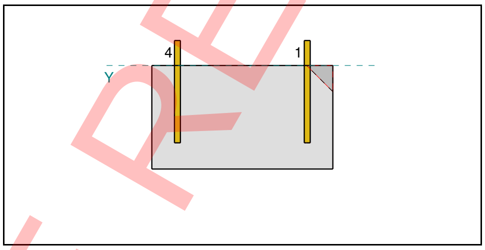
Only the anchors nearest to the failure edge are assumed to resist the shear load.



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
$c_{left,s1}$	Single anchor concrete edge distance (left)	300.0 mm
$c_{right,s1}$	Single anchor concrete edge distance (right)	50.0 mm
$c_{top,s1}$	Single anchor concrete edge distance (top)	50.0 mm
$c_{bottom,s1}$	Single anchor concrete edge distance (bottom)	300.0 mm
t_{conc}	Concrete thickness	200.0 mm
$c_{1,s1}$	Single anchor distance to failure edge (+Vy shear)	50.0 mm
	Narrow Member	FALSE

Calculation for critical anchor: Anchor ID 1.

Calculate alpha and beta factors

EN 1992-4:2018 Clause 7.2.2.5(14)

$c_{1,s1} = 50\ \mathrm{mm}$ - Single anchor distance to failure edge (+Vy shear)

$h_{ef} = 150\ \mathrm{mm}$ - Anchor rod embedment length

$d_{anc} = 12\ \mathrm{mm}$ - Anchor rod diameter

EN 1992-4:2018 Clause 7.2.2.5

l_f - Length of fastener

$$l_f = \min\left(\mathrm{h_{ef}},\ 12\mathrm{d_{anc}}\right) = \min\left(150\ \mathrm{mm},\ 12 \times 12\ \mathrm{mm}\right) = 144\ \mathrm{mm}$$

EN 1992-4:2018 Eq. 7.42

α - Alpha factor

$$\alpha = 0.1\left(\frac{l_f}{c_{1,s1}}\right)^{0.5} = 0.1 \times \left(\frac{144\text{ mm}}{50\text{ mm}}\right)^{0.5} = 0.16971$$

EN 1992-4:2018 Eq. 7.42

β - Beta factor

$$\beta = 0.1\left(\frac{d_{anc}}{c_{1,s1}}\right)^{0.2} = 0.1 \times \left(\frac{12\text{ mm}}{50\text{ mm}}\right)^{0.2} = 0.07517$$

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)

EN 1992-4:2018 Clause 7.2.2.5(14)

$c_{1,s1} = 50\text{ mm}$ - Single anchor distance to failure edge (+Vy shear)

EN 1992-4-2018 Eq. 7.41

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

$$V^0_{Rk,c} = k_9\left(\frac{d_{anc}}{mm}\right)^{\alpha}\left(\frac{l_f}{mm}\right)^{\beta}\sqrt{\frac{f_{ck}}{MPa}}\left(\frac{c_{1,s1}}{mm}\right)^{1.5}N$$

$$V^0_{Rk,c} = 1.7 \times \left(\frac{12\text{ mm}}{1\text{ mm}}\right)^{0.16971} \times \left(\frac{144\text{ mm}}{1\text{ mm}}\right)^{0.07517} \times \sqrt{\frac{20\text{ MPa}}{1\text{ MPa}}} \times \left(\frac{50\text{ mm}}{1\text{ mm}}\right)^{1.5} \times 0.001\text{ kN}$$

$$V^0_{Rk,c} = 5.954\text{ kN}$$

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

$$A^0_{c,V} = 4.5(c_{1,s1})^2 = 4.5 \times (50\text{ mm})^2 = 11250\text{ mm}^2$$

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

$$B_{c,V} = \min\left(\mathrm{c_{left,s1}},\ 1.5\mathrm{c_{1,s1}}\right) + \min\left(\mathrm{c_{right,s1}},\ 1.5\mathrm{c_{1,s1}}\right)$$

$$B_{c,V} = \min\left(300\text{ mm},\ 1.5 \times 50\text{ mm}\right) + \min\left(50\text{ mm},\ 1.5 \times 50\text{ mm}\right) = 125\text{ mm}$$

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

$$H_{c,V} = \min\left(1.5\mathrm{c_{1,s1}},\ \mathrm{t_{conc}}\right) = \min\left(1.5 \times 50\text{ mm},\ 200\text{ mm}\right) = 75\text{ mm}$$

Calculate actual projected area on failure surface

EN 1992-4:2018 Clause 7.2.2.5

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

$$A_{c,V} = H_{c,V}B_{c,V} = 75\text{ mm} \times 125\text{ mm} = 9375\text{ mm}^2$$

Calculate parameters for breakout resistance

EN 1992-4:2018 Eq 7.4

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

$$\Psi_{s,V} = \min\left(0.7 + 0.3\left(\frac{\mathrm{c_{2,s1}}}{1.5\mathrm{c_{1,s1}}}\right),\ 1.0\right) = \min\left(0.7 + 0.3 \times \left(\frac{50\text{ mm}}{1.5 \times 50\text{ mm}}\right),\ 1\right) = 0.9$$

EN 1992-4-2018 Eq. 7.46

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

$$\Psi_{h,V} = \max\left(\left(\frac{1.5\mathrm{c_{1,s1}}}{\mathrm{t_{conc}}}\right)^{0.5},\ 1\right) = \max\left(\left(\frac{1.5 \times 50\text{ mm}}{200\text{ mm}}\right)^{0.5},\ 1\right) = 1$$

Recall applied perpendicular and parallel loads:

$V_{\perp} = 2.5\text{ kN}$

$V_{\parallel} = 1.25\text{ kN}$

EN 1992-4-2018 Eq. 7.48

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

$$\alpha_V = \tan^{-1}\left(\frac{\mathrm{V_{\parallel}}}{\mathrm{V_{\perp}}}\right) = \tan^{-1}\left(\frac{1.25\text{ kN}}{2.5\text{ kN}}\right) = 0.46365\text{ rad}$$

EN 1992-4-2018 Eq. 7.48

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

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

$$\Psi_{\alpha,V} = \max\left(\sqrt{\frac{1}{\left((\cos(0.46365\text{ rad}))^2\right) + \left((0.5 \times (\sin(0.46365\text{ rad}))^2\right)}},\ 1\right)$$

$$\Psi_{\alpha,V} = 1.0847$$

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 for anchor group

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

$$V_{Rk,c} = 5.954 \text{ kN} \times \left(\frac{9375 \text{ mm}^2}{11250 \text{ mm}^2}\right) \times 0.9 \times 1 \times 1 \times 1.0847 \times 1 = 4.8435 \text{ kN}$$

EN 1992-4:2018 Eq. 7.1

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

$$V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}} = \frac{4.8435 \text{ kN}}{1.5} = 3.229 \text{ kN}$$

Result:

DCR - Demand-to-Capacity Ratio

$$DCR = \frac{V_{Ed}}{V_{Rd,c}} = \frac{2.7951 \text{ kN}}{3.229 \text{ kN}} = 0.86562$$

PASS = 0.87

Check No. 3: Concrete Breakout Capacity (Vz Shear)

$V_z = 5 \text{ kN}$ - 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

$$V_{\perp} = \frac{V_z}{n_{a,s}} = \frac{5 \text{ kN}}{2} = 2.5 \text{ kN}$$

$V_y = 5 \text{ kN}$ - Vy shear load

$n_{anc} = 4$ - Total number of anchor rods

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

$$V_{\parallel} = \frac{V_y}{n_{anc}} = \frac{5 \text{ kN}}{4} = 1.25 \text{ kN}$$

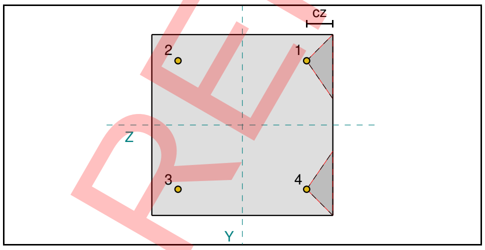
Calculate total shear load per anchor group

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

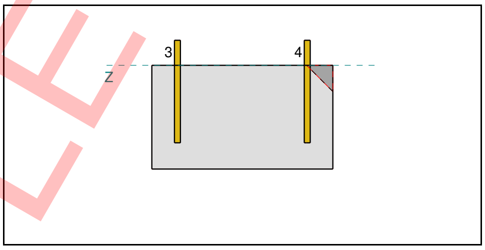
$$V_{Ed} = \sqrt{\left((V_{\perp})^2\right) + \left((V_{\parallel})^2\right)}$$

$$V_{Ed} = \sqrt{\left((2.5 \text{ kN})^2\right) + \left((1.25 \text{ kN})^2\right)} = 2.7951 \text{ kN}$$

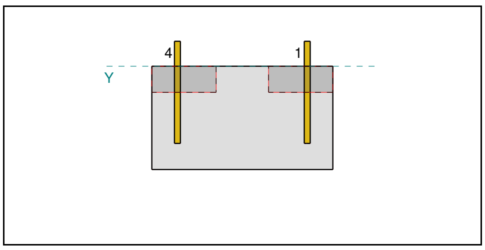
Only the anchors nearest to the failure edge are assumed to resist the shear load.



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
$c_{left,s1}$	Single anchor concrete edge distance (left)	300.0 mm
$c_{right,s1}$	Single anchor concrete edge distance (right)	50.0 mm
$c_{top,s1}$	Single anchor concrete edge distance (top)	50.0 mm
$c_{bottom,s1}$	Single anchor concrete edge distance (bottom)	300.0 mm
t_{conc}	Concrete thickness	200.0 mm
$c_{1,s1}$	Single anchor distance to failure edge (+Vz shear)	50.0 mm
	Narrow Member	FALSE

Calculation for critical anchor: Anchor ID 1.

Calculate alpha and beta factors

EN 1992-4:2018 Clause 7.2.2.5(14) $c_{1,s1} = 50 \text{ mm}$ - Single anchor distance to failure edge (+Vz shear)

$h_{ef} = 150 \text{ mm}$ - Anchor rod embedment length

$d_{anc} = 12 \text{ mm}$ - Anchor rod diameter

EN 1992-4:2018 Clause 7.2.2.5 l_f - Length of fastener

$$l_f = \min\left(\mathrm{h_{ef}},\ 12\mathrm{d_{anc}}\right) = \min\left(150 \text{ mm},\ 12 \times 12 \text{ mm}\right) = 144 \text{ mm}$$

EN 1992-4:2018 Eq. 7.42 α - Alpha factor

$$\alpha = 0.1\left(\frac{l_f}{c_{1,s1}}\right)^{0.5} = 0.1 \times \left(\frac{144 \text{ mm}}{50 \text{ mm}}\right)^{0.5} = 0.16971$$

EN 1992-4:2018 Eq. 7.42 β - Beta factor

$$\beta = 0.1\left(\frac{d_{anc}}{c_{1,s1}}\right)^{0.2} = 0.1 \times \left(\frac{12 \text{ mm}}{50 \text{ mm}}\right)^{0.2} = 0.07517$$

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)

EN 1992-4:2018 Clause 7.2.2.5(14) $c_{1,s1} = 50 \text{ mm}$ - 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

$$V^0_{Rk,c} = k_9\left(\frac{d_{anc}}{mm}\right)^{\alpha}\left(\frac{l_f}{mm}\right)^{\beta}\sqrt{\frac{f_{ck}}{MPa}}\left(\frac{c_{1,s1}}{mm}\right)^{1.5} N$$

$$V^0_{Rk,c} = 1.7 \times \left(\frac{12 \text{ mm}}{1 \text{ mm}}\right)^{0.16971} \times \left(\frac{144 \text{ mm}}{1 \text{ mm}}\right)^{0.07517} \times \sqrt{\frac{20 \text{ MPa}}{1 \text{ MPa}}} \times \left(\frac{50 \text{ mm}}{1 \text{ mm}}\right)^{1.5} \times 0.001 \text{ kN}$$

$$V^0_{Rk,c} = 5.954 \text{ kN}$$

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

$$A^0_{c,V} = 4.5(c_{1,s1})^2 = 4.5 \times (50 \text{ mm})^2 = 11250 \text{ mm}^2$$

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

$$B_{c,V} = \min\left(\mathrm{c_{top,s1}},\ 1.5\mathrm{c_{1,s1}}\right) + \min\left(\mathrm{c_{bottom,s1}},\ 1.5\mathrm{c_{1,s1}}\right)$$

$$B_{c,V} = \min\left(50 \text{ mm},\ 1.5 \times 50 \text{ mm}\right) + \min\left(300 \text{ mm},\ 1.5 \times 50 \text{ mm}\right) = 125 \text{ mm}$$

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

$$H_{c,V} = \min\left(1.5\mathrm{c_{1,s1}},\ \mathrm{t_{conc}}\right) = \min\left(1.5 \times 50 \text{ mm},\ 200 \text{ mm}\right) = 75 \text{ mm}$$

Calculate actual projected area on failure surface

EN 1992-4:2018 Clause 7.2.2.5 $A_{c,V}$ - Actual projected area

$$A_{c,V} = H_{c,V}B_{c,V} = 75 \text{ mm} \times 125 \text{ mm} = 9375 \text{ mm}^2$$

Calculate parameters for breakout resistance

EN 1992-4:2018 Eq 7.4 $\Psi_{s,V}$ - Factor that takes account the disturbance of stress distribution

$$\Psi_{s,V} = \min\left(0.7 + 0.3\left(\frac{\mathrm{c_{2,s1}}}{1.5\mathrm{c_{1,s1}}}\right),\ 1.0\right) = \min\left(0.7 + 0.3 \times \left(\frac{50 \text{ mm}}{1.5 \times 50 \text{ mm}}\right),\ 1\right) = 0.9$$

EN 1992-4-2018 Eq. 7.46 $\Psi_{h,V}$ - Parameter that takes account the member thickness

$$\Psi_{h,V} = \max\left(\left(\frac{1.5\mathrm{c_{1,s1}}}{\mathrm{t_{conc}}}\right)^{0.5},\ 1\right) = \max\left(\left(\frac{1.5 \times 50 \text{ mm}}{200 \text{ mm}}\right)^{0.5},\ 1\right) = 1$$

Recall applied perpendicular and parallel loads:

$V_{\perp} = 2.5 \text{ kN}$

$V_{\parallel} = 1.25 \text{ kN}$

EN 1992-4-2018 Eq. 7.48	α_V - Angle between design shear load V and a line perpendicular to the verified edge	

$$\alpha_V = \tan^{-1}\left(\frac{V_{\parallel}}{V_{\perp}}\right) = \tan^{-1}\left(\frac{1.25\text{ kN}}{2.5\text{ kN}}\right) = 0.46365\text{ rad}$$

EN 1992-4-2018 Eq. 7.48	$\Psi_{\alpha,V}$ - Parameter that takes account the influence of a shear load inclined to edge	

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

$$\Psi_{\alpha,V} = \max\left(\sqrt{\frac{1}{\left((\cos(0.46365\text{ rad}))^2\right) + \left((0.5 \times (\sin(0.46365\text{ rad})))^2\right)}}, 1\right)$$

$$\Psi_{\alpha,V} = 1.0847$$

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 for anchor group	

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

$$V_{Rk,c} = 5.954\text{ kN} \times \left(\frac{9375\text{ mm}^2}{11250\text{ mm}^2}\right) \times 0.9 \times 1 \times 1 \times 1.0847 \times 1 = 4.8435\text{ kN}$$

EN 1992-4:2018 Eq. 7.1	$V_{Rd,c}$ - Design shear breakout resistance	

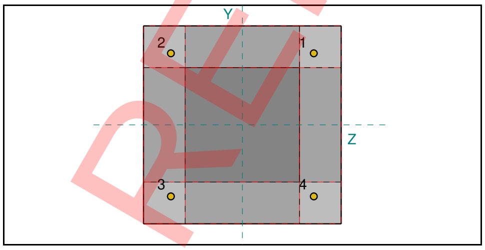
$$V_{Rd,c} = \frac{V_{Rk,c}}{\gamma_{Mc}} = \frac{4.8435\text{ kN}}{1.5} = 3.229\text{ kN}$$

Result: **PASS = 0.87**

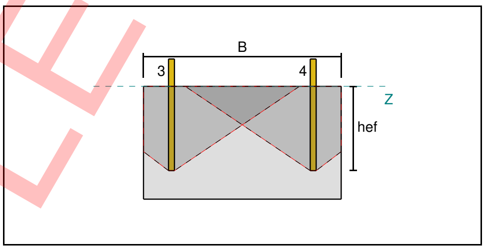
DCR - Demand-to-Capacity Ratio

$$DCR = \frac{V_{Ed}}{V_{Rd,c}} = \frac{2.7951\text{ kN}}{3.229\text{ kN}} = 0.86562$$

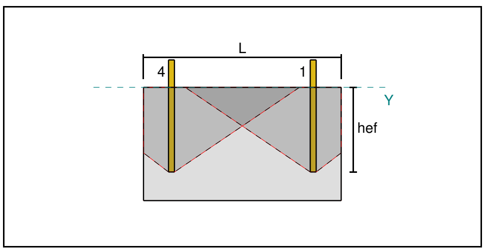
Check No. 4: Concrete Pryout Capacity



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate total shear load on anchor group

$V_y = 5\text{ kN}$ - Vy shear load

$V_z = 5\text{ kN}$ - Vz shear load

V_{res} - Resultant shear load

$$V_{res} = \sqrt{\left((V_y)^2\right) + \left((V_z)^2\right)} = \sqrt{\left((5\text{ kN})^2\right) + \left((5\text{ kN})^2\right)} = 7.0711\text{ kN}$$

$n_{anc} = 4$ - Total number of anchor rods

$n_{a,g1} = 4$ - Number of anchors in anchor group PO 1

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

$$V_{Ed} = \left(\frac{V_{res}}{n_{anc}}\right) n_{a,g1} = \left(\frac{7.0711\text{ kN}}{4}\right) \times 4 = 7.0711\text{ kN}$$

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)	50.0 mm
$c_{right,g1}$	Anchor group PO 1 concrete edge distance (right)	50.0 mm
$c_{top,g1}$	Anchor group PO 1 concrete edge distance (top)	50.0 mm
$c_{bottom,g1}$	Anchor group PO 1 concrete edge distance (bottom)	50.0 mm
h_{ef}	Anchor rod embedment length	150.0 mm
s_{cr}	Anchor rod characteristic spacing	450.0 mm
c_{cr}	Anchor rod characteristic edge distance	225.0 mm
$h'_{ef,g1}$	Anchor group PO 1 modified effective embedment length	83.3 mm
$s'_{cr,g1}$	Anchor group PO 1 modified characteristic spacing	250.0 mm
$c'_{cr,g1}$	Anchor group PO 1 modified characteristic edge distance	125.0 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)

$h'_{ef,g1} = 83.333\text{ mm}$ - 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

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

$$N^0_{Rk,c} = 8.9 \times \sqrt{\frac{20\text{ MPa}}{1\text{ MPa}}} \times \left(\frac{83.333\text{ mm}}{1\text{ mm}}\right)^{1.5} \times 0.001\text{ kN} = 30.278\text{ kN}$$

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

$$A^0_{c,N} = s'_{cr,g1} s'_{cr,g1} = 250\text{ mm} \times 250\text{ mm} = 62500\text{ mm}^2$$

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

$s_{sum,z,g1} = 250\text{ mm}$ - Anchor group PO 1 sum of spacing along Z-axis

$n_{z,g1} = 2$ - 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

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

$$L_{Nc} = \min(50\text{ mm},\ 125\text{ mm}) + (\min(250\text{ mm},\ 250\text{ mm} \times (2-1))) + \min(50\text{ mm},\ 125\text{ mm})$$

$$L_{Nc} = 350\text{ mm}$$

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

$s_{sum,y,g1} = 250\text{ mm}$ - 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

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

$$B_{Nc} = \min(50\text{ mm},\ 125\text{ mm}) + (\min(250\text{ mm},\ 250\text{ mm} \times (2-1))) + \min(50\text{ mm},\ 125\text{ mm})$$

$$B_{Nc} = 350\ \text{mm}$$

Calculate actual projected area of the anchor group

$n_{a,g1} = 4$ - 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

$$A_{Nc} = L_{Nc} B_{Nc} = 350\ \text{mm} \times 350\ \text{mm} = 122500\ \text{mm}^2$$

Calculate shortest edge distance

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

$$c_{min,N} = \min\left(\mathrm{c_{left,g1}},\ \mathrm{c_{right,g1}},\ \mathrm{c_{top,g1}},\ \mathrm{c_{bottom,g1}}\right) = \min\left(50\ \text{mm},\ 50\ \text{mm},\ 50\ \text{mm},\ 50\ \text{mm}\right) = 50\ \text{mm}$$

Calculate parameters for breakout resistance

EN 1992-4:2018 Eq 7.4

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

$$\Psi_{s,N} = \min\left(0.7 + 0.3\left(\frac{\mathrm{c_{min,N}}}{\mathrm{c'_{cr,g1}}}\right),\ 1.0\right) = \min\left(0.7 + 0.3 \times \left(\frac{50\ \text{mm}}{125\ \text{mm}}\right),\ 1\right) = 0.82$$

EN 1992-4:2018 Eq. 7.5

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

$$\Psi_{re,N} = \min\left(0.5 + \frac{\frac{\mathrm{h'_{ef,g1}}}{\mathrm{mm}}}{200},\ 1.0\right) = \min\left(0.5 + \frac{\frac{83.333\ \text{mm}}{1\ \text{mm}}}{200},\ 1\right) = 0.91667$$

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

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

$$N_{cbg} = \left(\frac{122500\ \text{mm}^2}{62500\ \text{mm}^2}\right) \times 0.82 \times 0.91667 \times 1 \times 1 \times 30.278\ \text{kN} = 44.608\ \text{kN}$$

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

$$V_{Rd,cp} = \frac{k_8 N_{cbg}}{\gamma_C} = \frac{2 \times 44.608\ \text{kN}}{1.5} = 59.478\ \text{kN}$$

Result:

PASS = 0.12

DCR - Demand-to-Capacity Ratio

$$DCR = \frac{V_{Ed}}{V_{Rd,cp}} = \frac{7.0711\ \text{kN}}{59.478\ \text{kN}} = 0.11889$$

Check No. 5: Anchor Rod Shear Capacity

$V_y = 5\ \text{kN}$ - Vy shear load

$V_z = 5\ \text{kN}$ - Vz shear load

$n_{anc} = 4$ - Total number of anchor rods

V_{Ed} - Design shear force on anchor rod

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

$$V_{Ed} = \frac{\sqrt{\left((5\ \text{kN})^2\right) + \left((5\ \text{kN})^2\right)}}{4} = 1.7678\ \text{kN}$$

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
Grout compressive strength is greater than or equal to 30 MPa	Yes
Grout thickness is less than 50% of anchor diameter	Yes
Shear load is applied with lever arm	FALSE

Calculate anchor stress area

$d_{anc} = 12\ \text{mm}$ - Anchor rod diameter

A_s - Tensile stress area of anchor

$$A_s = \frac{\pi}{4}(d_{anc})^2 = \frac{\pi}{4} \times (12\ \text{mm})^2 = 113.1\ \text{mm}^2$$

Calculate characteristic resistance of a single fastener in steel failure

$F_{u\_anc} = 800\ \text{MPa}$ - 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 $$V^0_{Rk,s} = k_6 A_s F_{u\_anc} = 0.5 \times 113.1\ \mathrm{mm}^2 \times 800\ \mathrm{MPa} = 45.239\ \mathrm{kN}$$	
	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 $$V_{Rk,s} = k_7 V^0_{Rk,s} = 1 \times 45.239\ \mathrm{kN} = 45.239\ \mathrm{kN}$$	
	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 $$V_{Rd,s} = \frac{V_{Rk,s}}{\gamma_{Ms,shear}} = \frac{45.239\ \mathrm{kN}}{1.25} = 36.191\ \mathrm{kN}$$	
	Result: DCR - Demand-to-Capacity Ratio $$DCR = \frac{V_{Ed}}{V_{Rd,s}} = \frac{1.7678\ \mathrm{kN}}{36.191\ \mathrm{kN}} = 0.048845$$	**PASS = 0.05**

REFERENCES	CALCULATIONS	RESULTS
	Summary of Design Checks	The governing combination is Load Combination 1.

Load Combination	Design Check	Demand	Capacity	DCR	Result
1	Weld Capacity	4.91	360.00	0.01	**PASS**
1	Concrete Breakout Capacity (Vy Shear)	2.80	3.23	0.87	**PASS**
1	Concrete Breakout Capacity (Vz Shear)	2.80	3.23	0.87	**PASS**
1	Concrete Pryout Capacity	7.07	59.48	0.12	**PASS**
1	Anchor Rod Shear Capacity	1.77	36.19	0.05	**PASS**

The design is adequate!