REFERENCES	CALCULATIONS	RESULTS

SkyCiv Base Plate and Anchor Rod Design

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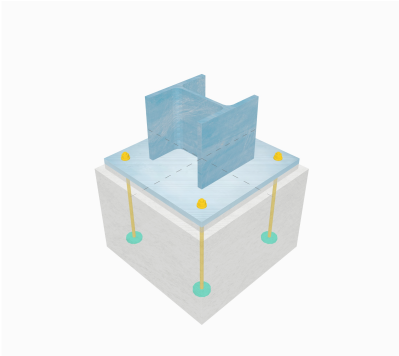
Project Information:
Design Code: EN 1993-1-8-2005, EN 1993-1-1-2005 and EN 1992-1-1-2004
Anchoring Code: EN 1992-4:2018

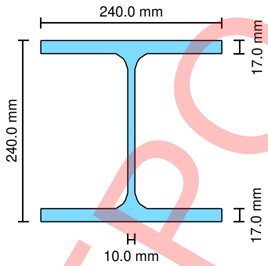


Load Combinations:

Load Combination	Axial Load, Nx (kN)	Strong-axis Shear, Vy (kN)	Weak-axis Shear, Vz (kN)
1	-50.00	0.00	0.00

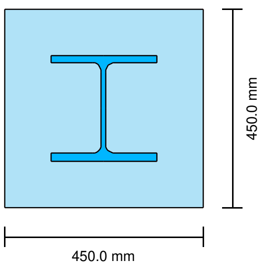
Note: Positive Nx (+) indicates compression; negative Nx (-) indicates tension.

Column Properties:



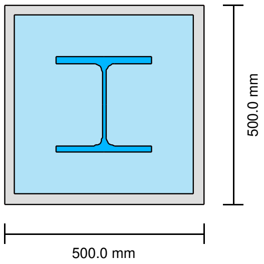
Symbol	Description	Value
$Section$	Column section	HE 240 B
d_{col}	Column depth	240.0 mm
t_w	Column web thickness	10.0 mm
b_f	Column flange width	240.0 mm
t_f	Column flange thickness	17.0 mm
A_{col}	Column area	10600.0 mm^2
r_{col}	Column root radius	21.0 mm
f_{y_col}	Column yield strength (S235)	225.0 MPa
f_{u_col}	Column ultimate tensile strength (S235)	360.0 MPa

Base Plate Properties:



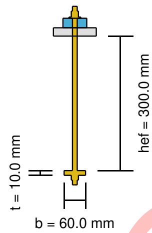
Symbol	Description	Value
B_{bp}	Base plate width	450.0 mm
L_{bp}	Base plate length	450.0 mm
t_{bp}	Base plate thickness	20.0 mm
A_{bp}	Base plate plan area	202500.0 mm^2
f_{y_bp}	Base plate yield strength (S235)	225.0 MPa
f_{u_bp}	Base plate ultimate tensile strength (S235)	360.0 MPa
t_{grout}	Grout thickness	20.0 mm

Concrete Properties:



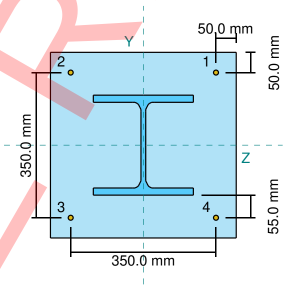
Symbol	Description	Value
B_{conc}	Concrete width	500.0 mm
L_{conc}	Concrete length	500.0 mm
t_{conc}	Concrete thickness	350.0 mm
A_{conc}	Concrete plan area	250000.0 mm^2
f_{ck}	Concrete compressive strength (C25/30)	25.0 MPa
–	Concrete assumption: cracked or uncracked	Cracked

Anchor Information:



Symbol	Description	Value
d_{anc}	Anchor rod diameter	12.0 mm
h_{ef}	Anchor rod embedment length	300.0 mm
b_{embed_plate}	Anchor embed plate diameter	60.0 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	350.0 mm
s_y	Spacing of anchor rods along Y-axis	350.0 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)	Anchor in Tension Zone	Breakout (Tension)	Side-Face Blowout (Y-direction)	Side-Face Blowout (Z-direction)
1	175	175	✓	BO Group 1	Single	Single
2	-175	175	✓	BO Group 1	Single	Single
3	-175	-175	✓	BO Group 1	Single	Single
4	175	-175	✓	BO Group 1	Single	Single

Weld Properties:

Symbol	Description	Value
$Type$	Weld Type	FPBW
f_{uw}	Filler metal ultimate tensile strength (E35)	440.0 MPa

Summary of Detailing Checks

Check Name	Dimensions (Min/Max/Actual)	Status
Anchor Clearance	Min: 30.16 mm, Actual: 73.00 mm	**PASS**
Base Plate Edge Distance	Min: 18.00 mm, Actual: 50.00 mm	**PASS**
Minimum Number of Anchors	Min: 4.00, Actual: 4.00	**PASS**
Embedded Plate Dimension	Min: 48.00 mm, Actual: 60.00 mm	**PASS**
Min. Anchor Spacing to Prevent Concrete Splitting	Min: 20.00 mm, Actual: 350.00 mm	**PASS**
Min. Concrete Cover to Prevent Concrete Splitting	Min: 40.00 mm, Actual: 75.00 mm	**PASS**

The design geometry meets requirements!

REFERENCES	CALCULATIONS	RESULTS

Load Combination No. 1: Tension Load Only

Check No. 1: Weld Capacity
Calculate design weld stress on cross-section

$b_f = 240\ \mathrm{mm}$ - Column flange width

$t_f = 17\ \mathrm{mm}$ - Column flange thickness

$d_{col} = 240\ \mathrm{mm}$ - Column depth

$t_w = 10\ \mathrm{mm}$ - Column web thickness

$r_{col} = 21\ \mathrm{mm}$ - Column root radius

$N_x = 50\ \mathrm{kN}$ - Tension load

$F_{w,Ed}$ - Design stress on cross-section for FPBW

$$F_{w,Ed} = \frac{N_x}{2b_f t_f + (d_{col} - 2t_f - 2r_{col})t_w}$$

$$F_{w,Ed} = \frac{50\ \mathrm{kN}}{2 \times 240\ \mathrm{mm} \times 17\ \mathrm{mm} + (240\ \mathrm{mm} - 2 \times 17\ \mathrm{mm} - 2 \times 21\ \mathrm{mm}) \times 10\ \mathrm{mm}} = 5.102\ \mathrm{MPa}$$

Determine the tensile yielding strength of the weakest material

$f_{y\_col} = 225\ \mathrm{MPa}$ - Column yield strength (S235)

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

EN 1993-1-8:2005 Clause 4.7.1

f_y - Nominal tensile yielding strength of the weaker part joined

$$f_y = \min\left(\mathrm{f_{y\_col}},\ \mathrm{f_{y\_bp}}\right) = \min\left(225\ \mathrm{MPa},\ 225\ \mathrm{MPa}\right) = 225\ \mathrm{MPa}$$

Calculate design resistance of base metal for FPBW

EN 1993-1-8:2005 Clause 4.7.1

$f_y = 225\ \mathrm{MPa}$

EN 1993-1-1:2005 Clause 6.1

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

EN 1993-1-8:2005 Clause 4.7.1 and EN 1993-1-1:2005 Eq. 6.6

$F_{w,Rd3}$ - Design resistance of base metal for full penetration butt weld

$$F_{w,Rd3} = \frac{f_y}{\gamma_{M0}} = \frac{225\ \mathrm{MPa}}{1} = 225\ \mathrm{MPa}$$

Result:

DCR - Demand over capacity ratio:

$$DCR = \frac{F_{w,Ed}}{F_{w,Rd3}} = \frac{5.102\ \mathrm{MPa}}{225\ \mathrm{MPa}} = 0.022676$$

PASS = 0.02

Check No. 2: Base Plate Yield Capacity (Tension Load)
Calculate load per flange

$N_x = 50\ \mathrm{kN}$ - Tension load

$F_{T,Ed}$ - Tensile load per flange

$$F_{T,Ed} = \frac{N_x}{2} = \frac{50\ \mathrm{kN}}{2} = 25\ \mathrm{kN}$$

Determine dimensions for yield line calculations

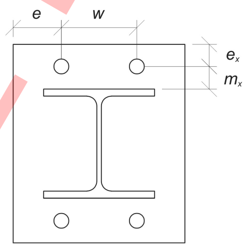


Fig. Dimensions for base plate yielding.

$d_{col} = 240\ \mathrm{mm}$ - Column depth

$a_{flg} = 4.95\ \mathrm{mm}$ - Design weld throat at flange

$s_z = 350\ \mathrm{mm}$ - Spacing of anchor rods along Z-axis

$s_y = 350\ \mathrm{mm}$ - Spacing of anchor rods along Y-axis

$B_{bp} = 450\ \mathrm{mm}$ - Base plate width

$L_{bp} = 450\ \mathrm{mm}$ - Base plate length

$n_{a,side} = 2$ - Number of anchor rods in tension per side

m_x - mx dimension

$$m_x = \frac{s_y - d_{col}}{2} = \frac{350\ \mathrm{mm} - 240\ \mathrm{mm}}{2} = 55\ \mathrm{mm}$$

w - w dimension

$$w = s_z\left(n_{a,side} - 1\right) = 350\ \mathrm{mm} \times (2 - 1) = 350\ \mathrm{mm}$$

e_x - ex dimension

$$e_x = \frac{L_{bp} - s_y}{2} = \frac{450 \text{ mm} - 350 \text{ mm}}{2} = 50 \text{ mm}$$

b_p - bp dimension

$$b_p = B_{bp} = 450 \text{ mm}$$

e - e dimension

$$e = \frac{B_{bp} - w}{2} = \frac{450 \text{ mm} - 350 \text{ mm}}{2} = 50 \text{ mm}$$

n - Edge distance on base plate

$$n = \min\left(\mathrm{e_x},\ 1.25\mathrm{m_x}\right) = \min\left(50 \text{ mm},\ 1.25 \times 55 \text{ mm}\right) = 50 \text{ mm}$$

Calculate circular yield patterns

SCI P398 Table 5.3

$l_{eff,cp1}$ - Effective length for circular yielding

$$l_{eff,cp1} = n_{a,side}\pi m_x = 2 \times \pi \times 55 \text{ mm} = 345.58 \text{ mm}$$

SCI P398 Table 5.3

$l_{eff,cp2}$ - Effective length for individual end yielding

$$l_{eff,cp2} = \left(\frac{n_{a,side}}{2}\right)\left(\pi m_x + 2e_x\right) = \left(\frac{2}{2}\right) \times \left(\pi \times 55 \text{ mm} + 2 \times 50 \text{ mm}\right) = 272.79 \text{ mm}$$

SCI P398 Table 2.2

$l_{eff,cp}$ - Governing effective length for circular pattern

$$l_{eff,cp} = \min\left(\mathrm{l_{eff,cp1}},\ \mathrm{l_{eff,cp2}}\right) = \min\left(345.58 \text{ mm},\ 272.79 \text{ mm}\right) = 272.79 \text{ mm}$$

Calculate non-circular yield patterns

SCI P398 Table 5.3

$l_{eff,nc1}$ - Effective length for single curvature

$$l_{eff,nc1} = \frac{b_p}{2} = \frac{450 \text{ mm}}{2} = 225 \text{ mm}$$

SCI P398 Table 5.3

$l_{eff,nc2}$ - Effective length for individual end yielding

$$l_{eff,nc2} = \left(\frac{n_{a,side}}{2}\right)\left(4m_x + 1.25e_x\right) = \left(\frac{2}{2}\right) \times \left(4 \times 55 \text{ mm} + 1.25 \times 50 \text{ mm}\right) = 282.5 \text{ mm}$$

SCI P398 Table 2.2

$l_{eff,nc3}$ - Effective length for corner yielding

$$l_{eff,nc3} = 2m_x + 0.625e_x + e = 2 \times 55 \text{ mm} + 0.625 \times 50 \text{ mm} + 50 \text{ mm} = 191.25 \text{ mm}$$

SCI P398 Table 5.3

$l_{eff,nc4}$ - Effective length for group end yielding

$$l_{eff,nc4} = 2m_x + 0.625e_x + \frac{\left(n_{a,side} - 1\right)s_z}{2} = 2 \times 55 \text{ mm} + 0.625 \times 50 \text{ mm} + \frac{(2-1) \times 350 \text{ mm}}{2} = 316.25 \text{ mm}$$

SCI P398 Table 2.2

$l_{eff,nc}$ - Governing effective length for non-circular pattern

$$l_{eff,nc} = \min\left(\mathrm{l_{eff,nc1}},\ \mathrm{l_{eff,nc2}},\ \mathrm{l_{eff,nc3}},\ \mathrm{l_{eff,nc4}}\right) = \min\left(225 \text{ mm},\ 282.5 \text{ mm},\ 191.25 \text{ mm},\ 316.25 \text{ mm}\right) = 191.25 \text{ mm}$$

SCI P398 pg. 10

Calculate total effective length for Mode 1-2

SCI P398 pg. 10

$l_{eff,1}$ - Total effective length for Mode 1

$$l_{eff,1} = \min\left(\mathrm{l_{eff,cp}},\ \mathrm{l_{eff,nc}}\right) = \min\left(272.79 \text{ mm},\ 191.25 \text{ mm}\right) = 191.25 \text{ mm}$$

EN 1993-1-8:2005 Table 6.2

Calculate plate moment resistance for Mode 1-2

SCI P398 pg. 10

$l_{eff,1} = 191.25 \text{ mm}$

$t_{bp} = 20 \text{ mm}$ - Base plate thickness

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

EN 1993-1-1:2005 Clause 6.1

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

EN 1993-1-8:2005 Table 6.2

$M_{pl,1,Rd}$ - Plate moment resistance for Mode 1

$$M_{pl,1,Rd} = \frac{0.25 l_{eff,1}\left(t_{bp}\right)^2 f_{y\_bp}}{\gamma_{M0}} = \frac{0.25 \times 191.25 \text{ mm} \times (20 \text{ mm})^2 \times 225 \text{ MPa}}{1} = 4303.1 \text{ kN}\cdot\text{mm}$$

Calculate tensile resistance of anchor rod

See anchor rod tensile capacity for the detailed calculations steps.

EN 1992-4:2018 Clause 7.2.1.3

$F_{t,Rd}$ - Tensile resistance of anchor rod

$$F_{t,Rd} = \frac{c k_2 F_{u\_anc} A_s}{\gamma_{M2,anchor}} = \frac{0.85 \times 0.9 \times 800 \text{ MPa} \times 113.1 \text{ mm}^2}{1.25} = 55.372 \text{ kN}$$

Calculate base plate bending resistance

EN 1993-1-8:2005 Table 6.2

$M_{pl,1,Rd} = 4303.1 \text{ kN}\cdot\text{mm}$

$m_x = 55 \text{ mm}$

$n_{a,side} = 2$ - Number of anchor rods in tension per side

EN 1993-1-8:2005 Table 6.2

$F_{T,1,Rd}$ - Design resistance of base plate on failure mode 1-2

$$F_{T,1,Rd} = \frac{2M_{pl,1,Rd}}{m_x} = \frac{2 \times 4303.1 \text{ kN}\cdot\text{mm}}{55 \text{ mm}} = 156.48 \text{ kN}$$

EN 1993-1-8:2005 Table 6.2

$F_{T,3,Rd}$ - Design resistance of base plate on failure mode 3

$$F_{T,3,Rd} = n_{a,side} F_{t,Rd} = 2 \times 55.372 \text{ kN} = 110.74 \text{ kN}$$

EN 1993-1-8:2005 Table 6.2

$F_{T,Rd}$ - Design resistance of base plate

$$F_{T,Rd} = \min\left(\mathrm{F_{T,1,Rd}},\ \mathrm{F_{T,3,Rd}}\right) = \min\left(156.48\ \mathrm{kN},\ 110.74\ \mathrm{kN}\right) = 110.74\ \mathrm{kN}$$

Result:

PASS = 0.23

DCR - Demand over capacity ratio:

$$DCR = \frac{F_{T,Ed}}{F_{T,Rd}} = \frac{25\ \mathrm{kN}}{110.74\ \mathrm{kN}} = 0.22574$$

Check No. 3: Anchor Rod Tensile Capacity

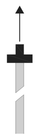


Fig. Anchor steel tension failure.

Calculate load per tension anchor

$N_x = 50\ \mathrm{kN}$ - Tension load

$n_{a,t} = 4$ - Number of anchors in tension

N_{Ed} - Design tension force on anchor rod

$$N_{Ed} = \frac{N_x}{n_{a,t}} = \frac{50\ \mathrm{kN}}{4} = 12.5\ \mathrm{kN}$$

Calculate anchor tensile area

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

A_s - Tensile stress area of anchor

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

Calculate anchor steel tensile capacity

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

EN 1993-1-8:2005 Clause 3.6.1 Note 3

$c = 0.85$ - Factor for anchor with cut threads

EN 1993-1-8:2005 Table 3.4

$k_2 = 0.9$ - Factor for non-countersunk anchor

EN 1993-1-8:2005

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

EN 1992-4:2018 Clause 7.2.1.3

$N_{Rd,s}$ - Design resistance of anchor rod in tension

$$N_{Rd,s} = \frac{c k_2 F_{u\_anc} A_s}{\gamma_{M2,anchor}} = \frac{0.85 \times 0.9 \times 800\ \mathrm{MPa} \times 113.1\ \mathrm{mm}^2}{1.25} = 55.372\ \mathrm{kN}$$

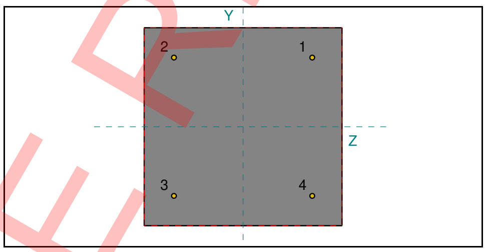
Result:

PASS = 0.23

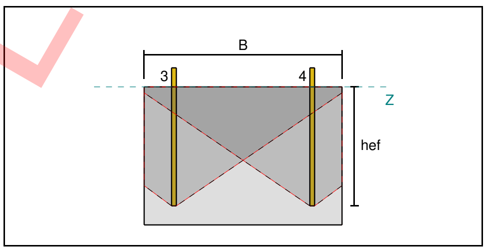
DCR - Demand over capacity ratio:

$$DCR = \frac{N_{Ed}}{N_{Rd,s}} = \frac{12.5\ \mathrm{kN}}{55.372\ \mathrm{kN}} = 0.22574$$

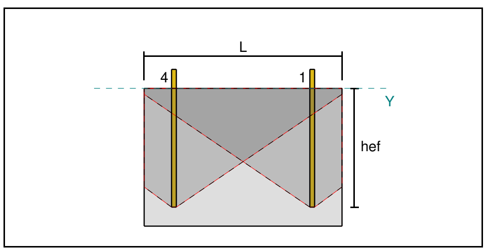
Check No. 4: Concrete Breakout Capacity (Tension Load)



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate total tension load on anchor group

$N_x = 50 \text{ kN}$ - Tension load

$n_{a,t} = 4$ - Number of anchors in tension

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

N_{fa} - Factored tensile load on anchor group

$$N_{fa} = \left(\frac{N_x}{n_{a,t}}\right) n_{a,g1} = \left(\frac{50 \text{ kN}}{4}\right) \times 4 = 50 \text{ kN}$$

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 BO 1 concrete edge distance (left)	75.0 mm
$c_{right,g1}$	Anchor group BO 1 concrete edge distance (right)	75.0 mm
$c_{top,g1}$	Anchor group BO 1 concrete edge distance (top)	75.0 mm
$c_{bottom,g1}$	Anchor group BO 1 concrete edge distance (bottom)	75.0 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
	Narrow Member	TRUE
$h'_{ef,g1}$	Anchor group BO 1 modified effective embedment length	116.7 mm
$s'_{cr,g1}$	Anchor group BO 1 modified characteristic spacing	350.0 mm
$c'_{cr,g1}$	Anchor group BO 1 modified characteristic edge distance	175.0 mm

Sample calculation for worst case: Anchor Group 1.

Calculate characteristic strength of a single anchor

$f_{ck} = 25 \text{ MPa}$ - Concrete compressive strength (C25/30)

EN 1992-4:2018 Clause 7.2.1.4(8)

$h'_{ef,g1} = 116.67 \text{ mm}$ - Anchor group BO 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

$N0_{Rk,c}$ - Characteristic strength of a single fastener

$$N0_{Rk,c} = k_1 \sqrt{\frac{f_{ck}}{MPa}} \left(\frac{h'_{ef,g1}}{mm}\right)^{1.5} N$$

$$N0_{Rk,c} = 8.9 \times \sqrt{\frac{25 \text{ MPa}}{1 \text{ MPa}}} \times \left(\frac{116.67 \text{ mm}}{1 \text{ mm}}\right)^{1.5} \times 0.001 \text{ kN} = 56.076 \text{ kN}$$

Calculate reference projected area of a single anchor

EN 1992-4:2018 Eq. 7.3

$A0_{c,N}$ - Reference projected area of a single fastener

$$A0_{c,N} = s'_{cr,g1} s'_{cr,g1} = 350 \text{ mm} \times 350 \text{ mm} = 122500 \text{ mm}^2$$

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

$n_{z,g1} = 2$ - Number of anchors along Z-axis for anchor group BO 1

EN 1992-4:2018 Clause 7.2.1.4

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

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

$$L_{Nc} = \min(75 \text{ mm},\ 175 \text{ mm}) + (\min(350 \text{ mm},\ 350 \text{ mm} \times (2-1))) + \min(75 \text{ mm},\ 175 \text{ mm})$$

$$L_{Nc} = 500 \text{ mm}$$

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

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

EN 1992-4:2018 Clause 7.2.1.4

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

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

$$B_{Nc} = \min(75 \text{ mm},\ 175 \text{ mm}) + (\min(350 \text{ mm},\ 350 \text{ mm} \times (2-1))) + \min(75 \text{ mm},\ 175 \text{ mm})$$

$$B_{Nc} = 500 \text{ mm}$$

Calculate actual projected area of the anchor group

EN 1992-4:2018 Clause 7.2.1.4

A_{Nc} - Actual projected area for a single anchor

$$A_{Nc} = L_{Nc} B_{Nc} = 500 \text{ mm} \times 500 \text{ mm} = 250000 \text{ mm}^2$$

Calculate shortest edge distance

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

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

Calculate parameters for breakout resistance

EN 1992-4:2018 Eq 7.4

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

$$\Psi_{s,N} = \min\left(0.7 + 0.3\left(\frac{c_{\text{min,N}}}{c'_{\text{cr,g1}}}\right),\ 1.0\right) = \min\left(0.7 + 0.3 \times \left(\frac{75 \text{ mm}}{175 \text{ mm}}\right),\ 1\right) = 0.82857$$

EN 1992-4:2018 Eq. 7.5

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

$$\Psi_{re,N} = \min\left(0.5 + \frac{\frac{h'_{\text{ef,g1}}}{\text{mm}}}{200},\ 1.0\right) = \min\left(0.5 + \frac{\frac{116.67 \text{ mm}}{1 \text{ mm}}}{200},\ 1\right) = 1$$

Calculate design concrete cone breakout resistance

EN 1992-4:2018 Eq. 7.6

$\Psi_{ec,N} = 1$ - Parameter accounting for the influence of eccentricity

EN 1992-4:2018 Eq. 7.7

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

EN 1992-4:2018 Table 4.1

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

EN 1992-4:2018 Eq. 7.1

$N_{Rd,c}$ - Design concrete cone breakout resistance for anchor group

$$N_{Rd,c} = \frac{N0_{Rk,c}\left(\frac{A_{Nc}}{A0_{c,N}}\right)\Psi_{s,N}\Psi_{re,N}\Psi_{ec,N}\Psi_{M,N}}{\gamma_{Mc}}$$

$$N_{Rd,c} = \frac{56.076 \text{ kN} \times \left(\frac{250000 \text{ mm}^2}{122500 \text{ mm}^2}\right) \times 0.82857 \times 1 \times 1 \times 1}{1.5} = 63.215 \text{ kN}$$

Result:

PASS = 0.79

DCR - Demand over capacity ratio:

$$DCR = \frac{N_{fa}}{N_{Rd,c}} = \frac{50 \text{ kN}}{63.215 \text{ kN}} = 0.79095$$

Check No. 5: Anchor Pullout Capacity

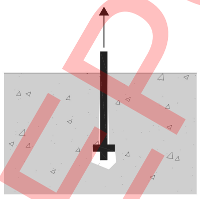


Fig. Headed anchor concrete pullout failure.

Calculate load per tension anchor

$N_x = 50 \text{ kN}$ - Tension load

$n_{a,t} = 4$ - Number of anchors in tension

N_{Ed} - Design tension force on anchor rod

$$N_{Ed} = \frac{N_x}{n_{a,t}} = \frac{50 \text{ kN}}{4} = 12.5 \text{ kN}$$

EN 1992-4:2018 Clause 7.2.1.5

Calculate max anchor head dimension

$b_{embed\_plate} = 60 \text{ mm}$ - Anchor embed plate diameter

$t_{embed\_plate} = 10 \text{ mm}$ - Anchor embed plate thickness

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

EN 1992-4:2018 Clause 7.2.1.5 Note

$d_{h,max}$ - Maximum allowed anchor head dimension

$$d_{h,max} = \min\left(b_{\text{embed\_plate}},\ 6\left(t_{\text{embed\_plate}}\right) + d_{\text{anc}}\right) = \min\left(60 \text{ mm},\ 6 \times (10 \text{ mm}) + 12 \text{ mm}\right) = 60 \text{ mm}$$

Calculate area of bearing on circular plate

EN 1992-4:2018 Eq 7.12

A_{brg} - Net area of bearing for circular end

$$A_{brg} = \frac{\pi}{4}\left(\left(\left(d_{h,max}\right)^2\right) - \left(\left(d_{anc}\right)^2\right)\right)$$

$$A_{brg} = \frac{\pi}{4} \times \left(\left((60 \text{ mm})^2\right) - \left((12 \text{ mm})^2\right)\right) = 2714.3 \text{ mm}^2$$

Calculate basic anchor pullout strength

EN 1992-4:2018 Clause 7.2.1.5

$k_2 = 7.5$ - Pullout cracking factor

EN 1992-4:2018 Eq 7.12

$A_{brg} = 2714.3 \text{ mm}^2$

$f_{ck} = 25 \text{ MPa}$ - Concrete compressive strength (C25/30)

EN 1992-4:2018 Table 4.1

$\gamma_{Mp} = 1.5$ - Partial safety factor for anchor pullout failure

EN 1992-4:2018 Clause 7.2.1.5

$N_{Rd,s}$ - Design concrete pullout resistance of cast-in anchor in tension

$$N_{Rd,s} = \frac{k_2 A_{brg} f_{ck}}{\gamma_{Mp}} = \frac{7.5 \times 2714.3 \text{ mm}^2 \times 25 \text{ MPa}}{1.5} = 339.29 \text{ kN}$$

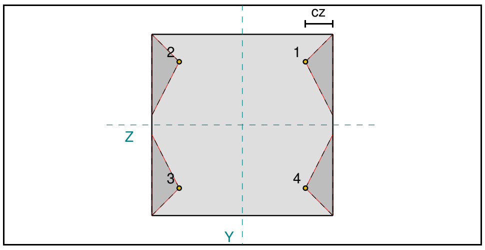
Result:

DCR - Demand over capacity ratio:

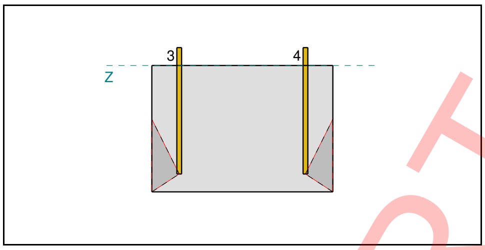
PASS = 0.04

$$DCR = \frac{N_{Ed}}{N_{Rd,s}} = \frac{12.5\ \mathrm{kN}}{339.29\ \mathrm{kN}} = 0.036841$$

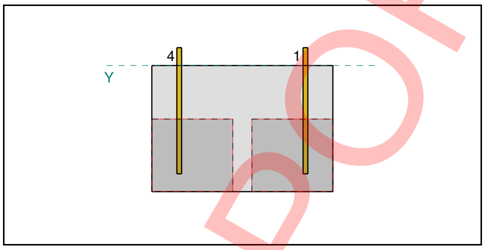
Check No. 6: Concrete Side-Face Blowout Capacity (Y-Direction)



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate tension load on single anchor in Y-direction

$N_x = 50\ \mathrm{kN}$ - Tension load

$n_{a,t} = 4$ - Number of anchors in tension

N_{Ed} - Design tension force on anchor rod

$$N_{Ed} = \frac{N_x}{n_{a,t}} = \frac{50\ \mathrm{kN}}{4} = 12.5\ \mathrm{kN}$$

Symbol	Description	Value
$c_{left,s3}$	Single anchor concrete edge distance (left)	75.0 mm
$c_{right,s3}$	Single anchor concrete edge distance (right)	425.0 mm
$c_{top,s3}$	Single anchor concrete edge distance (top)	425.0 mm
$c_{bottom,s3}$	Single anchor concrete edge distance (bottom)	75.0 mm

Calculation for critical anchor: Anchor ID 3.

Calculate minimum edge distance to failure edge

$c_{left,s3} = 75\ \mathrm{mm}$ - Single anchor concrete edge distance (left)

$c_{right,s3} = 425\ \mathrm{mm}$ - Single anchor concrete edge distance (right)

$c_{z,min}$ - Minimum edge distance along Z-axis

$$c_{z,min} = \min\left(\mathrm{c_{left,s3}},\ \mathrm{c_{right,s3}}\right) = \min\left(75\ \mathrm{mm},\ 425\ \mathrm{mm}\right) = 75\ \mathrm{mm}$$

Calculate minimum edge distance to the orthogonal edge

$c_{top,s3} = 425\ \mathrm{mm}$ - Single anchor concrete edge distance (top)

$c_{bottom,s3} = 75\ \mathrm{mm}$ - Single anchor concrete edge distance (bottom)

$c_{y,min}$ - Minimum edge distance along Y-axis

$$c_{y,min} = \min\left(\mathrm{c_{top,s3}},\ \mathrm{c_{bottom,s3}}\right) = \min\left(425\ \mathrm{mm},\ 75\ \mathrm{mm}\right) = 75\ \mathrm{mm}$$

Calculate reference projected area

EN 1992-4:2018 Eq. 7.27

$A0_{c,Nb}$ - Reference projected area of a single fastener

$$A0_{c,Nb} = \left(4c_{z,min}\right)^2 = \left(4 \times 75\ \mathrm{mm}\right)^2 = 90000\ \mathrm{mm}^2$$

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

EN 1992-4:2018 Eq. 7.27

$B_{c,Nb}$ - Width of actual projected area of the fastener

$$B_{c,Nb} = 2c_{z,min} + \min\left(2\mathrm{c_{z,min}},\ \mathrm{c_{y,min}}\right) = 2 \times 75\ \mathrm{mm} + \min\left(2 \times 75\ \mathrm{mm},\ 75\ \mathrm{mm}\right) = 225\ \mathrm{mm}$$

Calculate height of actual projected cone area (across concrete thickness)

$t_{conc} = 350\ \mathrm{mm}$ - Concrete thickness

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

EN 1992-4:2018 Eq. 7.27 — $H_{c,Nb}$ - Height of actual projected area of the fastener

$$H_{c,Nb} = 2c_{z,min} + (\min(\mathrm{t_{conc}} - \mathrm{h_{ef}},\ 2\mathrm{c_{z,min}})) = 2 \times 75\ \mathrm{mm} + (\min(350\ \mathrm{mm} - 300\ \mathrm{mm},\ 2 \times 75\ \mathrm{mm})) = 200\ \mathrm{mm}$$

Calculate actual projected cone area

EN 1992-4:2018 Eq. 7.27 — A_{Nc} - Actual projected area

$$A_{Nc} = B_{c,Nb}H_{c,Nb} = 225\ \mathrm{mm} \times 200\ \mathrm{mm} = 45000\ \mathrm{mm}^2$$

Calculate characteristic concrete blow-out strength of an individual anchor

EN 1992-4:2018 Eq 7.12 — $A_{brg} = 2714.3\ \mathrm{mm}^2$

$f_{ck} = 25\ \mathrm{MPa}$ - Concrete compressive strength (C25/30)

EN 1992-4:2018 Clause 7.2.1.8 — $k_5 = 8.7$ - Side-face blowout factor

EN 1992-4:2018 Eq. 7.26 — $N0_{Rk,cb}$ - Characteristic concrete blow-out strength of an individual fastener

$$N0_{Rk,cb} = k_5\left(\frac{c_{z,min}}{mm}\right)\sqrt{\frac{A_{brg}}{mm^2}}\sqrt{\frac{f_{ck}}{MPa}}N$$

$$N0_{Rk,cb} = 8.7 \times \left(\frac{75\ \mathrm{mm}}{1\ \mathrm{mm}}\right) \times \sqrt{\frac{2714.3\ \mathrm{mm}^2}{1\ \mathrm{mm}^2}} \times \sqrt{\frac{25\ \mathrm{MPa}}{1\ \mathrm{MPa}}} \times 0.001\ \mathrm{kN}$$

$$N0_{Rk,cb} = 169.97\ \mathrm{kN}$$

Calculate parameter for disturbance of the distribution of stress

EN 1992-4:2018 Eq 7.28 — $\Psi_{s,Nb}$ - Parameter accounting for disturbance of the distribution of stresses in concrete

$$\Psi_{s,Nb} = \min\left(0.7 + 0.3\left(\frac{\mathrm{c_{y,min}}}{2\mathrm{c_{z,min}}}\right),\ 1.0\right) = \min\left(0.7 + 0.3 \times \left(\frac{75\ \mathrm{mm}}{2 \times 75\ \mathrm{mm}}\right),\ 1\right) = 0.85$$

Calculate side-face blowout resistance (Y-direction)

EN 1992-4:2018 Eq. 7.29 — $\Psi_{g,Nb} = 1$ - Parameter accounting for a group effect

EN 1992-4:2018 Eq. 7.6 — $\Psi_{ec,N} = 1$ - Parameter accounting for the influence of eccentricity

EN 1992-4:2018 Table 4.1 — $\gamma_{Mc} = 1.5$ - Partial safety factor for concrete failure

EN 1992-4:2018 Eq. 7.25 — $N_{Rk,cb}$ - Design concrete blow-out resistance, adapted for headed anchor rods

$$N_{Rk,cb} = \frac{N0_{Rk,cb}\left(\frac{A_{Nc}}{A0_{c,Nb}}\right)\Psi_{s,Nb}\Psi_{g,Nb}\Psi_{ec,N}}{\gamma_{Mc}}$$

$$N_{Rk,cb} = \frac{169.97\ \mathrm{kN} \times \left(\frac{45000\ \mathrm{mm}^2}{90000\ \mathrm{mm}^2}\right) \times 0.85 \times 1 \times 1}{1.5} = 48.159\ \mathrm{kN}$$

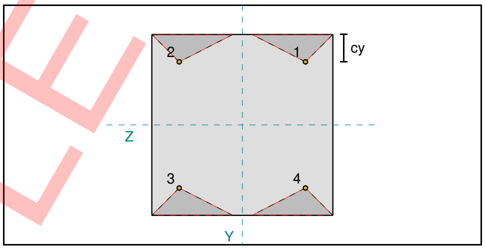
Result:

DCR - Demand over capacity ratio:

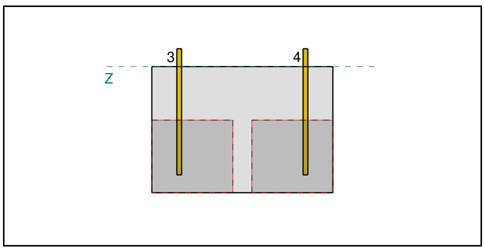
PASS = 0.26

$$DCR = \frac{N_{Ed}}{N_{Rk,cb}} = \frac{12.5\ \mathrm{kN}}{48.159\ \mathrm{kN}} = 0.25956$$

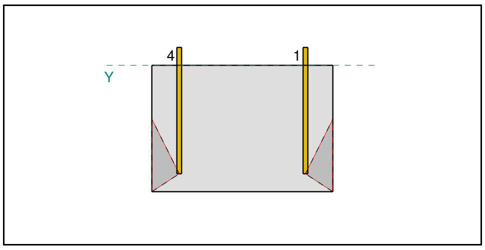
Check No. 7: Concrete Side-Face Blowout Capacity (Z-Direction)



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate tension load on single anchor in Z-direction

$N_z = 50\ \mathrm{kN}$ - Tension load

$n_{a,t} = 4$ - Number of anchors in tension

N_{Ed} - Design tension force on anchor rod

$$N_{Ed} = \frac{N_z}{n_{a,t}} = \frac{50\ \mathrm{kN}}{4} = 12.5\ \mathrm{kN}$$

Symbol	Description	Value
$c_{left,s2}$	Single anchor concrete edge distance (left)	75.0 mm
$c_{right,s2}$	Single anchor concrete edge distance (right)	425.0 mm
$c_{top,s2}$	Single anchor concrete edge distance (top)	75.0 mm
$c_{bottom,s2}$	Single anchor concrete edge distance (bottom)	425.0 mm

Calculation for critical anchor: Anchor ID 2.

Calculate minimum edge distance to failure edge

$c_{top,s2} = 75\ \mathrm{mm}$ - Single anchor concrete edge distance (top)

$c_{bottom,s2} = 425\ \mathrm{mm}$ - Single anchor concrete edge distance (bottom)

$c_{y,min}$ - Minimum edge distance along Y-axis

$$c_{y,min} = \min\left(\mathrm{c_{top,s2}},\ \mathrm{c_{bottom,s2}}\right) = \min\left(75\ \mathrm{mm},\ 425\ \mathrm{mm}\right) = 75\ \mathrm{mm}$$

Calculate minimum edge distance to the orthogonal edge

$c_{left,s2} = 75\ \mathrm{mm}$ - Single anchor concrete edge distance (left)

$c_{right,s2} = 425\ \mathrm{mm}$ - Single anchor concrete edge distance (right)

$c_{z,min}$ - Minimum edge distance along Z-axis

$$c_{z,min} = \min\left(\mathrm{c_{left,s2}},\ \mathrm{c_{right,s2}}\right) = \min\left(75\ \mathrm{mm},\ 425\ \mathrm{mm}\right) = 75\ \mathrm{mm}$$

Calculate reference projected area

EN 1992-4:2018 Eq. 7.27 — $A0_{c,Nb}$ - Reference projected area of a single fastener

$$A0_{c,Nb} = \left(4c_{y,min}\right)^2 = \left(4 \times 75\ \mathrm{mm}\right)^2 = 90000\ \mathrm{mm}^2$$

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

EN 1992-4:2018 Eq. 7.27 — $B_{c,Nb}$ - Width of actual projected area of the fastener

$$B_{c,Nb} = 2c_{y,min} + \min\left(2\mathrm{c_{y,min}},\ \mathrm{c_{z,min}}\right) = 2 \times 75\ \mathrm{mm} + \min\left(2 \times 75\ \mathrm{mm},\ 75\ \mathrm{mm}\right) = 225\ \mathrm{mm}$$

Calculate height of actual projected cone area (across concrete thickness)

$t_{conc} = 350\ \mathrm{mm}$ - Concrete thickness

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

EN 1992-4:2018 Eq. 7.27 — $H_{c,Nb}$ - Height of actual projected area of the fastener

$$H_{c,Nb} = 2c_{y,min} + \left(\min\left(\mathrm{t_{conc}} - \mathrm{h_{ef}},\ 2\mathrm{c_{y,min}}\right)\right) = 2 \times 75\ \mathrm{mm} + \left(\min\left(350\ \mathrm{mm} - 300\ \mathrm{mm},\ 2 \times 75\ \mathrm{mm}\right)\right) = 200\ \mathrm{mm}$$

Calculate actual projected area

EN 1992-4:2018 Eq. 7.27 — A_{Nc} - Actual projected area

$$A_{Nc} = B_{c,Nb}H_{c,Nb} = 225\ \mathrm{mm} \times 200\ \mathrm{mm} = 45000\ \mathrm{mm}^2$$

Calculate characteristic concrete blow-out strength of an individual anchor

EN 1992-4:2018 Eq 7.12 — $A_{brg} = 2714.3\ \mathrm{mm}^2$

$f_{ck} = 25\ \mathrm{MPa}$ - Concrete compressive strength (C25/30)

EN 1992-4:2018 Clause 7.2.1.8 — $k_5 = 8.7$ - Side-face blowout factor

EN 1992-4:2018 Eq. 7.26 — $N0_{Rk,cb}$ - Characteristic concrete blow-out strength of an individual fastener

$$N0_{Rk,cb} = k_5\left(\frac{c_{y,min}}{mm}\right)\sqrt{\frac{A_{brg}}{mm^2}}\sqrt{\frac{f_{ck}}{MPa}}N$$

$$N0_{Rk,cb} = 8.7 \times \left(\frac{75\ \mathrm{mm}}{1\ \mathrm{mm}}\right) \times \sqrt{\frac{2714.3\ \mathrm{mm}^2}{1\ \mathrm{mm}^2}} \times \sqrt{\frac{25\ \mathrm{MPa}}{1\ \mathrm{MPa}}} \times 0.001\ \mathrm{kN}$$

	$$N0_{Rk,cb} = 169.97\ \text{kN}$$	
	Calculate parameter for disturbance of the distribution of stress	
EN 1992-4:2018 Eq 7.28	$\Psi_{s,Nb}$ - Parameter accounting for disturbance of the distribution of stresses in concrete	
	$$\Psi_{s,Nb} = \min\left(0.7 + 0.3\left(\frac{c_{z,\min}}{2c_{y,\min}}\right),\ 1.0\right) = \min\left(0.7 + 0.3 \times \left(\frac{75\ \text{mm}}{2 \times 75\ \text{mm}}\right),\ 1\right) = 0.85$$	
	Calculate side-face blowout resistance (Z-direction)	
EN 1992-4:2018 Eq. 7.29	$\Psi_{g,Nb} = 1$ - Parameter accounting for a group effect	
EN 1992-4:2018 Eq. 7.6	$\Psi_{ec,N} = 1$ - Parameter accounting for the influence of eccentricity	
EN 1992-4:2018 Table 4.1	$\gamma_{Mc} = 1.5$ - Partial safety factor for concrete failure	
EN 1992-4:2018 Eq. 7.25	$N_{Rk,cb}$ - Design concrete blow-out resistance, adapted for headed anchor rods	
	$$N_{Rk,cb} = \frac{N0_{Rk,cb}\left(\frac{A_{Nc}}{A0_{c,Nb}}\right)\Psi_{s,Nb}\Psi_{g,Nb}\Psi_{ec,N}}{\gamma_{Mc}}$$	
	$$N_{Rk,cb} = \frac{169.97\ \text{kN} \times \left(\frac{45000\ \text{mm}^2}{90000\ \text{mm}^2}\right) \times 0.85 \times 1 \times 1}{1.5} = 48.159\ \text{kN}$$	
	Result:	**PASS = 0.26**
	DCR - Demand over capacity ratio:	
	$$DCR = \frac{N_{Ed}}{N_{Rk,cb}} = \frac{12.5\ \text{kN}}{48.159\ \text{kN}} = 0.25956$$	

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	5.10	225.00	0.02	**PASS**
1	Base Plate Yield Capacity (Tension Load)	25.00	110.74	0.23	**PASS**
1	Anchor Rod Tensile Capacity	12.50	55.37	0.23	**PASS**
1	Concrete Breakout Capacity (Tension Load)	50.00	63.22	0.79	**PASS**
1	Anchor Pullout Capacity	12.50	339.29	0.04	**PASS**
1	Concrete Side-Face Blowout Capacity (Y-Direction)	12.50	48.16	0.26	**PASS**
1	Concrete Side-Face Blowout Capacity (Z-Direction)	12.50	48.16	0.26	**PASS**

The design is adequate!