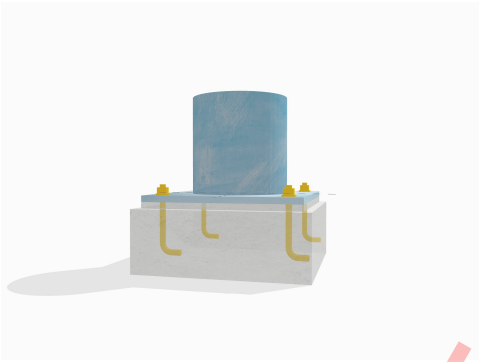
REFERENCES	CALCULATIONS	RESULTS

SkyCiv Base Plate and Anchor Rod Design

t - csa

Project Information:
Design Code: CSA S16:19 and CSA A23.3:19

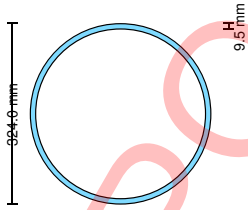


Load Combinations:

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

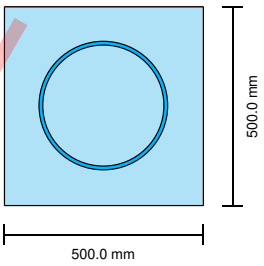
Note: Positive Nx (+) indicates compression; negative Nx (-) indicates tension.

Column Properties:



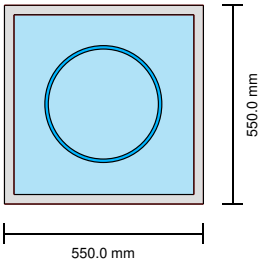
Symbol	Description	Value
$Section$	Column section	HS324x9.5
d_{col}	Column outside diameter	324.0 mm
t_{col}	Column thickness	9.5 mm
A_{col}	Column area	9410.0 mm^2
F_{y_col}	Column yield stress (230G)	230.0 MPa
F_{u_col}	Column tensile stress (230G)	380.0 MPa

Base Plate Properties:



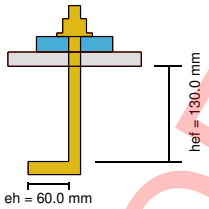
Symbol	Description	Value
B_{bp}	Base plate width	500.0 mm
L_{bp}	Base plate length	500.0 mm
t_{bp}	Base plate thickness	20.0 mm
A_{bp}	Base plate plan area	250000.0 mm^2
F_{y_bp}	Base plate yield stress	230.0 MPa
F_{u_bp}	Base plate tensile stress (230G)	380.0 MPa
t_{grout}	Grout thickness	20.0 mm

Concrete Properties:



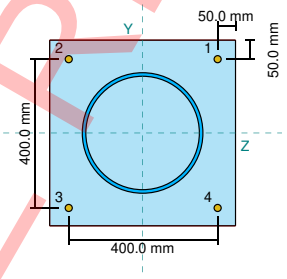
Symbol	Description	Value
B_{conc}	Concrete width	550.0 mm
L_{conc}	Concrete length	550.0 mm
t_{conc}	Concrete thickness	200.0 mm
A_{conc}	Concrete plan area	302500.0 mm^2
f_c'	Concrete compressive strength (20.68)	20.7 MPa
λ	Factor for normal-weight concrete	1.0
–	Concrete assumption: cracked or uncracked	Cracked

Anchor Information:



Symbol	Description	Value
d_a	Anchor rod diameter	19.1 mm
h_{ef}	Anchor rod effective embedment length	130.0 mm
e_h	Anchor hook length	60.0 mm
F_{y_anc}	Anchor rod yield stress (ASTM F1554 G36)	248.2 MPa
F_{u_anc}	Anchor rod tensile stress (ASTM F1554 G36)	399.9 MPa

Anchor Layout:



Symbol	Description	Value
n_a	Total number of anchor rods	4.0
s_z	Spacing of anchor rods along Z-axis	400.0 mm
s_y	Spacing of anchor rods along Y-axis	400.0 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	200	200	✓	Single	N/A	N/A
2	-200	200	✓	Single	N/A	N/A
3	-200	-200	✓	Single	N/A	N/A
4	200	-200	✓	Single	N/A	N/A

Weld Properties:

Symbol	Description	Value
$Type$	Weld Type	CJP
X_u	Filler metal classification strength (E43XX)	490.0 MPa

Summary of Detailing Checks

Check Name	Dimensions (Min/Max/Actual)	Status
Anchor Clearance	Min: 30.16 mm, Actual: 113.39 mm	PASS
Base Plate Edge Distance	Min: 26.00 mm, Actual: 50.00 mm	PASS
Minimum Number of Anchors	Min: 4.00, Actual: 4.00	PASS
Min. Anchor Spacing to Prevent Concrete Splitting	Min: 76.20 mm, Actual: 400.00 mm	PASS
Min. Concrete Cover to Prevent Concrete Splitting	Min: 75.00 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

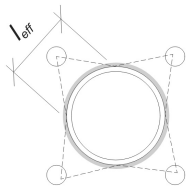


Fig. Effective welds on column to base plate.

Calculate effective weld length on pipe

The effective weld length per anchor is calculated as the arc length to the tangent points of the column. In the case of closely spaced anchors, a shorter arc length is determined to prevent overlap.

$l_{arc} = 254.47\ \text{mm}$ - Arc length of the tangent points to the column

$d_{col} = 324\ \text{mm}$ - Column outside diameter

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

l_{eff} - Design effective weld length

$$l_{eff} = \min\left(\mathrm{l_{arc}},\ \frac{\pi \mathrm{d_{col}}}{\mathrm{n_{a,t}}}\right) = \min\left(254.47\ \text{mm},\ \frac{\pi \times 324\ \text{mm}}{4}\right) = 254.47\ \text{mm}$$

Calculate load per unit length of weld

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

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

$l_{eff} = 254.47\ \text{mm}$

$T_{u,anchor}$ - Tension load per anchor

$$T_{u,anchor} = \frac{N_x}{n_{a,t}} = \frac{50\ \text{kN}}{4} = 12.5\ \text{kN}$$

v_f - Factored load per unit length of weld

$$v_f = \frac{T_{u,anchor}}{l_{eff}} = \frac{12.5\ \text{kN}}{254.47\ \text{mm}} = 0.049122\ \text{kN/mm}$$

Calculate base metal capacity for CJP

$F_{y\_col} = 230\ \text{MPa}$ - Column yield stress (230G)

$F_{y\_bp} = 230\ \text{MPa}$ - Base plate yield stress

$t_{col} = 9.53\ \text{mm}$ - Column thickness

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

$\phi = 0.9$ - Structural steel resistance factor

CSA S16:19 Clause 13.13.3.1

$v_{r,bm}$ - Factored base metal resistance per unit length (CJP)

$$v_{r,bm} = \phi\left(\min\left(\mathrm{F_{y\_col}t_{col}},\ \mathrm{F_{y\_bp}t_{bp}}\right)\right)$$

$$v_{r,bm} = 0.9 \times \left(\min\left(230\ \text{MPa} \times 9.53\ \text{mm},\ 230\ \text{MPa} \times 20\ \text{mm}\right)\right) = 1.9727\ \text{kN/mm}$$

Result:

DCR - Demand over capacity ratio:

$$DCR = \frac{v_f}{v_{r,bm}} = \frac{0.049122\ \text{kN/mm}}{1.9727\ \text{kN/mm}} = 0.024901$$

PASS = 0.02

Check No. 2: Base Plate Yield Capacity (Tension Load)

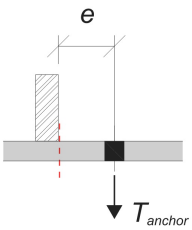


Fig. Bending of base plate from eccentric anchor load.

Calculate lever arm distance

$d_o = 120.84\ \text{mm}$ - Offset distance to face of column

$r_{col} = 162\ \text{mm}$ - Column outside radius

$l_{eff} = 254.47\ \text{mm}$

e_{pipe} - Adjusted lever arm for pipe (distance to face of column plus sagitta of welded arc)

$$e_{pipe} = d_o + r_{col}\left(1 - \cos\left(\frac{\mathrm{l_{eff}}}{2\mathrm{r_{col}}}\right)\right)$$

$$e_{pipe} = 120.84\ \text{mm} + 162\ \text{mm} \times \left(1 - \cos\left(\frac{254.47\ \text{mm}}{2 \times 162\ \text{mm}}\right)\right) = 168.29\ \text{mm}$$

Calculate applied moment load on effective width of base plate

$T_{u,anchor} = 12.5$ kN

$e_{pipe} = 168.29$ mm - Tensile load eccentricity

M_f - Factored bending load on base plate

$$M_f = T_{u,anchor} e_{pipe} = 12.5 \text{ kN} \times 168.29 \text{ mm} = 2103.6 \text{ kN·mm}$$

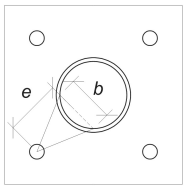


Fig. Assumed bending width on base plate.

Calculate bending width

$d_{col} = 324$ mm - Column outside diameter

$l_{eff} = 254.47$ mm

θ_{rad} - Central angle of weld arc

$$\theta_{rad} = \frac{l_{eff}}{0.5 d_{col}} = \frac{254.47 \text{ mm}}{0.5 \times 324 \text{ mm}} = 1.5708$$

b - Bending width

$$b = d_{col}\left(\sin\left(\frac{\theta_{\text{rad}}}{2}\right)\right) = 324 \text{ mm} \times \left(\sin\left(\frac{1.5708}{2}\right)\right) = 229.1 \text{ mm}$$

Calculate flexural yielding capacity of base plate

$b = 229.1$ mm

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

CSA S16:19 Clause 13.5

Z_{eff} - Plastic modulus of the effective section

$$Z_{eff} = \frac{b(t_{bp})^2}{4} = \frac{229.1 \text{ mm} \times (20 \text{ mm})^2}{4} = 22910 \text{ mm}^3$$

$F_{y\_bp} = 230$ MPa - Base plate yield stress

$\phi = 0.9$ - Structural steel resistance factor

CSA S16:19 Clause 13.5

M_r - Factored bending resistance of base plate

$$M_r = \phi F_{y\_bp} Z_{eff} = 0.9 \times 230 \text{ MPa} \times 22910 \text{ mm}^3 = 4742.4 \text{ kN·mm}$$

Result:

PASS = 0.44

DCR - Demand over capacity ratio:

$$DCR = \frac{M_f}{M_r} = \frac{2103.6 \text{ kN·mm}}{4742.4 \text{ kN·mm}} = 0.44358$$

Check No. 3: Anchor Rod Tensile Capacity

Fig. Anchor steel tension failure.

Calculate load per tension anchor

$N_x = 50$ kN - Tension load

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

N_{fa} - Factored tensile load on anchor rod

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

Calculate specified tensile strength of anchor

$F_{u\_anc} = 400$ MPa - Anchor rod tensile stress (ASTM F1554 G36)

$F_{y\_anc} = 248.2$ MPa - Anchor rod yield stress (ASTM F1554 G36)

CSA A23.3:19 Clause D.6.1.2

f_{uta} - Specified tensile strength of anchor steel

$$f_{uta} = \min\left(\mathrm{F_{u\_anc}},\ 1.9\mathrm{F_{y\_anc}},\ 860\right) = \min\left(400 \text{ MPa},\ 1.9 \times 248.2 \text{ MPa},\ 860.00 \text{ MPa}\right) = 400 \text{ MPa}$$

Calculate anchor steel tensile capacity from CSA A23.3:19

CSA A23.3:19 Clause D.6.1.2 and CAC Concrete Design Handbook 3rd Ed. Table 12.3

$A_{se,N} = 215$ mm^2 - Effective cross-sectional area of anchor rod in tension

$\phi_s = 0.85$ - Anchor rod resistance factor

$R = 0.8$ - Resistance modification factor of anchor rod in tension

CSA A23.3:19 Eq. D.2

N_{sar} - Factored resistance of anchor rod in tension

$$N_{sar} = A_{se,N} \phi_s f_{uta} R = 215 \text{ mm}^2 \times 0.85 \times 400 \text{ MPa} \times 0.8 = 58.465 \text{ kN}$$

Calculate anchor steel tensile capacity from CSA S16:19

$F_{u\_anc} = 400$ MPa - Anchor rod tensile stress (ASTM F1554 G36)

CSA S16:19 pg. 31

$A_{ar} = 285.02\ \text{mm}^2$ - Nominal cross-sectional area of anchor rod

S16:19 Clause 25.3.2.1

$\phi_{ar} = 0.67$ - Anchor rod resistance factor

CSA S16:19 Clause 25.3.2.1

T_r - Factored resistance of anchor rod in tension

$$T_r = \phi_{ar} 0.85 A_{ar} F_{u\_anc} = 0.67 \times 0.85 \times 285.02\ \text{mm}^2 \times 400\ \text{MPa} = 64.912\ \text{kN}$$

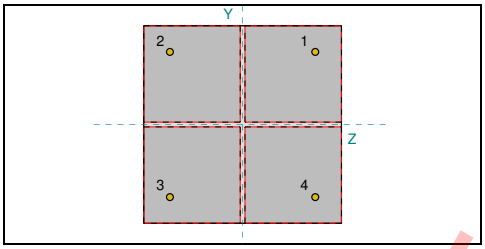
Result:

PASS = 0.21

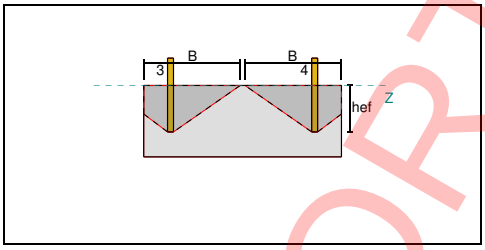
DCR - Demand over capacity ratio:

$$DCR = \frac{N_{fa}}{N_{ra}} = \frac{12.5\ \text{kN}}{58.465\ \text{kN}} = 0.2138$$

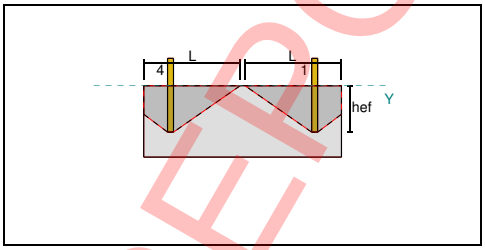
Check No. 4: Concrete Breakout Capacity (Tension Load)



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate tension load per single anchor

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

$n_{a,s} = 4$ - Number of single anchors

N_{fa} - Factored tensile load on single anchor

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

Determine if the support is a narrow concrete member

CSA A23.3:19 Clause D.6.2.3

The support is not a narrow member.

Symbol	Description	Value
$c_{left,s1}$	Single anchor concrete edge distance (left)	475.0 mm
$c_{right,s1}$	Single anchor concrete edge distance (right)	75.0 mm
$c_{top,s1}$	Single anchor concrete edge distance (top)	75.0 mm
$c_{bottom,s1}$	Single anchor concrete edge distance (bottom)	475.0 mm
h_{ef}	Anchor rod effective embedment length	130.0 mm
	Narrow Member	FALSE

Sample calculation for worst case: Anchor ID 1.

Calculate maximum projected area for a single anchor

ACI 318-19 Clause 17.6.2.1.2

$h_{ef,s1} = 130\ \text{mm}$ - Anchor rod effective embedment length

CSA A23.3:19 Eq. D.5

A_{Nco} - Maximum projected area for a single anchor

$$A_{Nco} = 9(h_{ef,s1})^2 = 9 \times (130\ \text{mm})^2 = 152100\ \text{mm}^2$$

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

$r_{embed\_plate} = 0\ \text{mm}$ - This variable should not be used.

CSA A23.3:19 Clause D.6.2.1

L_{Nc} - Actual length of concrete cone for a single anchor

$$L_{Nc} = (\min(c_{left,s1},\ 1.5h_{ef,s1} + r_{embed\_plate})) + (\min(c_{right,s1},\ 1.5h_{ef,s1} + r_{embed\_plate}))$$

$$L_{Nc} = (\min(475\ \text{mm},\ 1.5 \times 130\ \text{mm} + 0\ \text{mm})) + (\min(75\ \text{mm},\ 1.5 \times 130\ \text{mm} + 0\ \text{mm}))$$

$$L_{Nc} = 270\ \text{mm}$$

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

$r_{embed\_plate} = 0\ \text{mm}$

CSA A23.3:19 Clause D.6.2.1

B_{Nc} - Actual width of concrete cone for a single anchor

$$B_{Nc} = (\min(c_{top,s1},\ 1.5h_{ef,s1} + r_{embed\_plate})) + (\min(c_{bottom,s1},\ 1.5h_{ef,s1} + r_{embed\_plate}))$$

$$B_{Nc} = (\min(75\ \text{mm},\ 1.5 \times 130\ \text{mm} + 0\ \text{mm})) + (\min(475\ \text{mm},\ 1.5 \times 130\ \text{mm} + 0\ \text{mm}))$$

$$B_{Nc} = 270\ \text{mm}$$

Calculate actual projected area of the single anchor

CSA A23.3:19 Clause D.6.2.1

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

$$A_{Nc} = L_{Nc}B_{Nc} = 270\ \text{mm} \times 270\ \text{mm} = 72900\ \text{mm}^2$$

Calculate modification factor for lightweight concrete

$\lambda = 1$ - Factor for normal-weight concrete

CSA A23.3:19 Clause D.4.6

λ_a - Modification factor for lightweight concrete

$$\lambda_a = 1.0\lambda = 1 \times 1 = 1$$

Calculate basic single anchor breakout strength

CSA A23.3:19 Clause D.6.2.1

$k_c = 10$ - Factor for cast-in anchors breakout strength

$\phi = 0.65$ - Concrete resistance factor

$f_c^{'} = 20.68\ \text{MPa}$ - Concrete compressive strength (20.68)

ACI 318-19 Clause 17.6.2.1.2

$h_{ef,s1} = 130\ \text{mm}$ - Anchor rod effective embedment length

$R = 1$ - Resistance modification factor of cast-in anchor rod in tension

CSA A23.3:19 Eq. D.6

N_{br} - Factored concrete breakout resistance of a single anchor in tension

$$N_{br} = k_c\phi\lambda_a\sqrt{\frac{f_c^{'}}{MPa}}\left(\frac{h_{ef,s1}}{mm}\right)^{1.5}RN$$

$$N_{br} = 10 \times 0.65 \times 1 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{130\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN} = 43.813\ \text{kN}$$

Calculate minimum edge distance of anchor

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

$$c_{a,min} = \min(c_{left,s1},\ c_{right,s1},\ c_{top,s1},\ c_{bottom,s1}) = \min(475\ \text{mm},\ 75\ \text{mm},\ 75\ \text{mm},\ 475\ \text{mm}) = 75\ \text{mm}$$

Calculate edge effect factor

CSA A23.3:19 Eq. D.10 and D.11

$\Psi_{ed,N}$ - Modification factor for edge effects of anchors

$$\Psi_{ed,N} = \min\left(1.0,\ 0.7 + 0.3\left(\frac{c_{a,min}}{1.5h_{ef,s1}}\right)\right) = \min\left(1,\ 0.7 + 0.3 \times \left(\frac{75\ \text{mm}}{1.5 \times 130\ \text{mm}}\right)\right) = 0.81538$$

Calculate concrete breakout capacity of the single anchor

CSA A23.3:19 Eq. D.10 and D.11

$\Psi_{ed,N} = 0.81538$

CSA A23.3:19 Clause D.6.2.6

$\Psi_{c,N} = 1$ - Modification factor for cracking

CSA A23.3:19 Clause D.6.2.7

$\Psi_{cp,N} = 1$ - Modification factor for concrete splitting

CSA A23.3:19 Eq. D.3

N_{cbr} - Factored concrete breakout resistance

$$N_{cbr} = \left(\frac{A_{Nc}}{A_{Nco}}\right)\Psi_{ed,N}\Psi_{c,N}\Psi_{cp,N}N_{br} = \left(\frac{72900\ \text{mm}^2}{152100\ \text{mm}^2}\right) \times 0.81538 \times 1 \times 1 \times 43.813\ \text{kN} = 17.122\ \text{kN}$$

Result:

PASS = 0.73

DCR - Demand over capacity ratio:

$$DCR = \frac{N_{fa}}{N_{cbr}} = \frac{12.5\ \text{kN}}{17.122\ \text{kN}} = 0.73004$$

Check No. 5: Anchor Pullout Capacity

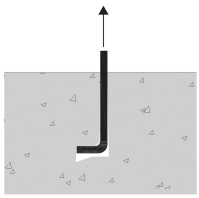


	Fig. Hook anchor concrete pullout failure. **Calculate load per tension anchor** $N_x = 50$ kN - Tension load $n_{a,t} = 4$ - Number of anchors in tension N_{fa} - Factored load on cast-in anchor $$N_{fa} = \frac{N_x}{n_{a,t}} = \frac{50 \text{ kN}}{4} = 12.5 \text{ kN}$$	
CSA A23.3:19 Clause D.6.3.6	**Calculate basic anchor pullout strength** $\Psi_{c,P} = 1$ - Modification factor for pullout $\phi = 0.65$ - Concrete resistance factor $f_c^{'} = 20.68$ MPa - Concrete compressive strength (20.68) $e_h = 60$ mm - Anchor hook length $d_a = 19.05$ mm - Anchor rod diameter $R = 1$ - Resistance modification factor of cast-in anchor rod in tension	
CSA A23.3:19 Eq. D.17	N_{pr} - Factored pullout resistance of a single J-bolt or L-bolt $$N_{pr} = \Psi_{c,P} 0.9 \phi \left(f_c^{'}\right) e_h d_a R = 1 \times 0.9 \times 0.65 \times (20.68 \text{ MPa}) \times 60 \text{ mm} \times 19.05 \text{ mm} \times 1 = 13.828 \text{ kN}$$	
	Result: DCR - Demand over capacity ratio: $$DCR = \frac{N_{fa}}{N_{pr}} = \frac{12.5 \text{ kN}}{13.828 \text{ kN}} = 0.90398$$	**PASS = 0.90**
	Check No. 6: Concrete Side-Face Blowout Capacity (Y-Direction) **Calculation Note:** Check is not applicable for anchors with non-headed ends	**N/A = 0.00**
	Check No. 7: Concrete Side-Face Blowout Capacity (Z-Direction) **Calculation Note:** Check is not applicable for anchors with non-headed ends	**N/A = 0.00**

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	0.05	1.97	0.02	PASS
1	Base Plate Yield Capacity (Tension Load)	2103.64	4742.42	0.44	PASS
1	Anchor Rod Tensile Capacity	12.50	58.47	0.21	PASS
1	Concrete Breakout Capacity (Tension Load)	12.50	17.12	0.73	PASS
1	Anchor Pullout Capacity	12.50	13.83	0.90	PASS
1	Concrete Side-Face Blowout Capacity (Y-Direction)	0.00	0.00	0.00	N/A
1	Concrete Side-Face Blowout Capacity (Z-Direction)	0.00	0.00	0.00	N/A

The design is adequate!