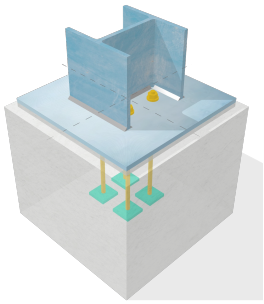
REFERENCES	CALCULATIONS	RESULTS

SkyCiv Base Plate and Anchor Rod Design

Shear - CSA

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

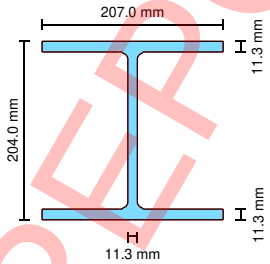


Load Combinations:

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

Note(s):
1. Positive Nx (+) indicates compression; negative Nx (-) indicates tension.
2. Shear forces are assumed to be distributed to all anchors in the base plate.
3. Engineering methods other than welded plate washers are assumed to be used to distribute shear forces.
4. Ductile steel is assumed for resistance modification factor for steel failure.
5. Condition B is used for resistance modification factor for concrete failure.

Column Properties:

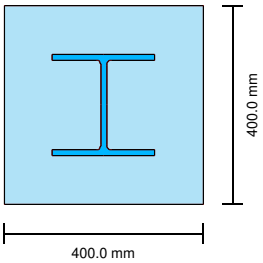


Symbol	Description	Value
$Section$	Column section	HP200x54
d_{col}	Column depth	204.0 mm
t_w	Column web thickness	11.3 mm
b_f	Column flange width	207.0 mm
t_f	Column flange thickness	11.3 mm
A_{col}	Column area	6840.0 mm^2
r_{col}	Column root radius	9.7 mm
F_{y_col}	Column yield stress (350W)	350.0 MPa
F_{u_col}	Column tensile stress (350W)	450.0 MPa

SAMPLE REPORT ONLY

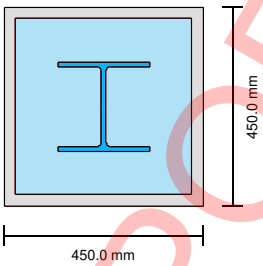
REFERENCES	CALCULATIONS	RESULTS

Base Plate Properties:



Symbol	Description	Value
B_{bp}	Base plate width	400.0 mm
L_{bp}	Base plate length	400.0 mm
t_{bp}	Base plate thickness	13.0 mm
A_{bp}	Base plate plan area	160000.0 mm^2
F_{y_bp}	Base plate yield stress (300W)	300.0 MPa
F_{u_bp}	Base plate tensile stress (300W)	450.0 MPa
t_{grout}	Grout thickness	13.0 mm

Concrete Properties:



Symbol	Description	Value
B_{conc}	Concrete width	450.0 mm
L_{conc}	Concrete length	450.0 mm
t_{conc}	Concrete thickness	380.0 mm
A_{conc}	Concrete plan area	202500.0 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

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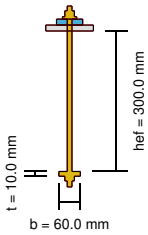
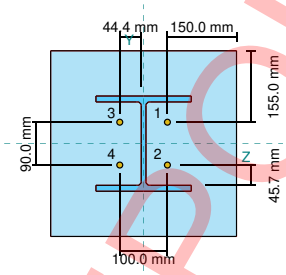
REFERENCES	CALCULATIONS	RESULTS

Anchor Information:



Symbol	Description	Value
d_a	Anchor rod diameter	12.7 mm
h_{ef}	Anchor rod effective embedment length	300.0 mm
b_{embed_plate}	Anchor embed plate dimension	60.0 mm
t_{embed_plate}	Thickness of embed plate	10.0 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
F_{y_ep}	Embed plate yield stress (300W)	300.0 MPa
t_{pw}	Plate washer thickness	0.0 mm
$Threads$	Threads in shear plane	Included

Anchor Layout:



Symbol	Description	Value
n_a	Total number of anchor rods	4.0
s_z	Spacing of anchor rods along Z-axis	100.0 mm
s_y	Spacing of anchor rods along Y-axis	90.0 mm
$l_{edge,z}$	Base plate edge distance along Z-axis	150.0 mm
$l_{edge,y}$	Base plate edge distance along Y-axis	155.0 mm

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REFERENCES	CALCULATIONS	RESULTS

Anchor Data Summary:

ID	Z (mm)	Y (mm)
1	50.000	45.000
2	50.000	-45.000
3	-50.000	45.000
4	-50.000	-45.000

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

Weld Properties:

Symbol	Description	Value
$Type$	Weld Type	Fillet
D_{top_flange}	Fillet weld size at Top Flange	8.000 mm
D_{bottom_flange}	Fillet weld size at Bottom Flange	8.000 mm
D_{web}	Fillet weld size at Web	8.000 mm
$t_{w_top_flange}$	Weld throat at Top Flange	5.657 mm
$t_{w_bottom_flange}$	Weld throat at Bottom Flange	5.657 mm
t_{w_web}	Weld throat at Web	5.657 mm
X_u	Filler metal classification strength (E43XX)	430.000 MPa

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REFERENCES	CALCULATIONS	RESULTS

Summary of Detailing Checks

Check Name	Dimensions (Min/Max/Actual)	Status	Reference
Weld Size Requirement (Flange)	Min: 6.00 mm, Max: 19.00 mm, Actual: 8.00 mm	PASS	CSA W59-13 Table 4.4
Weld Size Requirement (Web)	Min: 6.00 mm, Max: 19.00 mm, Actual: 8.00 mm	PASS	CSA W59-13 Table 4.4
Anchor Clearance	Min: 30.16 mm, Actual: 36.35 mm	PASS	SkyCiv Recommendation
Base Plate Edge Distance	Min: 20.00 mm, Actual: 150.00 mm	PASS	CSA S16:19 Table 5
Minimum Number of Anchors	Min: 4.00, Actual: 4.00	PASS	CSA S16:19 Clause 25.2
Embedded Plate Dimension	Min: 50.80 mm, Actual: 60.00 mm	PASS	SkyCiv Recommendation
Min. Anchor Spacing to Prevent Concrete Splitting	Min: 50.80 mm, Actual: 90.00 mm	PASS	CSA A23.3.19 Clause D.9.2
Min. Concrete Cover to Prevent Concrete Splitting	Min: 75.00 mm, Actual: 175.00 mm	PASS	CSA A23.3.19 Clause D.9.3

✔ All Detailing Checks Passed

The design geometry meets requirements.

Summary of Design Checks

Design Check	Governing LC	Demand	Capacity	DCR	Result
Weld Capacity	1	0.01	1.09	0.01	PASS
Concrete Breakout Capacity (Vy Shear)	1	5.00	16.67	0.30	PASS
Concrete Breakout Capacity (Vz Shear)	1	5.00	16.64	0.30	PASS
Concrete Pryout Capacity	1	7.07	120.41	0.06	PASS
Anchor Rod Shear Capacity	1	3.54	11.26	0.31	PASS

✔ All Design Checks Passed

The design is adequate.

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REFERENCES	CALCULATIONS	RESULTS

Load Combination No. 1: Shear Load Only

Check No. 1: Weld Capacity

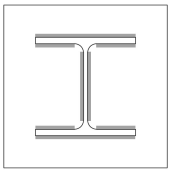

Fig. Welds on column to base plate.

Calculate total weld length on column flange and web

$d_{col} = 204\ \text{mm}$ - Column depth

$b_f = 207\ \text{mm}$ - Column flange width

$t_f = 11.3\ \text{mm}$ - Column flange thickness

$t_w = 11.3\ \text{mm}$ - Column web thickness

$r_{col} = 9.7\ \text{mm}$ - Column root radius

L_{weld} - Total length of weld

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

$$L_{weld} = 2 \times 207\ \text{mm} + 2 \times (204\ \text{mm} - 2 \times 11.3\ \text{mm} - 2 \times 9.7\ \text{mm}) + 2 \times (207\ \text{mm} - 11.3\ \text{mm} - 2 \times 9.7\ \text{mm}) = 1090.6\ \text{mm}$$

Calculate load per unit length of weld

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

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

v_{fy} - Required weld strength per unit length

$$v_{fy} = \frac{V_y}{L_{weld}} = \frac{5\ \text{kN}}{1090.6\ \text{mm}} = 0.0045846\ \text{kN/mm}$$

v_{fz} - Required weld strength per unit length

$$v_{fz} = \frac{V_z}{L_{weld}} = \frac{5\ \text{kN}}{1090.6\ \text{mm}} = 0.0045846\ \text{kN/mm}$$

v_f - Required weld strength per unit length

$$v_f = \sqrt{\left((v_{fy})^2\right) + \left((v_{fz})^2\right)}$$

$$v_f = \sqrt{\left((0.0045846\ \text{kN/mm})^2\right) + \left((0.0045846\ \text{kN/mm})^2\right)} = 0.0064836\ \text{kN/mm}$$

Calculate fillet weld capacity on flange

$X_u = 430\ \text{MPa}$ - Filler metal classification strength (E43XX)

$t_{w,flange} = 5.657\ \text{mm}$ - Design weld throat at flange

$\phi = 0.67$ - Weld resistance factor

$\theta = 0$ - Angle of load in radians (conservative)

CSA S16:19 Clause 13.13.2.2

k_{ds} - Directional strength increase factor

$$k_{ds} = 1.0 + 0.5(\sin(\theta))^{1.5} = 1 + 0.5 \times (\sin(0))^{1.5} = 1$$

CSA S16:19 Clause 13.13.2.2

v_r - Factored weld resistance per unit length

$$v_r = 0.67\phi t_{w,flange} X_u = 0.67 \times 0.67 \times 5.657\ \text{mm} \times 430\ \text{MPa} = 1.092\ \text{kN/mm}$$

Calculate fillet weld capacity on web

$X_u = 430\ \text{MPa}$ - Filler metal classification strength (E43XX)

$t_{w,web} = 5.657\ \text{mm}$ - Design weld throat at web

$\phi = 0.67$ - Weld resistance factor

$\theta = 0$ - Angle of load in radians (conservative)

CSA S16:19 Clause 13.13.2.2

k_{ds} - Directional strength increase factor

$$k_{ds} = 1.0 + 0.5(\sin(\theta))^{1.5} = 1 + 0.5 \times (\sin(0))^{1.5} = 1$$

CSA S16:19 Clause 13.13.2.2

v_r - Factored weld resistance per unit length

$$v_r = 0.67\phi t_{w,web} X_u = 0.67 \times 0.67 \times 5.657\ \text{mm} \times 430\ \text{MPa} = 1.092\ \text{kN/mm}$$

Determine governing fillet weld capacity

CSA S16:19 Clause 13.13.2.2

$v_{r,fillet}$ - Governing factored strength between flange weld and web weld

$$v_{r,fillet} = \min\left(\text{v}_\text{r},\ \text{v}_\text{r}\right) = \min\left(1.092\ \text{kN/mm},\ 1.092\ \text{kN/mm}\right) = 1.092\ \text{kN/mm}$$

Result:

DCR - Demand-to-Capacity Ratio

PASS = 0.01

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$$DCR = \frac{v_f}{v_{r,fillet}} = \frac{0.0064836\ \text{kN/mm}}{1.092\ \text{kN/mm}} = 0.0059377$$

Go back to summary results table.

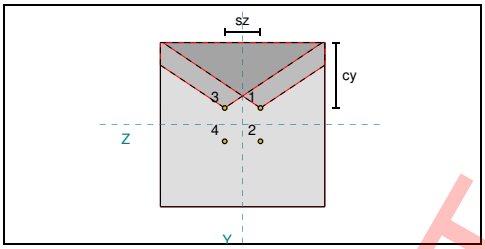
Check No. 2: Concrete Breakout Capacity (Vy Shear)

For breakout capacity on failure edge perpendicular to load:

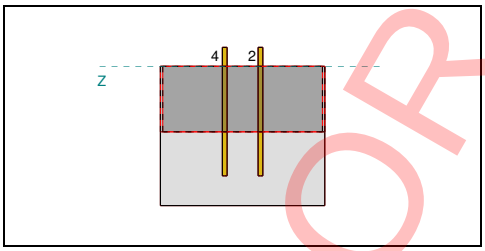
Determine cases:

Symbol	Description	Value
$s_{y,outer}$	Spacing of outer anchor rods along Y-axis	90.0 mm
$c_{a1,g1}$	Anchor group distance to failure edge (+Vy shear)	180.0 mm
	Are welded plate washers used?	No
	Applicable Cases	Case 3

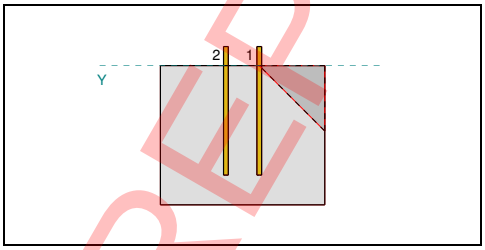
Calculations for Case 3



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate total shear load on anchor group.

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

$V_{fa\perp,case3}$ - Required concrete breakout shear strength of anchor group with failure edge perpendicular to load

$$V_{fa\perp,case3} = V_y = 5\ \text{kN}$$

CSA A23.3:19 Clause D.7.2.4

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)	175.0 mm
$c_{right,g1}$	Anchor group BO Vy 1 concrete edge distance (right)	175.0 mm
$c_{top,g1}$	Anchor group BO Vy 1 concrete edge distance (top)	180.0 mm
$c_{bottom,g1}$	Anchor group BO Vy 1 concrete edge distance (bottom)	270.0 mm
t_{conc}	Concrete thickness	380.0 mm
s_z	Spacing of anchor rods along Z-axis	100.0 mm
$c_{a1,g1}$	Anchor group distance to failure edge (+Vy shear)	180.0 mm
	Narrow Member	FALSE

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

Calculate maximum projected area for a single anchor

CSA A23.3:19 Clause D.7.2.4

$c_{a1,g1} = 180\ \text{mm}$ - Anchor group distance to failure edge (+Vy shear)

CSA A23.3:19 Equation D.34

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

$$A_{Vco} = 4.5(c_{a1,g1})^2 = 4.5 \times (180\ \text{mm})^2 = 145800\ \text{mm}^2$$

Calculate width of actual projected area on failure surface

$s_{sum,z,g1} = 100\ \text{mm}$ - Anchor group BO Vy 1 sum of spacing along Z-axis

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

CSA A23.3:19 Clause D.7.2.1

B_{Vc} - Actual width of failure surface for an anchor group

$$B_{Vc} = \min\left(c_{left,g1},\ 1.5c_{a1,g1}\right) + \left(\min\left(s_{sum,z,g1},\ 3c_{a1,g1}\left(n_{z,g1} - 1\right)\right)\right) + \min\left(c_{right,g1},\ 1.5c_{a1,g1}\right)$$

$$B_{Vc} = \min\left(175\ \text{mm},\ 1.5 \times 180\ \text{mm}\right) + \left(\min\left(100\ \text{mm},\ 3 \times 180\ \text{mm} \times (2-1)\right)\right) + \min\left(175\ \text{mm},\ 1.5 \times 180\ \text{mm}\right)$$

$$B_{Vc} = 450\ \text{mm}$$

Calculate height of actual projected area on failure surface

CSA A23.3:19 Clause D.7.2.1

H_{Vc} - Actual height of projected area

$$H_{Vc} = \min\left(1.5c_{a1,g1},\ t_{conc}\right) = \min\left(1.5 \times 180\ \text{mm},\ 380\ \text{mm}\right) = 270\ \text{mm}$$

Calculate actual projected area

CSA A23.3:19 Clause D.7.2.1

A_{Vc} - Actual projected area

$$A_{Vc} = B_{Vc}H_{Vc} = 450\ \text{mm} \times 270\ \text{mm} = 121500\ \text{mm}^2$$

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 load bearing length of the anchor

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

CSA A23.3:19 Clause D.7.2.2(a)

l_e - Load bearing length (equal to embedment height)

$$l_e = h_{ef} = 300\ \text{mm}$$

Calculate basic single anchor breakout strength

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

$d_a = 12.7\ \text{mm}$ - Anchor rod diameter

$\phi = 0.65$ - Concrete resistance factor

$R = 1$ - Resistance modification factor of concrete failure (Shear Loads)

CSA A23.3:19 Equation D.35

V_{br1} - Basic single anchor breakout strength condition 1

$$V_{br1} = 0.58\left(\frac{\min\left(l_e,\ 8d_a\right)}{d_a}\right)^{0.2}\sqrt{\frac{d_a}{mm}}\phi\lambda_a\sqrt{\frac{f_c^{'}}{MPa}}\left(\frac{c_{a1,g1}}{mm}\right)^{1.5}R(N)$$

$$V_{br1} = 0.58 \times \left(\frac{\min\left(300\ \text{mm},\ 8 \times 12.7\ \text{mm}\right)}{12.7\ \text{mm}}\right)^{0.2} \times \sqrt{\frac{12.7\ \text{mm}}{1\ \text{mm}}} \times 0.65 \times 1 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{180\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN}$$

$$V_{br1} = 22.364\ \text{kN}$$

CSA A23.3:19 Equation D.36

V_{br2} - Basic single anchor breakout strength condition 2

$$V_{br2} = 3.75\lambda_a\phi\sqrt{\frac{f_c^{'}}{MPa}}\left(\frac{c_{a1,g1}}{mm}\right)^{1.5}R(N)$$

$$V_{br2} = 3.75 \times 1 \times 0.65 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{180\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN} = 26.769\ \text{kN}$$

CSA A23.3:19 Clause D.7.2.2

V_{br} - Factored concrete breakout resistance in shear of a single anchor

$$V_{br} = \min\left(V_{br1},\ V_{br2}\right) = \min\left(22.364\ \text{kN},\ 26.769\ \text{kN}\right) = 22.364\ \text{kN}$$

Calculate eccentricity factor

$e_N^{'} = 0$ - Eccentricity of the resultant tensile force (assumed 0 for shear)

CSA A23.3:19 Clause D.7.2.5

$\Psi_{ec,V}$ - Breakout eccentricity factor

$$\Psi_{ec,V} = \min\left(1.0,\ \frac{1}{1 + \frac{2e_N^{'}}{3c_{a1,g1}}}\right) = \min\left(1,\ \frac{1}{1 + \frac{2 \times 0}{3 \times 180\ \text{mm}}}\right) = 1$$

Calculate edge effect factor

$c_{a2,g1} = 175\ \text{mm}$ - Anchor group distance to failure edge (+Vy shear)

CSA A23.3:19 Clause D.7.2.6

$\Psi_{ed,V}$ - Breakout edge effect factor

$$\Psi_{ed,V} = \min\left(1.0,\ 0.7 + 0.3\left(\frac{c_{a2,g1}}{1.5c_{a1,g1}}\right)\right) = \min\left(1,\ 0.7 + 0.3 \times \left(\frac{175\ \text{mm}}{1.5 \times 180\ \text{mm}}\right)\right) = 0.89444$$

Calculate thickness factor

CSA A23.3:19 Clause D.7.2.8

$\Psi_{h,V}$ - Breakout thickness factor

$$\Psi_{h,V} = \max\left(\sqrt{\frac{1.5c_{a1,g1}}{t_{conc}}},\ 1.0\right) = \max\left(\sqrt{\frac{1.5 \times 180\ \text{mm}}{380\ \text{mm}}},\ 1\right) = 1$$

Calculate concrete breakout capacity at the perpendicular edge

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CSA A23.3:19 Clause D.7.2.7

$\Psi_{c,V} = 1$ - Breakout cracking factor (shear)

CSA A23.3:19 Clause D.7.2.1

$V_{cbg\perp}$ - Factored concrete breakout strength in shear of an anchor group (perpendicular edge)

$$V_{cbg\perp} = \left(\frac{A_{Vc}}{A_{Vco}}\right) \Psi_{ec,V} \Psi_{ed,V} \Psi_{c,V} \Psi_{h,V} V_{br}$$

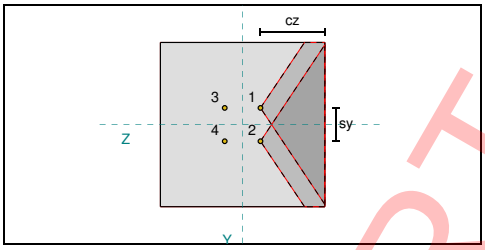
$$V_{cbg\perp} = \left(\frac{121500\ \text{mm}^2}{145800\ \text{mm}^2}\right) \times 1 \times 0.89444 \times 1 \times 1 \times 22.364\ \text{kN} = 16.669\ \text{kN}$$

For breakout capacity on failure edge parallel to load:

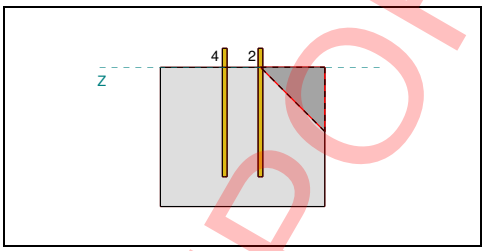
Determine cases:

Symbol	Description	Value
$s_{z,outer}$	Spacing of outer anchor rods along Z-axis	100.0 mm
$c_{a1,g1}$	Anchor group distance to failure edge (+Vz shear)	175.0 mm
	Are welded plate washers used?	No
	Applicable Cases	Case 3

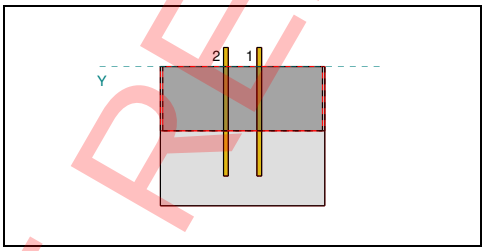
Calculations for Case 3



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate total shear load on anchor group.

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

Assume Vy load is acting perpendicular to the anchors along the failure edge.

$V_{fa\|,case3}$ - Required concrete breakout shear strength of anchor group with failure edge parallel to load

$$V_{fa\|,case3} = V_y = 5\ \text{kN}$$

Determine if the support is a narrow concrete member

CSA A23.3:19 Clause D.7.2.4

The support is not a narrow member.

Symbol	Description	Value
$c_{left,g1}$	Anchor group BO Vz 1 concrete edge distance (left)	275.0 mm
$c_{right,g1}$	Anchor group BO Vz 1 concrete edge distance (right)	175.0 mm
$c_{top,g1}$	Anchor group BO Vz 1 concrete edge distance (top)	180.0 mm
$c_{bottom,g1}$	Anchor group BO Vz 1 concrete edge distance (bottom)	180.0 mm
t_{conc}	Concrete thickness	380.0 mm
s_y	Spacing of anchor rods along Y-axis	90.0 mm
$c_{a1,g1}$	Anchor group distance to failure edge (+Vz shear)	175.0 mm
	Narrow Member	FALSE

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

Calculate maximum projected area for a single anchor

CSA A23.3:19 Clause D.7.2.4

$c_{a1,g1} = 175\ \text{mm}$ - Anchor group distance to failure edge (+Vz shear)

SAMPLE REPORT ONLY

CSA A23.3:19 Equation D.34

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

$$A_{Vco} = 4.5(c_{a1,g1})^2 = 4.5 \times (175\ \text{mm})^2 = 137810\ \text{mm}^2$$

Calculate width of actual projected area on failure surface

$s_{sum,y,g1} = 90\ \text{mm}$ - Anchor group BO Vz 1 sum of spacing along Y-axis

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

CSA A23.3:19 Clause D.7.2.1

B_{Vc} - Actual width of failure surface for an anchor group

$$B_{Vc} = \min(\text{c}_{\text{bottom,g1}},\ 1.5\text{c}_{\text{a1,g1}}) + (\min(\text{s}_{\text{sum,y,g1}},\ 3\text{c}_{\text{a1,g1}}(\text{n}_{\text{y,g1}} - 1))) + \min(\text{c}_{\text{top,g1}},\ 1.5\text{c}_{\text{a1,g1}})$$

$$B_{Vc} = \min(180\ \text{mm},\ 1.5 \times 175\ \text{mm}) + (\min(90\ \text{mm},\ 3 \times 175\ \text{mm} \times (2-1))) + \min(180\ \text{mm},\ 1.5 \times 175\ \text{mm})$$

$$B_{Vc} = 450\ \text{mm}$$

Calculate height of actual projected area on failure surface

CSA A23.3:19 Clause D.7.2.1

H_{Vc} - Actual height of projected area

$$H_{Vc} = \min(1.5\text{c}_{\text{a1,g1}},\ \text{t}_{\text{conc}}) = \min(1.5 \times 175\ \text{mm},\ 380\ \text{mm}) = 262.5\ \text{mm}$$

Calculate actual projected area

CSA A23.3:19 Clause D.7.2.1

A_{Vc} - Actual projected area

$$A_{Vc} = B_{Vc}H_{Vc} = 450\ \text{mm} \times 262.5\ \text{mm} = 118130\ \text{mm}^2$$

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 load bearing length of the anchor

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

CSA A23.3:19 Clause D.7.2.2(a)

l_e - Load bearing length (equal to embedment height)

$$l_e = h_{ef} = 300\ \text{mm}$$

Calculate basic single anchor breakout strength

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

$d_a = 12.7\ \text{mm}$ - Anchor rod diameter

$\phi = 0.65$ - Concrete resistance factor

$R = 1$ - Resistance modification factor of concrete failure (Shear Loads)

CSA A23.3:19 Equation D.35

V_{br1} - Basic single anchor breakout strength condition 1

$$V_{br1} = 0.58\left(\frac{\min(\text{l}_\text{e},\ 8\text{d}_\text{a})}{d_a}\right)^{0.2}\sqrt{\frac{d_a}{mm}}\phi\lambda_a\sqrt{\frac{f_c'}{MPa}}\left(\frac{c_{a1,g1}}{mm}\right)^{1.5}R(N)$$

$$V_{br1} = 0.58 \times \left(\frac{\min(300\ \text{mm},\ 8 \times 12.7\ \text{mm})}{12.7\ \text{mm}}\right)^{0.2} \times \sqrt{\frac{12.7\ \text{mm}}{1\ \text{mm}}} \times 0.65 \times 1 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{175\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN}$$

$$V_{br1} = 21.438\ \text{kN}$$

CSA A23.3:19 Equation D.36

V_{br2} - Basic single anchor breakout strength condition 2

$$V_{br2} = 3.75\lambda_a\phi\sqrt{\frac{f_c'}{MPa}}\left(\frac{c_{a1,g1}}{mm}\right)^{1.5}R(N)$$

$$V_{br2} = 3.75 \times 1 \times 0.65 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{175\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN} = 25.661\ \text{kN}$$

CSA A23.3:19 Clause D.7.2.2

V_{br} - Factored concrete breakout resistance in shear of a single anchor

$$V_{br} = \min(\text{V}_{\text{br1}},\ \text{V}_{\text{br2}}) = \min(21.438\ \text{kN},\ 25.661\ \text{kN}) = 21.438\ \text{kN}$$

Calculate eccentricity factor

$e_N' = 0$ - Eccentricity of the resultant tensile force (assumed 0 for shear)

CSA A23.3:19 Clause D.7.2.5

$\Psi_{ec,V}$ - Breakout eccentricity factor

$$\Psi_{ec,V} = \min\left(1.0,\ \frac{1}{1 + \frac{2e_N'}{3\text{c}_{\text{a1,g1}}}}\right) = \min\left(1,\ \frac{1}{1 + \frac{2 \times 0}{3 \times 175\ \text{mm}}}\right) = 1$$

Calculate thickness factor

CSA A23.3:19 Clause D.7.2.8

$\Psi_{h,V}$ - Breakout thickness factor

$$\Psi_{h,V} = \max\left(\sqrt{\frac{1.5\text{c}_{\text{a1,g1}}}{\text{t}_{\text{conc}}}},\ 1.0\right) = \max\left(\sqrt{\frac{1.5 \times 175\ \text{mm}}{380\ \text{mm}}},\ 1\right) = 1$$

Calculate concrete breakout capacity at the parallel edge

CSA A23.3:19 Clause D.7.2.7

$\Psi_{c,V} = 1$ - Breakout cracking factor (shear)

SAMPLE REPORT ONLY

CSA A23.3:19 Clause D.7.2.1(c)

$\Psi_{ed,V} = 1$ - Breakout edge effect factor for parallel failure edge

CSA A23.3:19 Clause D.7.2.1

$V_{cbgr\|}$ - Factored concrete breakout strength in shear of an anchor group (parallel edge)

$$V_{cbgr\|} = 2\left(\frac{A_{Vc}}{A_{Vco}}\right)\Psi_{ec,V}\Psi_{ed,V}\Psi_{c,V}\Psi_{h,V}V_{br}$$

$$V_{cbgr\|} = 2 \times \left(\frac{118130\ \text{mm}^2}{137810\ \text{mm}^2}\right) \times 1 \times 1 \times 1 \times 1 \times 21.438\ \text{kN} = 36.752\ \text{kN}$$

Result:

PASS = 0.30

DCR - Demand over capacity ratio, comparing two conditions:

$$DCR = \max\left(\frac{\text{V}_{\text{fa}\perp,\text{case3}}}{\text{V}_{\text{cbg}\perp}}, \frac{\text{V}_{\text{fa}\|,\text{case3}}}{\text{V}_{\text{cbgr}\|}}\right)$$

$$DCR = \max\left(\frac{5\ \text{kN}}{16.669\ \text{kN}}, \frac{5\ \text{kN}}{36.752\ \text{kN}}\right) = 0.29995$$

Go back to summary results table.

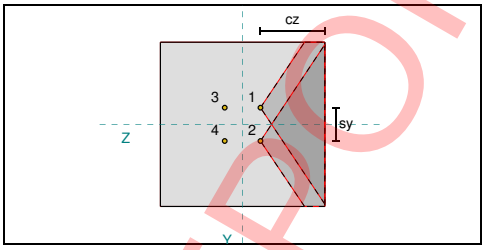
Check No. 3: Concrete Breakout Capacity (Vz Shear)

For breakout capacity on failure edge perpendicular to load:

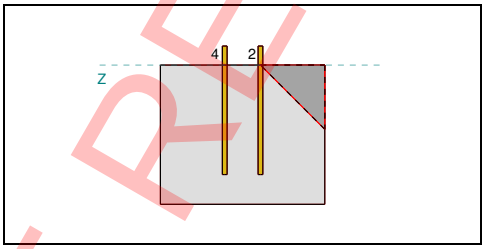
Determine cases:

Symbol	Description	Value
$s_{z,outer}$	Spacing of outer anchor rods along Z-axis	100.0 mm
$c_{a1,g1}$	Anchor group distance to failure edge (+Vz shear)	175.0 mm
	Are welded plate washers used?	No
	Applicable Cases	Case 3

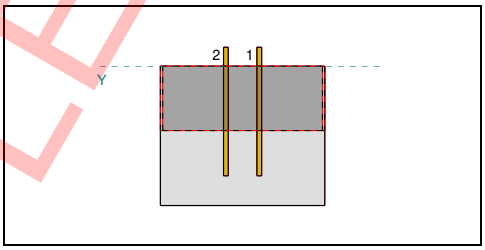
Calculations for Case 3



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate total shear load on anchor group.

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

$V_{fa\perp,case3}$ - Required concrete breakout shear strength of anchor group with failure edge perpendicular to load

$$V_{fa\perp,case3} = V_z = 5\ \text{kN}$$

Determine if the support is a narrow concrete member

CSA A23.3:19 Clause D.7.2.4

The support is not a narrow member.

SAMPLE REPORT ONLY

Symbol	Description	Value
$c_{left,g1}$	Anchor group BO Vz 1 concrete edge distance (left)	275.0 mm
$c_{right,g1}$	Anchor group BO Vz 1 concrete edge distance (right)	175.0 mm
$c_{top,g1}$	Anchor group BO Vz 1 concrete edge distance (top)	180.0 mm
$c_{bottom,g1}$	Anchor group BO Vz 1 concrete edge distance (bottom)	180.0 mm
t_{conc}	Concrete thickness	380.0 mm
s_y	Spacing of anchor rods along Y-axis	90.0 mm
$c_{a1,g1}$	Anchor group distance to failure edge (+Vz shear)	175.0 mm
	Narrow Member	FALSE

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

Calculate maximum projected area for a single anchor

CSA A23.3:19 Clause D.7.2.4

$c_{a1,g1} = 175\ \text{mm}$ - Anchor group distance to failure edge (+Vz shear)

CSA A23.3:19 Equation D.34

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

$$A_{Vco} = 4.5(c_{a1,g1})^2 = 4.5 \times (175\ \text{mm})^2 = 137810\ \text{mm}^2$$

Calculate width of actual projected area on failure surface

$s_{sum,y,g1} = 90\ \text{mm}$ - Anchor group BO Vz 1 sum of spacing along Y-axis

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

CSA A23.3:19 Clause D.7.2.1

B_{Vc} - Actual width of failure surface for an anchor group

$$B_{Vc} = \min(\text{c}_{\text{bottom,g1}},\ 1.5\text{c}_{\text{a1,g1}}) + (\min(\text{s}_{\text{sum,y,g1}},\ 3\text{c}_{\text{a1,g1}}(\text{n}_{\text{y,g1}} - 1))) + \min(\text{c}_{\text{top,g1}},\ 1.5\text{c}_{\text{a1,g1}})$$

$$B_{Vc} = \min(180\ \text{mm},\ 1.5 \times 175\ \text{mm}) + (\min(90\ \text{mm},\ 3 \times 175\ \text{mm} \times (2-1))) + \min(180\ \text{mm},\ 1.5 \times 175\ \text{mm})$$

$$B_{Vc} = 450\ \text{mm}$$

Calculate height of actual projected area on failure surface

CSA A23.3:19 Clause D.7.2.1

H_{Vc} - Actual height of projected area

$$H_{Vc} = \min(1.5\text{c}_{\text{a1,g1}},\ \text{t}_{\text{conc}}) = \min(1.5 \times 175\ \text{mm},\ 380\ \text{mm}) = 262.5\ \text{mm}$$

Calculate actual projected area

CSA A23.3:19 Clause D.7.2.1

A_{Vc} - Actual projected area

$$A_{Vc} = B_{Vc}H_{Vc} = 450\ \text{mm} \times 262.5\ \text{mm} = 118130\ \text{mm}^2$$

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 load bearing length of the anchor

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

CSA A23.3:19 Clause D.7.2.2(a)

l_e - Load bearing length (equal to embedment height)

$$l_e = h_{ef} = 300\ \text{mm}$$

Calculate basic single anchor breakout strength

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

$d_a = 12.7\ \text{mm}$ - Anchor rod diameter

$\phi = 0.65$ - Concrete resistance factor

$R = 1$ - Resistance modification factor of concrete failure (Shear Loads)

CSA A23.3:19 Equation D.35

V_{br1} - Basic single anchor breakout strength condition 1

$$V_{br1} = 0.58\left(\frac{\min(\text{l}_\text{e},\ 8\text{d}_\text{a})}{d_a}\right)^{0.2}\sqrt{\frac{d_a}{mm}}\phi\lambda_a\sqrt{\frac{f_c^{'}}{MPa}}\left(\frac{c_{a1,g1}}{mm}\right)^{1.5}R(N)$$

$$V_{br1} = 0.58 \times \left(\frac{\min(300\ \text{mm},\ 8 \times 12.7\ \text{mm})}{12.7\ \text{mm}}\right)^{0.2} \times \sqrt{\frac{12.7\ \text{mm}}{1\ \text{mm}}} \times 0.65 \times 1 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{175\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN}$$

$$V_{br1} = 21.438\ \text{kN}$$

CSA A23.3:19 Equation D.36

V_{br2} - Basic single anchor breakout strength condition 2

$$V_{br2} = 3.75\lambda_a\phi\sqrt{\frac{f_c^{'}}{MPa}}\left(\frac{c_{a1,g1}}{mm}\right)^{1.5}R(N)$$

$$V_{br2} = 3.75 \times 1 \times 0.65 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{175\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN} = 25.661\ \text{kN}$$

CSA A23.3:19 Clause D.7.2.2

V_{br} - Factored concrete breakout resistance in shear of a single anchor

$$V_{br} = \min(\text{V}_{\text{br1}},\ \text{V}_{\text{br2}}) = \min(21.438\ \text{kN},\ 25.661\ \text{kN}) = 21.438\ \text{kN}$$

SAMPLE REPORT ONLY

Calculate eccentricity factor

$e'_N = 0$ - Eccentricity of the resultant tensile force (assumed 0 for shear)

CSA A23.3:19 Clause D.7.2.5

$\Psi_{ec,V}$ - Breakout eccentricity factor

$$\Psi_{ec,V} = \min\left(1.0,\ \frac{1}{1+\frac{2e'_N}{3c_{a1,g1}}}\right) = \min\left(1,\ \frac{1}{1+\frac{2\times 0}{3\times 175\ \text{mm}}}\right) = 1$$

Calculate edge effect factor

$c_{a2,g1} = 180\ \text{mm}$ - Anchor group distance to failure edge (+Vz shear)

CSA A23.3:19 Clause D.7.2.6

$\Psi_{ed,V}$ - Breakout edge effect factor

$$\Psi_{ed,V} = \min\left(1.0,\ 0.7+0.3\left(\frac{c_{a2,g1}}{1.5c_{a1,g1}}\right)\right) = \min\left(1,\ 0.7+0.3\times\left(\frac{180\ \text{mm}}{1.5\times 175\ \text{mm}}\right)\right) = 0.90571$$

Calculate thickness factor

CSA A23.3:19 Clause D.7.2.8

$\Psi_{h,V}$ - Breakout thickness factor

$$\Psi_{h,V} = \max\left(\sqrt{\frac{1.5c_{a1,g1}}{t_{conc}}},\ 1.0\right) = \max\left(\sqrt{\frac{1.5\times 175\ \text{mm}}{380\ \text{mm}}},\ 1\right) = 1$$

Calculate concrete breakout capacity at the perpendicular edge

CSA A23.3:19 Clause D.7.2.7

$\Psi_{c,V} = 1$ - Breakout cracking factor (shear)

CSA A23.3:19 Clause D.7.2.1

$V_{cbg\perp}$ - Factored concrete breakout strength in shear of an anchor group (perpendicular edge)

$$V_{cbg\perp} = \left(\frac{A_{Vc}}{A_{Vco}}\right)\Psi_{ec,V}\Psi_{ed,V}\Psi_{c,V}\Psi_{h,V}V_{br}$$

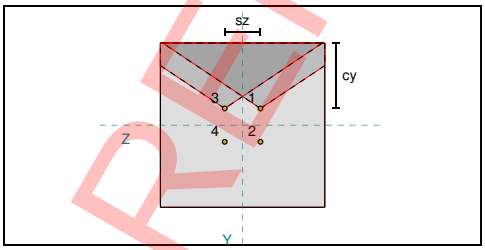
$$V_{cbg\perp} = \left(\frac{118130\ \text{mm}^2}{137810\ \text{mm}^2}\right)\times 1\times 0.90571\times 1\times 1\times 21.438\ \text{kN} = 16.643\ \text{kN}$$

For breakout capacity on failure edge parallel to load:

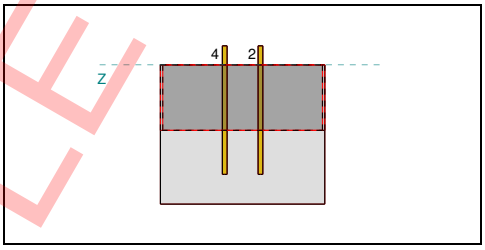
Determine cases:

Symbol	Description	Value
$s_{y,outer}$	Spacing of outer anchor rods along Y-axis	90.0 mm
$c_{a1,g1}$	Anchor group distance to failure edge (+Vy shear)	180.0 mm
	Are welded plate washers used?	No
	Applicable Cases	Case 3

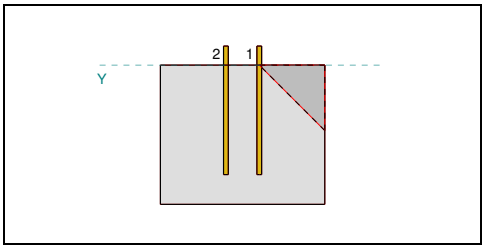
Calculations for Case 3



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate total shear load on anchor group.

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

Assume Vz load is acting perpendicular to the anchors along the failure edge.

$V_{fall,case3}$ - Required concrete breakout shear strength of anchor group with failure edge parallel to load

SAMPLE REPORT ONLY

$$V_{fa\|,case3} = V_z = 5\ \text{kN}$$

CSA A23.3:19 Clause D.7.2.4

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)	175.0 mm
$c_{right,g1}$	Anchor group BO Vy 1 concrete edge distance (right)	175.0 mm
$c_{top,g1}$	Anchor group BO Vy 1 concrete edge distance (top)	180.0 mm
$c_{bottom,g1}$	Anchor group BO Vy 1 concrete edge distance (bottom)	270.0 mm
t_{conc}	Concrete thickness	380.0 mm
s_z	Spacing of anchor rods along Z-axis	100.0 mm
$c_{a1,g1}$	Anchor group distance to failure edge (+Vy shear)	180.0 mm
	Narrow Member	FALSE

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

Calculate maximum projected area for a single anchor

CSA A23.3:19 Clause D.7.2.4

$c_{a1,g1} = 180\ \text{mm}$ - Anchor group distance to failure edge (+Vy shear)

CSA A23.3:19 Equation D.34

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

$$A_{Vco} = 4.5(c_{a1,g1})^2 = 4.5 \times (180\ \text{mm})^2 = 145800\ \text{mm}^2$$

Calculate width of actual projected area on failure surface

$s_{sum,z,g1} = 100\ \text{mm}$ - Anchor group BO Vy 1 sum of spacing along Z-axis

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

CSA A23.3:19 Clause D.7.2.1

B_{Vc} - Actual width of failure surface for an anchor group

$$B_{Vc} = \min(\text{c}_{\text{left,g1}},\ 1.5\text{c}_{\text{a1,g1}}) + (\min(\text{s}_{\text{sum,z,g1}},\ 3\text{c}_{\text{a1,g1}}(\text{n}_{\text{z,g1}} - 1))) + \min(\text{c}_{\text{right,g1}},\ 1.5\text{c}_{\text{a1,g1}})$$

$$B_{Vc} = \min(175\ \text{mm},\ 1.5 \times 180\ \text{mm}) + (\min(100\ \text{mm},\ 3 \times 180\ \text{mm} \times (2 - 1))) + \min(175\ \text{mm},\ 1.5 \times 180\ \text{mm})$$

$$B_{Vc} = 450\ \text{mm}$$

Calculate height of actual projected area on failure surface

CSA A23.3:19 Clause D.7.2.1

H_{Vc} - Actual height of projected area

$$H_{Vc} = \min(1.5\text{c}_{\text{a1,g1}},\ \text{t}_{\text{conc}}) = \min(1.5 \times 180\ \text{mm},\ 380\ \text{mm}) = 270\ \text{mm}$$

Calculate actual projected area

CSA A23.3:19 Clause D.7.2.1

A_{Vc} - Actual projected area

$$A_{Vc} = B_{Vc}H_{Vc} = 450\ \text{mm} \times 270\ \text{mm} = 121500\ \text{mm}^2$$

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 load bearing length of the anchor

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

CSA A23.3:19 Clause D.7.2.2(a)

l_e - Load bearing length (equal to embedment height)

$$l_e = h_{ef} = 300\ \text{mm}$$

Calculate basic single anchor breakout strength

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

$d_a = 12.7\ \text{mm}$ - Anchor rod diameter

$\phi = 0.65$ - Concrete resistance factor

$R = 1$ - Resistance modification factor of concrete failure (Shear Loads)

CSA A23.3:19 Equation D.35

V_{br1} - Basic single anchor breakout strength condition 1

$$V_{br1} = 0.58\left(\frac{\min(\text{l}_\text{e},\ 8\text{d}_\text{a})}{d_a}\right)^{0.2}\sqrt{\frac{d_a}{mm}}\phi\lambda_a\sqrt{\frac{f_c^{'}}{MPa}}\left(\frac{c_{a1,g1}}{mm}\right)^{1.5}R(N)$$

$$V_{br1} = 0.58 \times \left(\frac{\min(300\ \text{mm},\ 8 \times 12.7\ \text{mm})}{12.7\ \text{mm}}\right)^{0.2} \times \sqrt{\frac{12.7\ \text{mm}}{1\ \text{mm}}} \times 0.65 \times 1 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{180\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN}$$

$$V_{br1} = 22.364\ \text{kN}$$

CSA A23.3:19 Equation D.36

V_{br2} - Basic single anchor breakout strength condition 2

$$V_{br2} = 3.75\lambda_a\phi\sqrt{\frac{f_c^{'}}{MPa}}\left(\frac{c_{a1,g1}}{mm}\right)^{1.5}R(N)$$

SAMPLE REPORT ONLY

$$V_{br2} = 3.75 \times 1 \times 0.65 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{180\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN} = 26.769\ \text{kN}$$

CSA A23.3:19 Clause D.7.2.2

V_{br} - Factored concrete breakout resistance in shear of a single anchor

$$V_{br} = \min\left(\text{V}_{\text{br1}},\ \text{V}_{\text{br2}}\right) = \min\left(22.364\ \text{kN},\ 26.769\ \text{kN}\right) = 22.364\ \text{kN}$$

Calculate eccentricity factor

$e'_N = 0$ - Eccentricity of the resultant tensile force (assumed 0 for shear)

CSA A23.3:19 Clause D.7.2.5

$\Psi_{ec,V}$ - Breakout eccentricity factor

$$\Psi_{ec,V} = \min\left(1.0,\ \frac{1}{1 + \frac{2e'_N}{3c_{a1,g1}}}\right) = \min\left(1,\ \frac{1}{1 + \frac{2\times 0}{3\times 180\ \text{mm}}}\right) = 1$$

Calculate thickness factor

CSA A23.3:19 Clause D.7.2.8

$\Psi_{h,V}$ - Breakout thickness factor

$$\Psi_{h,V} = \max\left(\sqrt{\frac{1.5c_{a1,g1}}{t_{conc}}},\ 1.0\right) = \max\left(\sqrt{\frac{1.5 \times 180\ \text{mm}}{380\ \text{mm}}},\ 1\right) = 1$$

Calculate concrete breakout capacity at the parallel edge

CSA A23.3:19 Clause D.7.2.7

$\Psi_{c,V} = 1$ - Breakout cracking factor (shear)

CSA A23.3:19 Clause D.7.2.1(c)

$\Psi_{ed,V} = 1$ - Breakout edge effect factor for parallel failure edge

CSA A23.3:19 Clause D.7.2.1

$V_{cbgr\|}$ - Factored concrete breakout strength in shear of an anchor group (parallel edge)

$$V_{cbgr\|} = 2\left(\frac{A_{Vc}}{A_{Vco}}\right)\Psi_{ec,V}\Psi_{ed,V}\Psi_{c,V}\Psi_{h,V}V_{br}$$

$$V_{cbgr\|} = 2 \times \left(\frac{121500\ \text{mm}^2}{145800\ \text{mm}^2}\right) \times 1 \times 1 \times 1 \times 1 \times 22.364\ \text{kN} = 37.273\ \text{kN}$$

Result:

PASS = 0.30

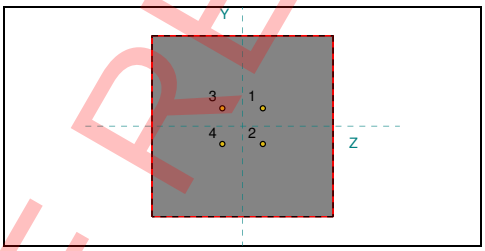
DCR - Demand over capacity ratio, comparing two conditions:

$$DCR = \max\left(\frac{\text{V}_{\text{fa}\perp,\text{case3}}}{\text{V}_{\text{cbg}\perp}},\ \frac{\text{V}_{\text{fa}\|,\text{case3}}}{\text{V}_{\text{cbgr}\|}}\right)$$

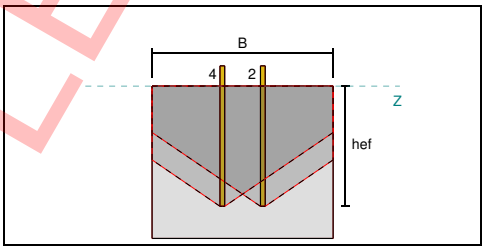
$$DCR = \max\left(\frac{5\ \text{kN}}{16.643\ \text{kN}},\ \frac{5\ \text{kN}}{37.273\ \text{kN}}\right) = 0.30042$$

Go back to summary results table.

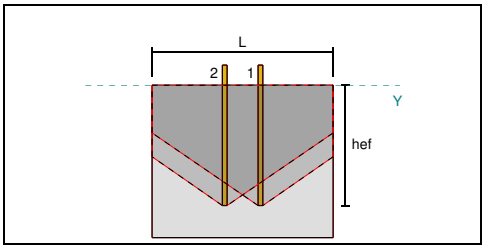
Check No. 4: Concrete Pryout Capacity



PLAN VIEW



FRONT VIEW



SIDE VIEW

Calculate total shear load on anchor group

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

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

V_{fa} - Resultant shear load

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

$n_a = 4$ - Total number of anchor rods

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

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

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

Determine if the support is a narrow concrete member

CSA A23.3:19 Clause D.6.2.3

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)	175.0 mm
$c_{right,g1}$	Anchor group PO 1 concrete edge distance (right)	175.0 mm
$c_{top,g1}$	Anchor group PO 1 concrete edge distance (top)	180.0 mm
$c_{bottom,g1}$	Anchor group PO 1 concrete edge distance (bottom)	180.0 mm
h_{ef}	Anchor rod effective embedment length	300.0 mm
$s_{sum,y,g1}$	Anchor group PO 1 sum of spacing along Y-axis	90.0 mm
$s_{sum,z,g1}$	Anchor group PO 1 sum of spacing along Z-axis	100.0 mm
$n_{y,g1}$	Number of anchors along Y-axis for anchor group PO 1	2.0
$n_{z,g1}$	Number of anchors along Z-axis for anchor group PO 1	2.0
	Narrow Member	TRUE
$h'_{ef,g1}$	Anchor group PO 1 modified effective embedment length	120.0 mm

Calculation for critical anchor group: Anchor Group PO 1.

Calculate maximum projected area for a single anchor

CSA A23.3:19 Eq. D.5

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

$$A_{Nco} = 9\left(h'_{ef,g1}\right)^2 = 9 \times (120\ \text{mm})^2 = 129600\ \text{mm}^2$$

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

$r_{embed_plate} = 16.35\ \text{mm}$ - Half side length of effective perimeter of embed plate

Equivalent to half anchor diameter plus thickness of embed plate

$s_{sum,z,g1} = 100\ \text{mm}$ - 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

CSA A23.3:19 Clause D.6.2.1

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

$$L_{Nc} = \min\left(c_{left,g1},\ 1.5h'_{ef,g1}\right) + \left(\min\left(s_{sum,z,g1},\ 3h'_{ef,g1}(n_{z,g1} - 1)\right)\right) + \min\left(c_{right,g1},\ 1.5h'_{ef,g1}\right)$$

$$L_{Nc} = \min(175\ \text{mm},\ 1.5 \times 120\ \text{mm}) + (\min(100\ \text{mm},\ 3 \times 120\ \text{mm} \times (2-1))) + \min(175\ \text{mm},\ 1.5 \times 120\ \text{mm})$$

$$L_{Nc} = 450\ \text{mm}$$

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

$s_{sum,y,g1} = 90\ \text{mm}$ - 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

CSA A23.3:19 Clause D.6.2.1

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

$$B_{Nc} = \min\left(c_{top,g1},\ 1.5h'_{ef,g1}\right) + \left(\min\left(s_{sum,y,g1},\ 3h'_{ef,g1}(n_{y,g1} - 1)\right)\right) + \min\left(c_{bottom,g1},\ 1.5h'_{ef,g1}\right)$$

$$B_{Nc} = \min(180\ \text{mm},\ 1.5 \times 120\ \text{mm}) + (\min(90\ \text{mm},\ 3 \times 120\ \text{mm} \times (2-1))) + \min(180\ \text{mm},\ 1.5 \times 120\ \text{mm})$$

$$B_{Nc} = 450\ \text{mm}$$

Calculate actual projected area of the anchor group

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

CSA A23.3:19 Clause D.6.2.1

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

$$A_{Nc} = \min\left(n_{a,g1}A_{Nco},\ L_{Nc}B_{Nc}\right) = \min\left(4 \times 129600\ \text{mm}^2,\ 450\ \text{mm} \times 450\ \text{mm}\right) = 202500\ \text{mm}^2$$

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

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

$\phi = 0.65$ - Concrete resistance factor

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$R = 1$ - Resistance modification factor of cast-in anchor rod in concrete failure (Tension Loads)

CSA A23.3:19 Clause D.6.2.1

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

CSA A23.3:19 Eq. D.6

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

$$N_{br} = k_c \phi \lambda_a \sqrt{\frac{f_c'}{MPa}} \left(\frac{h'_{ef,g1}}{mm}\right)^{1.5} R(N)$$

$$N_{br} = 10 \times 0.65 \times 1 \times \sqrt{\frac{20.68\ \text{MPa}}{1\ \text{MPa}}} \times \left(\frac{120\ \text{mm}}{1\ \text{mm}}\right)^{1.5} \times 1 \times 0.001\ \text{kN} = 38.856\ \text{kN}$$

Calculate minimum edge distance of anchor

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

$$c_{a,min} = \min\left(c_{\text{left,g1}},\ c_{\text{right,g1}},\ c_{\text{top,g1}},\ c_{\text{bottom,g1}}\right) = \min\left(175\ \text{mm},\ 175\ \text{mm},\ 180\ \text{mm},\ 180\ \text{mm}\right) = 175\ \text{mm}$$

Calculate eccentricity factor

$e'_N = 0$ - Eccentricity of the resultant tensile force (assumed 0 for shear)

CSA A23.3:19 Eq. D.8

$\Psi_{ec,N}$ - Modification factor for anchor groups loaded eccentrically in tension

$$\Psi_{ec,N} = \min\left(1.0,\ \frac{1}{1 + \frac{2e'_N}{3h'_{ef,g1}}}\right) = \min\left(1,\ \frac{1}{1 + \frac{2 \times 0}{3 \times 120\ \text{mm}}}\right) = 1$$

Calculate edge effect factor

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

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

$$\Psi_{ed,N} = \min\left(1.0,\ 0.7 + 0.3\left(\frac{c_{a,min}}{1.5h'_{ef,g1}}\right)\right) = \min\left(1,\ 0.7 + 0.3 \times \left(\frac{175\ \text{mm}}{1.5 \times 120\ \text{mm}}\right)\right) = 0.99167$$

Calculate factored concrete breakout capacity

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.4

N_{cbr} - Factored concrete breakout resistance

$$N_{cbr} = \left(\frac{A_{Nc}}{A_{Nco}}\right) \Psi_{ec,N} \Psi_{ed,N} \Psi_{c,N} \Psi_{cp,N} N_{br}$$

$$N_{cbr} = \left(\frac{202500\ \text{mm}^2}{129600\ \text{mm}^2}\right) \times 1 \times 0.99167 \times 1 \times 1 \times 38.856\ \text{kN} = 60.207\ \text{kN}$$

Calculate factored concrete pryout capacity

CSA A23.3:19 Clause D.7.3

$k_{cp} = 2$ - Factor for pryout strength

CSA A23.3:19 Clause D.7.3

V_{cpgr} - Factored concrete pryout strength of an anchor group

$$V_{cpgr} = k_{cp} N_{cbr} = 2 \times 60.207\ \text{kN} = 120.41\ \text{kN}$$

Result:

DCR - Demand-to-Capacity Ratio

$$DCR = \frac{V_{fa}}{V_{cpgr}} = \frac{7.0711\ \text{kN}}{120.41\ \text{kN}} = 0.058723$$

PASS = 0.06

Go back to summary results table.

Check No. 5: Anchor Rod Shear Capacity

Calculate portion of Vy shear load on most critical anchor

Governing case from concrete breakout calculation for Vy shear: **Case 3 (perpendicular)**. Therefore, check the perpendicular anchors for a portion of Vy load

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

$n_a = 4$ - Total number of anchor rods

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

$V_{fa,y}$ - Required shear strength on anchor due to Vy load

$$V_{fa,y} = \frac{V_y}{n_{z,g1}} = \frac{5\ \text{kN}}{2} = 2.5\ \text{kN}$$

Calculate portion of Vz shear load on most critical anchor

Governing case from concrete breakout calculation for Vz shear: **Case 3 (perpendicular)**. Therefore, check the perpendicular anchors for a portion of Vz load

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

$n_a = 4$ - Total number of anchor rods

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

$V_{fa,z}$ - Required shear strength on anchor due to Vz load

$$V_{fa,z} = \frac{V_z}{n_{y,g1}} = \frac{5\ \text{kN}}{2} = 2.5\ \text{kN}$$

Calculate resultant load on most critical anchor

V_{fa} - Required shear strength on anchor

$$V_{fa} = \sqrt{\left((V_{fa,y})^2\right) + \left((V_{fa,z})^2\right)} = \sqrt{\left((2.5\ \text{kN})^2\right) + \left((2.5\ \text{kN})^2\right)} = 3.5355\ \text{kN}$$

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	Calculations according to CSA A23.3:19 provisions: **Calculate specified tensile strength of anchor** $F_{u_anc} = 400\ \mathrm{MPa}$ - Anchor rod tensile stress (ASTM F1554 G36) $F_{y_anc} = 248.2\ \mathrm{MPa}$ - Anchor rod yield stress (ASTM F1554 G36)	
CSA A23.3:19 Clause D.7.1.2(b)	f_{uta} - Specified tensile strength of anchor steel $$f_{uta} = \min\left(\mathrm{F_{u_anc}},\ 1.9\mathrm{F_{y_anc}},\ 860\right) = \min\left(400\ \mathrm{MPa},\ 1.9 \times 248.2\ \mathrm{MPa},\ 860.00\ \mathrm{MPa}\right) = 400\ \mathrm{MPa}$$	
CSA A23.3:19 Clause D.7.1.2 and CAC Concrete Design Handbook 3rd Ed. Table 12.3	**Calculate factored shear strength of the anchor rod per CSA A23.3:19 provisions** $A_{se,V} = 92\ \mathrm{mm}^2$ - Effective cross-sectional area of anchor rod in shear $\phi_s = 0.85$ - Anchor rod resistance factor $R = 0.75$ - Resistance modification factor of anchor rod steel failure (Shear Loads)	
CSA A23.3:19 Equation D.31 and Clause D.7.1.3	$V_{sar,a23}$ - Factored anchor rod steel shear strength per CSA A23.3 (reduced capacity) *Factored resistance is multiplied by a 0.80 factor to account for the built-up grout pads per CSA A23.3:19 Clause D.7.1.3* $$V_{sar,a23} = 0.8A_{se,V}\phi_s 0.6 f_{uta} R = 0.8 \times 92\ \mathrm{mm}^2 \times 0.85 \times 0.6 \times 400\ \mathrm{MPa} \times 0.75 = 11.258\ \mathrm{kN}$$	
	Calculations according to CSA S16:19 provisions: **Calculate factored shear strength of the anchor rod per CSA S16:19 provisions**	
CSA S16:19 pg. 31	$A_{ar} = 126.68\ \mathrm{mm}^2$ - Nominal cross-sectional area of anchor rod	
CSA S16:19 Clause 25.3.2.1	$\phi_{ar} = 0.67$ - Anchor rod resistance factor $m = 1$ - Number of shear planes	
CSA S16:19 Clause 25.3.3.3	$V_{r,s16}$ - Factored anchor rod shear strength per CSA S16 $$V_{r,s16} = 0.7\phi_{ar} 0.6 m A_{ar} F_{u_anc} = 0.7 \times 0.67 \times 0.6 \times 1 \times 126.68\ \mathrm{mm}^2 \times 400\ \mathrm{MPa} = 14.255\ \mathrm{kN}$$	
	Result: DCR - Demand over capacity ratio, comparing two conditions: $$DCR = \max\left(\frac{\mathrm{V_{fa}}}{\mathrm{V_{sar,a23}}}, \frac{\mathrm{V_{fa}}}{\mathrm{V_{r,s16}}}\right) = \max\left(\frac{3.5355\ \mathrm{kN}}{11.258\ \mathrm{kN}}, \frac{3.5355\ \mathrm{kN}}{14.255\ \mathrm{kN}}\right) = 0.31405$$	**PASS = 0.31** Go back to summary results table.

SAMPLE REPORT ONLY