Project data

Project name	
Project number	
Author	
Description	
Date	2022-06-24
Design code	CSA

Material

Steel	350W, 300W
Concrete	4000 psi

Project item CON1

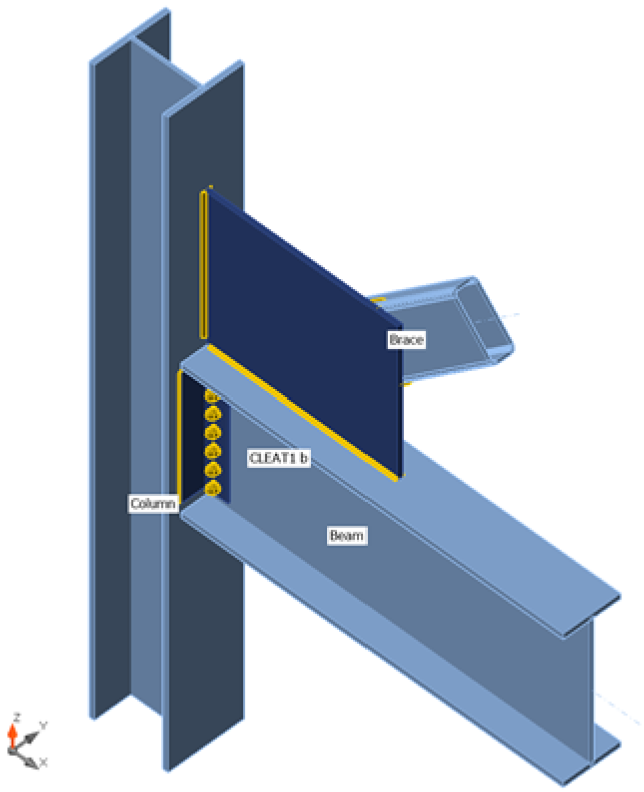
Design

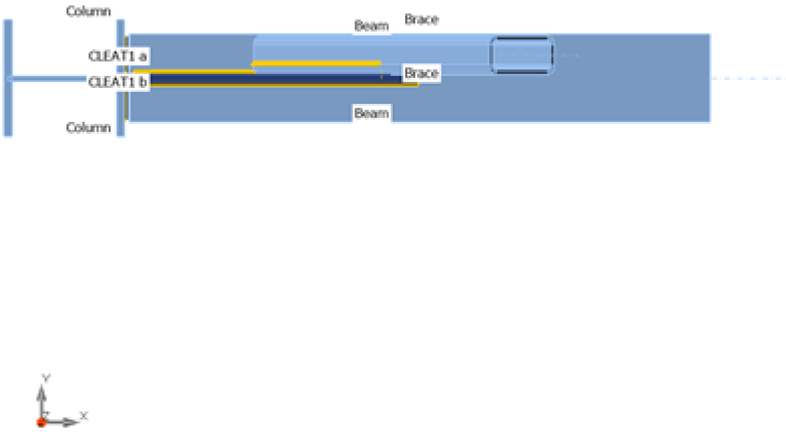
Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

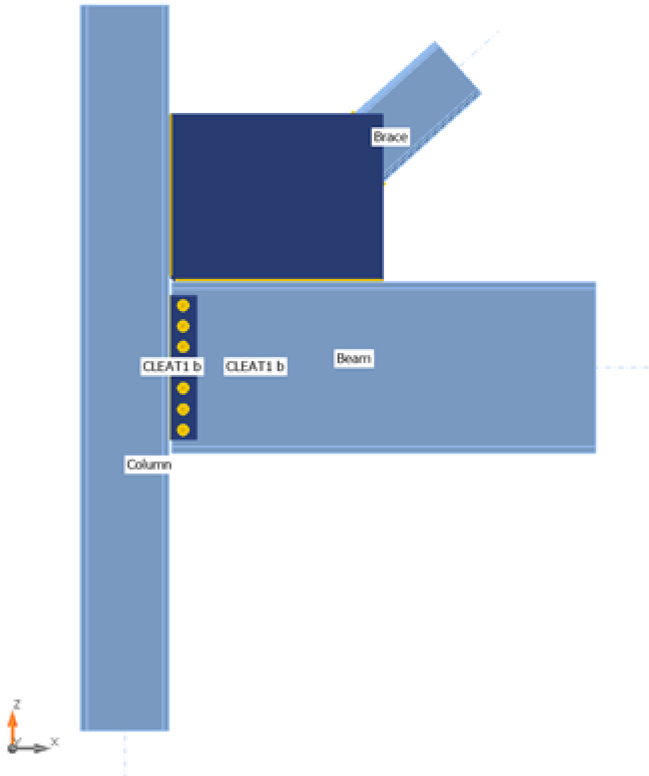
Members

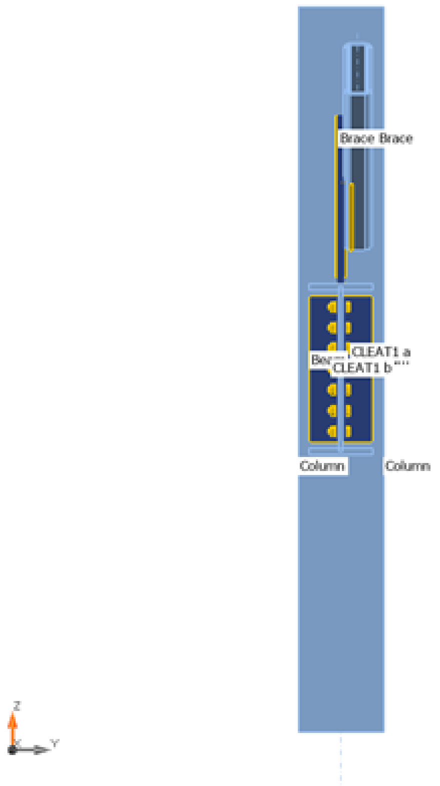
Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]	Forces in
Column	1 - W12X87	0.0	-90.0	0.0	0	0	0	Node
Beam	2 - W24X94	0.0	0.0	0.0	0	0	0	Node
Brace	3 - HSS10X4X.500	0.0	-42.0	0.0	787	61	0	Node




Column
Beam
Brace
CLEAT1 a
CLEAT1 b
Brace
Beam
Column

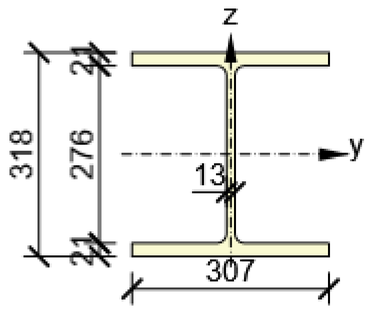
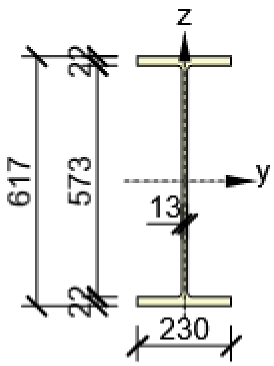
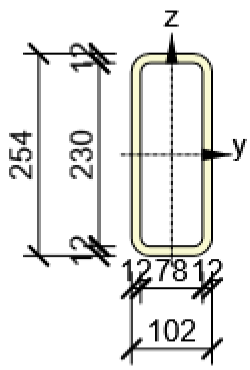
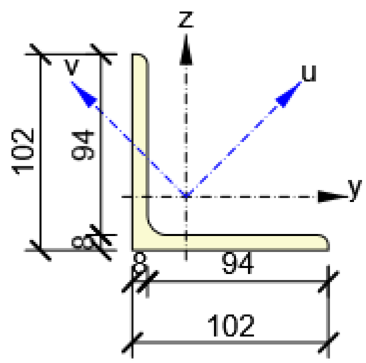

Brace
CLEAT1 b
CLEAT1 b
Beam
Column



Cross-sections

Name	Material
1 - W12X87	350W
2 - W24X94	350W
3 - HSS10X4X.500	350W
5 - L102x102x7.9	350W

Cross-sections

Name	Material	Drawing
1 - W12X87	350W	
2 - W24X94	350W	
3 - HSS10X4X.500	350W	
5 - L102x102x7.9	350W	

Bolts

Name	Bolt assembly	Diameter [mm]	fu [MPa]	Gross area [mm^2]
3/4 A325	3/4 A325	19	825.0	285

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
Compression - Brace	Column	5009.2	0.0	0.0	0.0	0.0	0.0
	Column	-4162.1	0.0	0.0	0.0	0.0	0.0
	Beam	340.3	0.0	-540.7	0.0	0.0	0.0
	Brace	-458.0	0.0	0.0	0.0	0.0	-27.7

Check

Summary

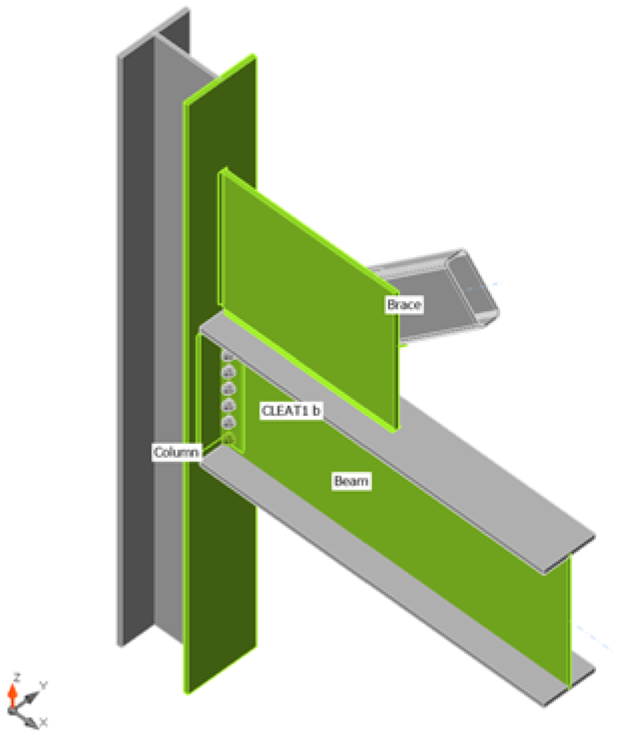
Name	Value	Check status
Analysis	100.0%	OK
Plates	2.0 < 5.0%	OK
Bolts	66.7 < 100%	OK
Welds	108.5 > 100%	**Not OK!**
Buckling	5.82	

Plates

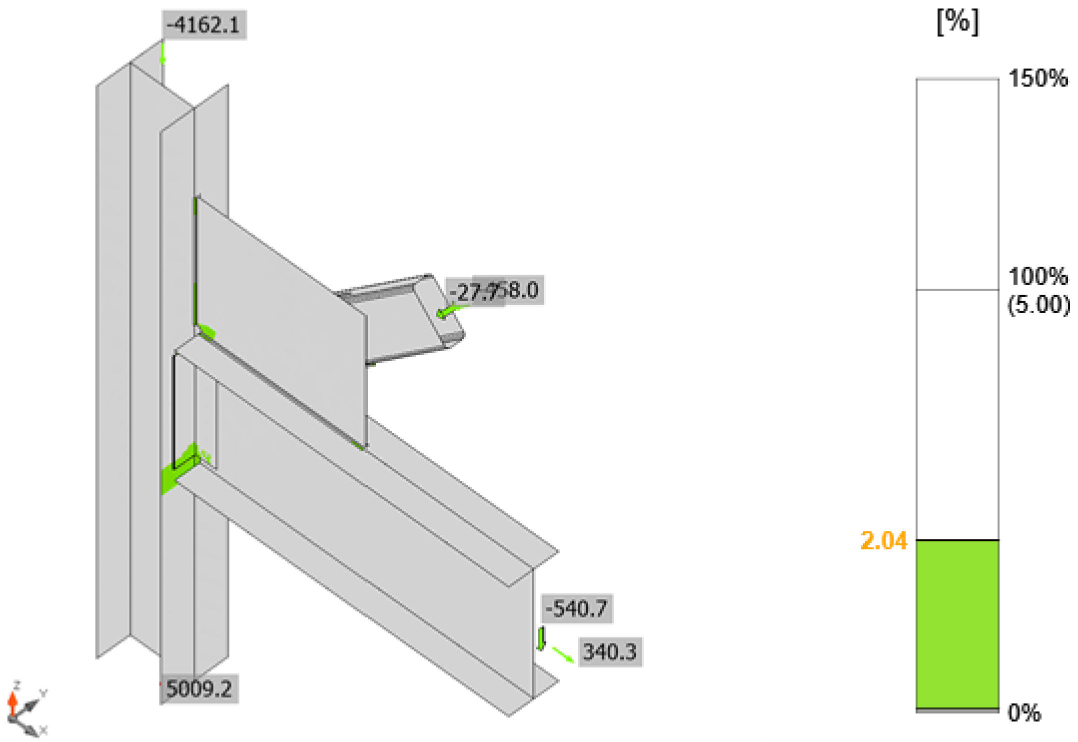
Name	Material	F_y [MPa]	Thickness [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	σc_{Ed} [MPa]	Check status
Column-bfl 1	350W	350.0	20.6	Compression - Brace	315.1	0.1	0.0	OK
Column-tfl 1	350W	350.0	20.6	Compression - Brace	310.5	0.0	0.0	OK
Column-w 1	350W	350.0	13.1	Compression - Brace	304.8	0.0	0.0	OK
Beam-bfl 1	350W	350.0	22.2	Compression - Brace	267.2	0.0	0.0	OK
Beam-tfl 1	350W	350.0	22.2	Compression - Brace	229.2	0.0	0.0	OK
Beam-w 1	350W	350.0	13.1	Compression - Brace	295.7	0.0	43.8	OK
Brace	350W	350.0	11.8	Compression - Brace	283.5	0.0	0.0	OK
CLEAT1 a-bfl 1	350W	350.0	7.9	Compression - Brace	319.1	2.0	43.9	OK
CLEAT1 a-w 1	350W	350.0	7.9	Compression - Brace	317.7	1.3	0.0	OK
CLEAT1 b-bfl 1	350W	350.0	7.9	Compression - Brace	319.1	2.0	36.9	OK
CLEAT1 b-w 1	350W	350.0	7.9	Compression - Brace	317.7	1.3	0.0	OK
SP1	300W	300.0	19.0	Compression - Brace	214.2	0.0	6.2	OK

Design data

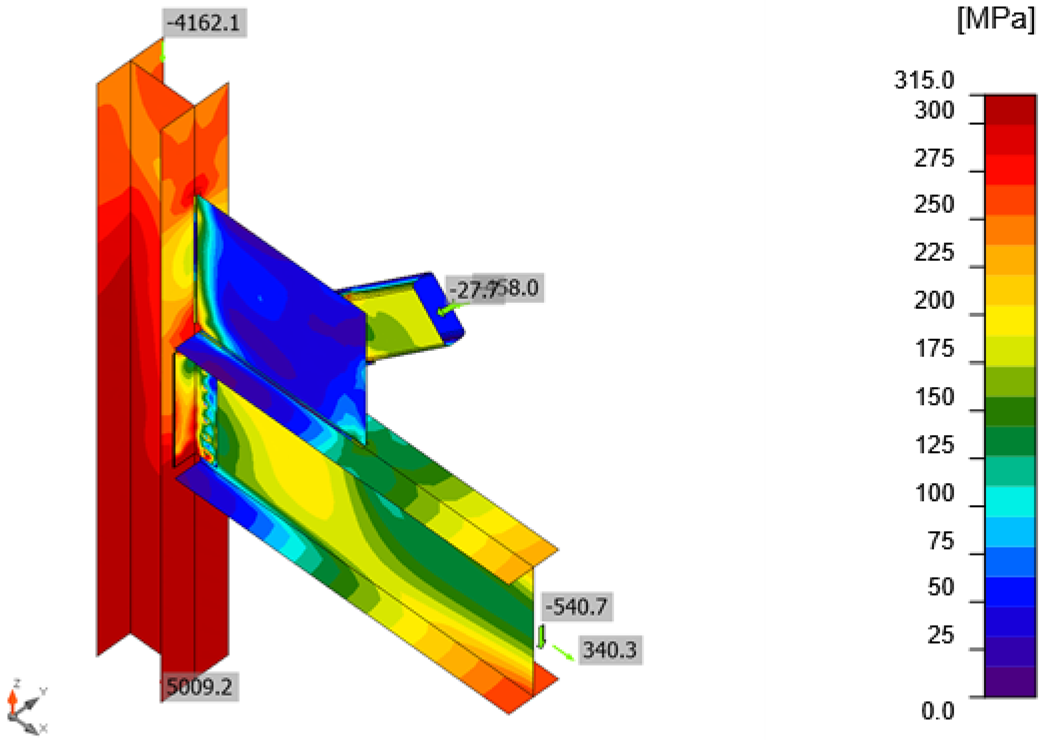
Material	F_y [MPa]	ε_{lim} [%]
350W	350.0	5.0
300W	300.0	5.0



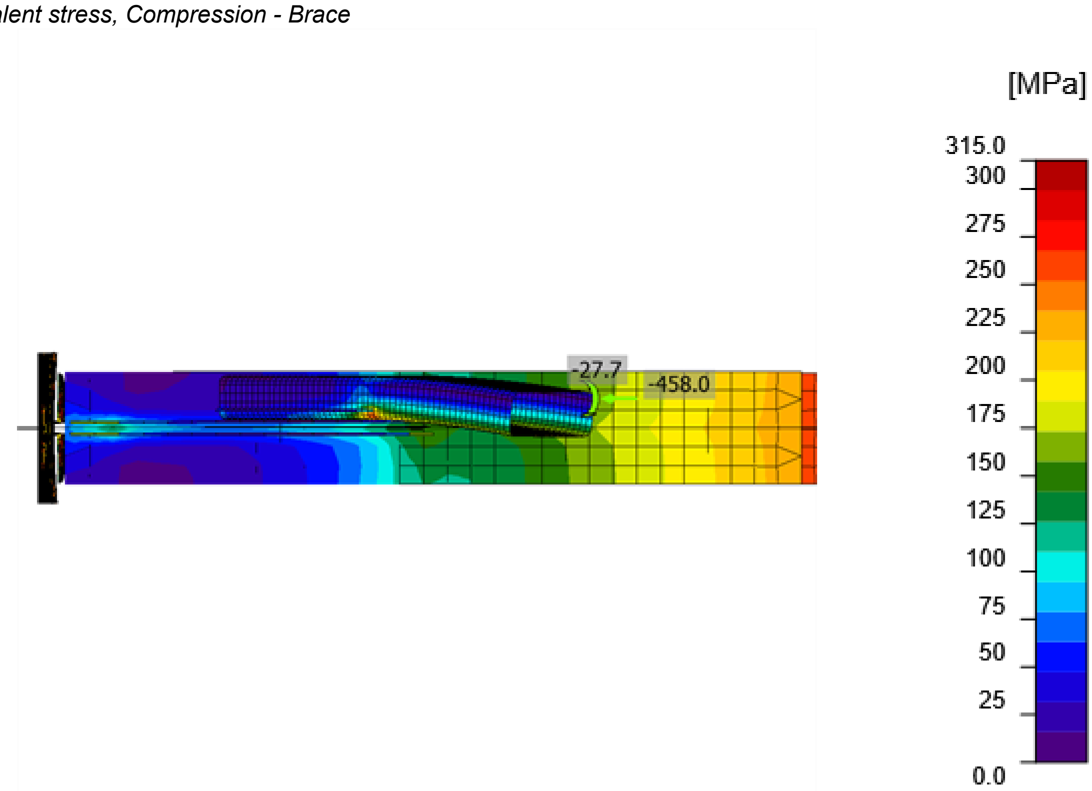
Overall check, Compression - Brace



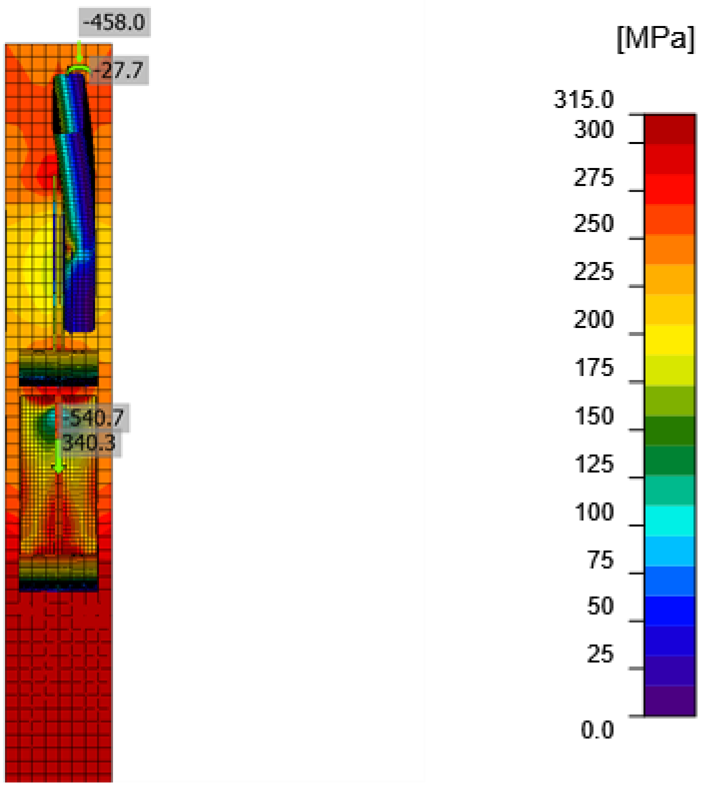
Strain check, Compression - Brace



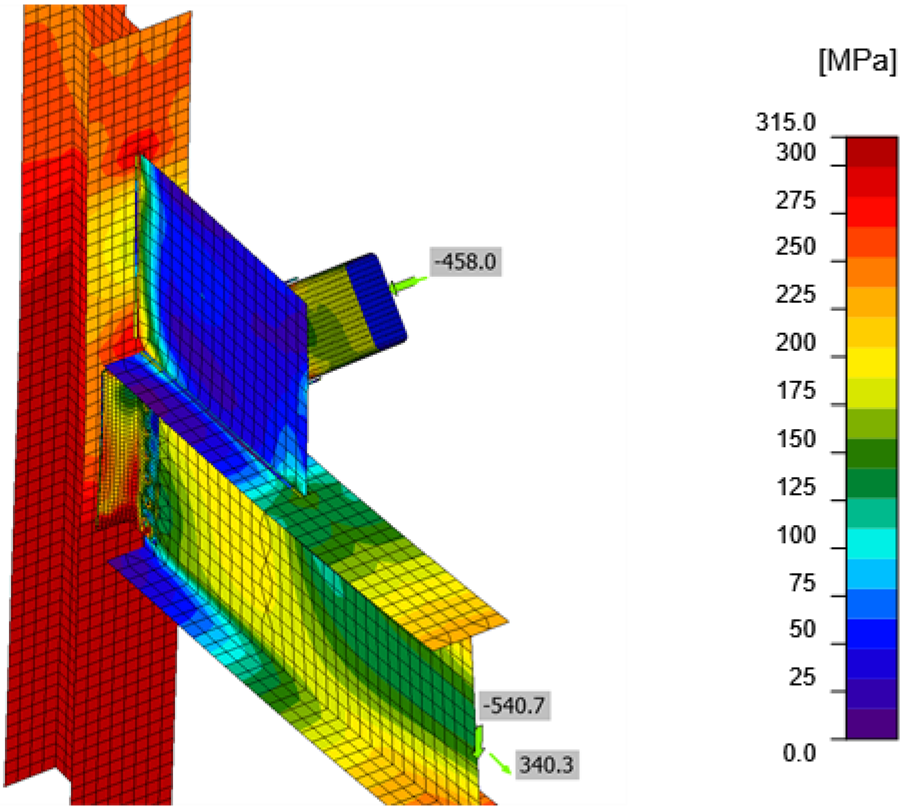
Equivalent stress, Compression - Brace



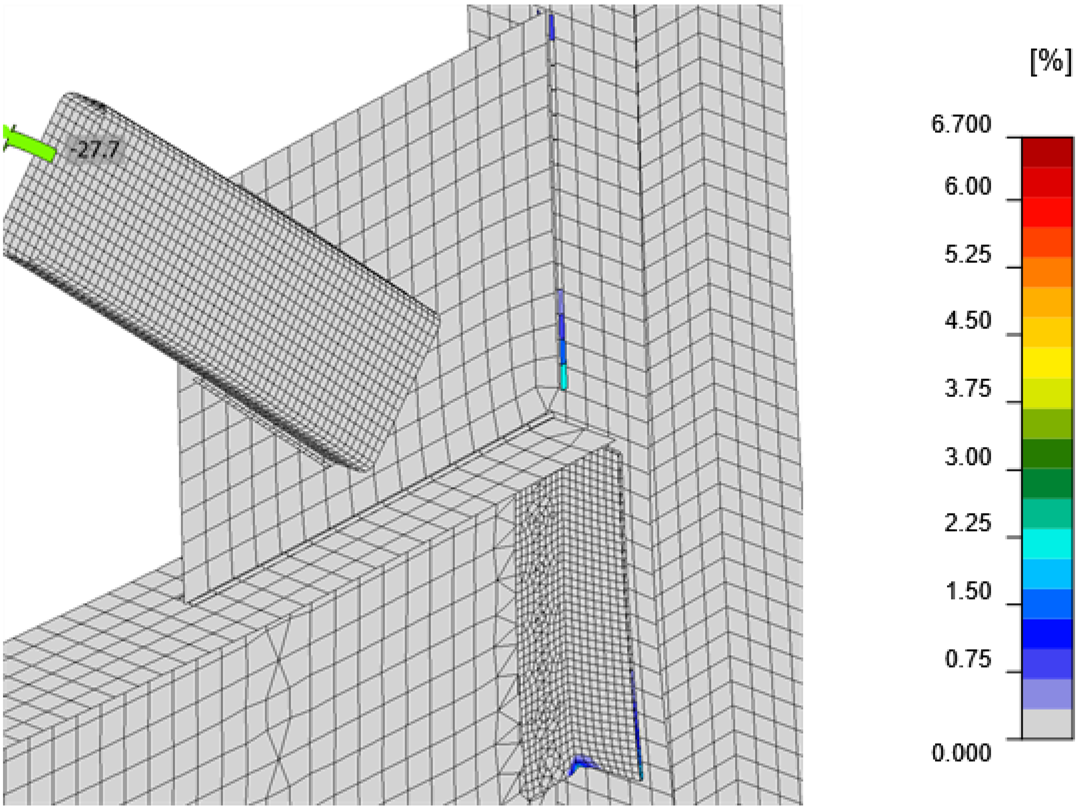
Plan View - 20x Deformed



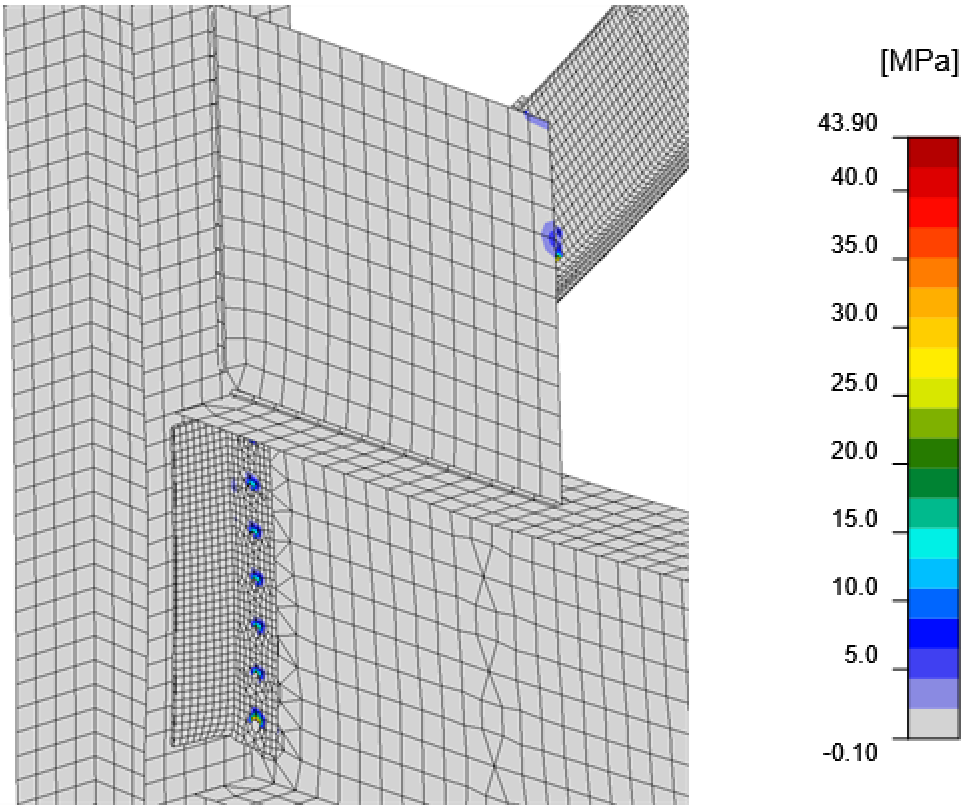
End View - 20x Deformed



ISO View - 20x Deformed

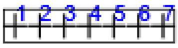


Plastic Strain



Contact Stress

Bolts

Shape	Item	Grade	Loads	T_f [kN]	V_f [kN]	B_r [kN]	$T_{r,bs}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	3/4 A325 - 1	Compression - Brace	22.6	52.7	269.1	266.9	16.0	66.7	47.1	OK
	B2	3/4 A325 - 1	Compression - Brace	10.4	42.6	269.1	425.8	7.3	54.0	29.6	OK
	B3	3/4 A325 - 1	Compression - Brace	9.7	38.6	269.1	353.2	6.9	48.8	24.3	OK
	B4	3/4 A325 - 1	Compression - Brace	8.7	37.3	269.1	353.2	6.2	47.2	22.6	OK
	B5	3/4 A325 - 1	Compression - Brace	7.6	36.3	269.1	353.2	5.4	46.0	21.4	OK
	B6	3/4 A325 - 1	Compression - Brace	6.8	34.9	269.1	353.2	4.8	44.1	19.7	OK
	B7	3/4 A325 - 1	Compression - Brace	7.0	32.8	269.1	344.5	5.0	41.6	17.5	OK

Design data

Grade	T_r [kN]	V_r [kN]
3/4 A325 - 1	141.1	79.0

Detailed result for B1

Tension resistance check (CSA S16-14: 13.12.1.3)

$$T_r = 0.75 \cdot \phi_b \cdot A_b \cdot F_u = \text{ 141.1 kN } \geq T_f = \text{ 22.6 kN}$$

Where:

ϕ_b = 0.80 – resistance factor for bolts

A_b = 285 mm^2 – gross bolt cross-sectional area

F_u = 825.0 MPa – specified minimum tensile strength of a bolt

Shear resistance check (CSA S16-14: 13.12.1.2)

$$V_r = r_{st} \cdot 0.6 \cdot \phi_b \cdot A_b \cdot F_u = \text{ 79.0 kN } \geq V_f = \text{ 52.7 kN}$$

Where:

r_{st} = 0.7 – reduction factor for shear plane in bolt thread

ϕ_b = 0.80 – resistance factor for bolts

A_b = 285 mm^2 – gross bolt cross-sectional area

F_u = 825.0 MPa – specified minimum tensile strength of a bolt

Bearing resistance check (CSA S16-14: 13.12.1.2)

$$B_r = 3.0 \cdot \phi_{br} \cdot t \cdot d \cdot F_u = \text{ 269.1 kN } \geq V_f = \text{ 105.4 kN}$$

Where:

ϕ_{br} = 0.80 – resistance factor for bearing of bolts on steel

t = 13 mm – thickness of the critical plate

d = 19 mm – diameter of a bolt

F_u = 450.0 MPa – tensile strength of the connected material

Interaction of tension and shear check (CSA S16-14: 13.12.1.4)

$\left(\frac{V_f}{V_r}\right)^2 + \left(\frac{T_f}{T_r}\right)^2 =$ 0.47 ≤ 1.0

Where:

V_f = 52.7 kN – shear force in a bolt under factored load

V_r = 79.0 kN – factored shear resistance of a bolt

T_f = 22.6 kN – tensile force in a bolt under factored load

T_r = 141.1 kN – factored tensile resistance of a bolt

Hole tear-out resistance check (CSA S16-14: 13.11)

$T_r = \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{F_y + F_u}{2} =$ 266.9 kN ≥ $V_f =$ 105.4 kN

Where:

ϕ_u = 0.75 – resistance factor for structural steel

A_{gv} = 1483 mm^2 – gross area in shear:

- $A_{gv} = 2 \cdot l \cdot t$, where:
  - $l =$ 57 mm – distance from centreline of the bolt to the plate edge in the direction of the shear force
  - $t =$ 13 mm – thickness of the critical plate

F_y = 350.0 MPa – yield strength of the connected material

F_u = 450.0 MPa – tensile strength of the connected material

Detailed result for B2

Tension resistance check (CSA S16-14: 13.12.1.3)

$T_r = 0.75 \cdot \phi_b \cdot A_b \cdot F_u =$ 141.1 kN ≥ $T_f =$ 10.4 kN

Where:

ϕ_b = 0.80 – resistance factor for bolts

A_b = 285 mm^2 – gross bolt cross-sectional area

F_u = 825.0 MPa – specified minimum tensile strength of a bolt

Shear resistance check (CSA S16-14: 13.12.1.2)

$V_r = r_{st} \cdot 0.6 \cdot \phi_b \cdot A_b \cdot F_u =$ 79.0 kN ≥ $V_f =$ 42.6 kN

Where:

r_{st} = 0.7 – reduction factor for shear plane in bolt thread

ϕ_b = 0.80 – resistance factor for bolts

A_b = 285 mm^2 – gross bolt cross-sectional area

F_u = 825.0 MPa – specified minimum tensile strength of a bolt

Bearing resistance check (CSA S16-14: 13.12.1.2)

$B_r = 3.0 \cdot \phi_{br} \cdot t \cdot d \cdot F_u =$ 269.1 kN ≥ $V_f =$ 85.2 kN

Where:

$\phi_{br} =$ 0.80 – resistance factor for bearing of bolts on steel

$t =$ 13 mm – thickness of the critical plate

$d =$ 19 mm – diameter of a bolt

$F_u =$ 450.0 MPa – tensile strength of the connected material

Interaction of tension and shear check (CSA S16-14: 13.12.1.4)

$\left(\frac{V_f}{V_r}\right)^2 + \left(\frac{T_f}{T_r}\right)^2 =$ 0.30 ≤ 1.0

Where:

$V_f =$ 42.6 kN – shear force in a bolt under factored load

$V_r =$ 79.0 kN – factored shear resistance of a bolt

$T_f =$ 10.4 kN – tensile force in a bolt under factored load

$T_r =$ 141.1 kN – factored tensile resistance of a bolt

Hole tear-out resistance check (CSA S16-14: 13.11)

$T_r = \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{F_y + F_u}{2} =$ 425.8 kN ≥ $V_f =$ 85.2 kN

Where:

$\phi_u =$ 0.75 – resistance factor for structural steel

$A_{gv} =$ 2366 mm^2 – gross area in shear:

- $A_{gv} = 2 \cdot l \cdot t$, where:
  - $l =$ 90 mm – distance from centreline of the bolt to the plate edge in the direction of the shear force
  - $t =$ 13 mm – thickness of the critical plate

$F_y =$ 350.0 MPa – yield strength of the connected material

$F_u =$ 450.0 MPa – tensile strength of the connected material

Detailed result for B3

Tension resistance check (CSA S16-14: 13.12.1.3)

$T_r = 0.75 \cdot \phi_b \cdot A_b \cdot F_u =$ 141.1 kN ≥ $T_f =$ 9.7 kN

Where:

$\phi_b =$ 0.80 – resistance factor for bolts

$A_b =$ 285 mm^2 – gross bolt cross-sectional area

$F_u =$ 825.0 MPa – specified minimum tensile strength of a bolt

Shear resistance check (CSA S16-14: 13.12.1.2)

$V_r = r_{st} \cdot 0.6 \cdot \phi_b \cdot A_b \cdot F_u =$ 79.0 kN ≥ $V_f =$ 38.6 kN

Where:

$r_{st} = 0.7$ – reduction factor for shear plane in bolt thread

$\phi_b = 0.80$ – resistance factor for bolts

$A_b = 285$ mm^2 – gross bolt cross-sectional area

$F_u = 825.0$ MPa – specified minimum tensile strength of a bolt

Bearing resistance check (CSA S16-14: 13.12.1.2)

$B_r = 3.0 \cdot \phi_{br} \cdot t \cdot d \cdot F_u =$ 269.1 kN ≥ $V_f =$ 77.1 kN

Where:

$\phi_{br} = 0.80$ – resistance factor for bearing of bolts on steel

$t = 13$ mm – thickness of the critical plate

$d = 19$ mm – diameter of a bolt

$F_u = 450.0$ MPa – tensile strength of the connected material

Interaction of tension and shear check (CSA S16-14: 13.12.1.4)

$\left(\frac{V_f}{V_r}\right)^2 + \left(\frac{T_f}{T_r}\right)^2 =$ 0.24 ≤ 1.0

Where:

$V_f = 38.6$ kN – shear force in a bolt under factored load

$V_r = 79.0$ kN – factored shear resistance of a bolt

$T_f = 9.7$ kN – tensile force in a bolt under factored load

$T_r = 141.1$ kN – factored tensile resistance of a bolt

Hole tear-out resistance check (CSA S16-14: 13.11)

$T_r = \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{F_y+F_u}{2} =$ 353.2 kN ≥ $V_f =$ 77.1 kN

Where:

$\phi_u = 0.75$ – resistance factor for structural steel

$A_{gv} = 1962$ mm^2 – gross area in shear:

- $A_{gv} = 2 \cdot l \cdot t$, where:
  - $l =$ 75 mm – distance from centreline of the bolt to the plate edge in the direction of the shear force
  - $t =$ 13 mm – thickness of the critical plate

$F_y = 350.0$ MPa – yield strength of the connected material

$F_u = 450.0$ MPa – tensile strength of the connected material

Detailed result for B4

Tension resistance check (CSA S16-14: 13.12.1.3)

$T_r = 0.75 \cdot \phi_b \cdot A_b \cdot F_u =$ 141.1 kN ≥ $T_f =$ 8.7 kN

Where:

$\phi_b = 0.80$ – resistance factor for bolts

$A_b = 285$ mm^2 – gross bolt cross-sectional area

$F_u = 825.0$ MPa – specified minimum tensile strength of a bolt

Shear resistance check (CSA S16-14: 13.12.1.2)

$V_r = r_{st} \cdot 0.6 \cdot \phi_b \cdot A_b \cdot F_u =$ 79.0 kN ≥ $V_f =$ 37.3 kN

Where:

$r_{st} = 0.7$ – reduction factor for shear plane in bolt thread

$\phi_b = 0.80$ – resistance factor for bolts

$A_b = 285$ mm^2 – gross bolt cross-sectional area

$F_u = 825.0$ MPa – specified minimum tensile strength of a bolt

Bearing resistance check (CSA S16-14: 13.12.1.2)

$B_r = 3.0 \cdot \phi_{br} \cdot t \cdot d \cdot F_u =$ 269.1 kN ≥ $V_f =$ 74.5 kN

Where:

$\phi_{br} = 0.80$ – resistance factor for bearing of bolts on steel

$t = 13$ mm – thickness of the critical plate

$d = 19$ mm – diameter of a bolt

$F_u = 450.0$ MPa – tensile strength of the connected material

Interaction of tension and shear check (CSA S16-14: 13.12.1.4)

$\left(\frac{V_f}{V_r}\right)^2 + \left(\frac{T_f}{T_r}\right)^2 =$ 0.23 ≤ 1.0

Where:

$V_f = 37.3$ kN – shear force in a bolt under factored load

$V_r = 79.0$ kN – factored shear resistance of a bolt

$T_f = 8.7$ kN – tensile force in a bolt under factored load

$T_r = 141.1$ kN – factored tensile resistance of a bolt

Hole tear-out resistance check (CSA S16-14: 13.11)

$T_r = \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{F_y + F_u}{2} =$ 353.2 kN ≥ $V_f =$ 74.5 kN

Where:

$\phi_u = 0.75$ – resistance factor for structural steel

$A_{gv} =$ 1962 mm^2 – gross area in shear:

- $A_{gv} = 2 \cdot l \cdot t$, where:
  - $l =$ 75 mm – distance from centreline of the bolt to the plate edge in the direction of the shear force
  - $t =$ 13 mm – thickness of the critical plate

$F_y =$ 350.0 MPa – yield strength of the connected material

$F_u =$ 450.0 MPa – tensile strength of the connected material

Detailed result for B5

Tension resistance check (CSA S16-14: 13.12.1.3)

$T_r = 0.75 \cdot \phi_b \cdot A_b \cdot F_u =$ 141.1 kN ≥ $T_f =$ 7.6 kN

Where:

$\phi_b = 0.80$ – resistance factor for bolts

$A_b =$ 285 mm^2 – gross bolt cross-sectional area

$F_u =$ 825.0 MPa – specified minimum tensile strength of a bolt

Shear resistance check (CSA S16-14: 13.12.1.2)

$V_r = r_{st} \cdot 0.6 \cdot \phi_b \cdot A_b \cdot F_u =$ 79.0 kN ≥ $V_f =$ 36.3 kN

Where:

$r_{st} = 0.7$ – reduction factor for shear plane in bolt thread

$\phi_b = 0.80$ – resistance factor for bolts

$A_b =$ 285 mm^2 – gross bolt cross-sectional area

$F_u =$ 825.0 MPa – specified minimum tensile strength of a bolt

Bearing resistance check (CSA S16-14: 13.12.1.2)

$B_r = 3.0 \cdot \phi_{br} \cdot t \cdot d \cdot F_u =$ 269.1 kN ≥ $V_f =$ 72.6 kN

Where:

$\phi_{br} = 0.80$ – resistance factor for bearing of bolts on steel

$t =$ 13 mm – thickness of the critical plate

$d =$ 19 mm – diameter of a bolt

$F_u =$ 450.0 MPa – tensile strength of the connected material

Interaction of tension and shear check (CSA S16-14: 13.12.1.4)

$$\left(\frac{V_f}{V_r}\right)^2 + \left(\frac{T_f}{T_r}\right)^2 = \quad 0.21 \quad \leq \quad 1.0$$

Where:

V_f = 36.3 kN – shear force in a bolt under factored load

V_r = 79.0 kN – factored shear resistance of a bolt

T_f = 7.6 kN – tensile force in a bolt under factored load

T_r = 141.1 kN – factored tensile resistance of a bolt

Hole tear-out resistance check (CSA S16-14: 13.11)

$$T_r = \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{F_y + F_u}{2} = \quad 353.2 \quad \text{kN} \quad \geq \quad V_f = \quad 72.6 \quad \text{kN}$$

Where:

ϕ_u = 0.75 – resistance factor for structural steel

A_{gv} = 1962 mm^2 – gross area in shear:

- $A_{gv} = 2 \cdot l \cdot t$, where:
  - $l =$ 75 mm – distance from centreline of the bolt to the plate edge in the direction of the shear force
  - $t =$ 13 mm – thickness of the critical plate

F_y = 350.0 MPa – yield strength of the connected material

F_u = 450.0 MPa – tensile strength of the connected material

Detailed result for B6

Tension resistance check (CSA S16-14: 13.12.1.3)

$$T_r = 0.75 \cdot \phi_b \cdot A_b \cdot F_u = \quad 141.1 \quad \text{kN} \quad \geq \quad T_f = \quad 6.8 \quad \text{kN}$$

Where:

ϕ_b = 0.80 – resistance factor for bolts

A_b = 285 mm^2 – gross bolt cross-sectional area

F_u = 825.0 MPa – specified minimum tensile strength of a bolt

Shear resistance check (CSA S16-14: 13.12.1.2)

$$V_r = r_{st} \cdot 0.6 \cdot \phi_b \cdot A_b \cdot F_u = \quad 79.0 \quad \text{kN} \quad \geq \quad V_f = \quad 34.9 \quad \text{kN}$$

Where:

r_{st} = 0.7 – reduction factor for shear plane in bolt thread

ϕ_b = 0.80 – resistance factor for bolts

A_b = 285 mm^2 – gross bolt cross-sectional area

F_u = 825.0 MPa – specified minimum tensile strength of a bolt

Bearing resistance check (CSA S16-14: 13.12.1.2)

$B_r = 3.0 \cdot \phi_{br} \cdot t \cdot d \cdot F_u =$ 269.1 kN ≥ $V_f =$ 69.7 kN

Where:

$\phi_{br} =$ 0.80 – resistance factor for bearing of bolts on steel

$t =$ 13 mm – thickness of the critical plate

$d =$ 19 mm – diameter of a bolt

$F_u =$ 450.0 MPa – tensile strength of the connected material

Interaction of tension and shear check (CSA S16-14: 13.12.1.4)

$\left(\frac{V_f}{V_r}\right)^2 + \left(\frac{T_f}{T_r}\right)^2 =$ 0.20 ≤ 1.0

Where:

$V_f =$ 34.9 kN – shear force in a bolt under factored load

$V_r =$ 79.0 kN – factored shear resistance of a bolt

$T_f =$ 6.8 kN – tensile force in a bolt under factored load

$T_r =$ 141.1 kN – factored tensile resistance of a bolt

Hole tear-out resistance check (CSA S16-14: 13.11)

$T_r = \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{F_y + F_u}{2} =$ 353.2 kN ≥ $V_f =$ 69.7 kN

Where:

$\phi_u =$ 0.75 – resistance factor for structural steel

$A_{gv} =$ 1962 mm^2 – gross area in shear:

- $A_{gv} = 2 \cdot l \cdot t$, where:
  - $l =$ 75 mm – distance from centreline of the bolt to the plate edge in the direction of the shear force
  - $t =$ 13 mm – thickness of the critical plate

$F_y =$ 350.0 MPa – yield strength of the connected material

$F_u =$ 450.0 MPa – tensile strength of the connected material

Detailed result for B7

Tension resistance check (CSA S16-14: 13.12.1.3)

$T_r = 0.75 \cdot \phi_b \cdot A_b \cdot F_u =$ 141.1 kN ≥ $T_f =$ 7.0 kN

Where:

$\phi_b =$ 0.80 – resistance factor for bolts

$A_b =$ 285 mm^2 – gross bolt cross-sectional area

$F_u =$ 825.0 MPa – specified minimum tensile strength of a bolt

Shear resistance check (CSA S16-14: 13.12.1.2)

$V_r = r_{st} \cdot 0.6 \cdot \phi_b \cdot A_b \cdot F_u =$ 79.0 kN ≥ $V_f =$ 32.8 kN

Where:

$r_{st} = 0.7$ – reduction factor for shear plane in bolt thread

$\phi_b = 0.80$ – resistance factor for bolts

$A_b = 285\ \text{mm}^2$ – gross bolt cross-sectional area

$F_u = 825.0$ MPa – specified minimum tensile strength of a bolt

Bearing resistance check (CSA S16-14: 13.12.1.2)

$B_r = 3.0 \cdot \phi_{br} \cdot t \cdot d \cdot F_u =$ 269.1 kN ≥ $V_f =$ 65.6 kN

Where:

$\phi_{br} = 0.80$ – resistance factor for bearing of bolts on steel

$t = 13$ mm – thickness of the critical plate

$d = 19$ mm – diameter of a bolt

$F_u = 450.0$ MPa – tensile strength of the connected material

Interaction of tension and shear check (CSA S16-14: 13.12.1.4)

$\left(\frac{V_f}{V_r}\right)^2 + \left(\frac{T_f}{T_r}\right)^2 =$ 0.18 ≤ 1.0

Where:

$V_f = 32.8$ kN – shear force in a bolt under factored load

$V_r = 79.0$ kN – factored shear resistance of a bolt

$T_f = 7.0$ kN – tensile force in a bolt under factored load

$T_r = 141.1$ kN – factored tensile resistance of a bolt

Hole tear-out resistance check (CSA S16-14: 13.11)

$T_r = \phi_u \cdot 0.6 \cdot A_{gv} \cdot \frac{F_y + F_u}{2} =$ 344.5 kN ≥ $V_f =$ 65.6 kN

Where:

$\phi_u = 0.75$ – resistance factor for structural steel

$A_{gv} = 1914\ \text{mm}^2$ – gross area in shear:

- $A_{gv} = 2 \cdot l \cdot t$, where:
  - $l =$ 73 mm – distance from centreline of the bolt to the plate edge in the direction of the shear force
  - $t =$ 13 mm – thickness of the critical plate

$F_y = 350.0$ MPa – yield strength of the connected material

$F_u = 450.0$ MPa – tensile strength of the connected material

Weld sections

Item	Edge	Material	T_h [mm]	L_s [mm]	L [mm]	L_c [mm]	Loads	F_w [kN]	V_r [kN]	Ut [%]	Status
Column-bfl 1	CLEAT1 a-w 1	E49xx	◢4.0	◢5.7	98	12	Compression - Brace	17.5	16.1	108.5	**Not OK!**
Column-bfl 1	CLEAT1 a-w 1	E49xx	◢4.0	◢5.7	98	12	Compression - Brace	13.9	15.8	87.5	OK
Column-bfl 1	CLEAT1 a-w 1	E49xx	◢4.0	◢5.7	518	13	Compression - Brace	11.2	13.3	84.6	OK
Column-bfl 1	CLEAT1 b-w 1	E49xx	◢4.0	◢5.7	98	12	Compression - Brace	13.9	15.8	87.4	OK
Column-bfl 1	CLEAT1 b-w 1	E49xx	◢4.0	◢5.7	98	12	Compression - Brace	17.5	16.1	108.5	**Not OK!**
Column-bfl 1	CLEAT1 b-w 1	E49xx	◢4.0	◢5.7	518	13	Compression - Brace	11.2	13.3	84.6	OK
Beam-tfl 1	SP1	E49xx	◢7.1◣	◢10.0◣	749	50	Compression - Brace	85.4	112.5	75.9	OK
		E49xx	◢7.1◣	◢10.0◣	749	50	Compression - Brace	85.6	112.7	76.0	OK
Column-bfl 1	SP1	E49xx	◢7.1◣	◢10.0◣	584	39	Compression - Brace	59.7	75.4	79.2	OK
		E49xx	◢7.1◣	◢10.0◣	584	39	Compression - Brace	59.6	75.3	79.2	OK
SP1	Brace-w 3	E49xx	◢7.1◣	◢10.0◣	450	16	Compression - Brace	19.8	35.9	55.3	OK
		E49xx	◢7.1◣	◢10.0◣	450	16	Compression - Brace	19.9	37.3	53.3	OK
SP1	Brace-w 1	E49xx	◢7.1◣	◢10.0◣	360	16	Compression - Brace	25.0	32.8	76.0	OK
		E49xx	◢7.1◣	◢10.0◣	360	16	Compression - Brace	24.5	32.3	76.0	OK

Detailed result for Column-bfl 1 / CLEAT1 a-w 1 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w = \text{ 16.1 kN } < F_w = \text{ 17.5 kN}$$

Where:

$\phi_w = 0.67$ – resistance factor for welded connections

$A_w = 49$ mm^2 – effective throat area of weld critical element

$X_u = 490.0$ MPa – ultimate strength as rated by the electrode classification number

$\theta = 86.6$ ° – angle of axis of weld segment with respect to the line of action of applied force

$M_w = 1.00$ – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for Column-bfl 1 / CLEAT1 a-w 1 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 15.8 kN ≥ $F_w =$ 13.9 kN

Where:

$\phi_w = 0.67$ – resistance factor for welded connections

$A_w = 49$ mm^2 – effective throat area of weld critical element

$X_u = 490.0$ MPa – ultimate strength as rated by the electrode classification number

$\theta = 75.4$ ° – angle of axis of weld segment with respect to the line of action of applied force

$M_w = 1.00$ – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for Column-bfl 1 / CLEAT1 a-w 1 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 13.3 kN ≥ $F_w =$ 11.2 kN

Where:

$\phi_w = 0.67$ – resistance factor for welded connections

$A_w = 51$ mm^2 – effective throat area of weld critical element

$X_u = 490.0$ MPa – ultimate strength as rated by the electrode classification number

$\theta = 32.0$ ° – angle of axis of weld segment with respect to the line of action of applied force

$M_w = 1.00$ – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for Column-bfl 1 / CLEAT1 b-w 1 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 15.8 kN ≥ $F_w =$ 13.9 kN

Where:

$\phi_w = 0.67$ – resistance factor for welded connections

$A_w = 49$ mm^2 – effective throat area of weld critical element

$X_u = 490.0$ MPa – ultimate strength as rated by the electrode classification number

$\theta = 75.4$ ° – angle of axis of weld segment with respect to the line of action of applied force

$M_w = 1.00$ – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for Column-bfl 1 / CLEAT1 b-w 1 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 16.1 kN < $F_w =$ 17.5 kN

Where:

$\phi_w = 0.67$ – resistance factor for welded connections

$A_w = 49$ mm^2 – effective throat area of weld critical element

$X_u = 490.0$ MPa – ultimate strength as rated by the electrode classification number

$\theta = 86.7$ ° – angle of axis of weld segment with respect to the line of action of applied force

$M_w = 1.00$ – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for Column-bfl 1 / CLEAT1 b-w 1 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 13.3 kN ≥ $F_w =$ 11.2 kN

Where:

$\phi_w =$ 0.67 – resistance factor for welded connections

$A_w =$ 51 mm^2 – effective throat area of weld critical element

$X_u =$ 490.0 MPa – ultimate strength as rated by the electrode classification number

$\theta =$ 32.0 ° – angle of axis of weld segment with respect to the line of action of applied force

$M_w =$ 1.00 – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for Beam-tfl 1 / SP1 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 112.5 kN ≥ $F_w =$ 85.4 kN

Where:

$\phi_w =$ 0.67 – resistance factor for welded connections

$A_w =$ 353 mm^2 – effective throat area of weld critical element

$X_u =$ 490.0 MPa – ultimate strength as rated by the electrode classification number

$\theta =$ 68.4 ° – angle of axis of weld segment with respect to the line of action of applied force

$M_w =$ 1.00 – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for Beam-tfl 1 / SP1 - 2

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 112.7 kN ≥ $F_w =$ 85.6 kN

Where:

$\phi_w =$ 0.67	– resistance factor for welded connections
$A_w =$ 353 mm^2	– effective throat area of weld critical element
$X_u =$ 490.0 MPa	– ultimate strength as rated by the electrode classification number
$\theta =$ 68.9 °	– angle of axis of weld segment with respect to the line of action of applied force
$M_w =$ 1.00	– strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for Column-bfl 1 / SP1 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 75.4 kN ≥ $F_w =$ 59.7 kN

Where:

$\phi_w =$ 0.67	– resistance factor for welded connections
$A_w =$ 275 mm^2	– effective throat area of weld critical element
$X_u =$ 490.0 MPa	– ultimate strength as rated by the electrode classification number
$\theta =$ 38.4 °	– angle of axis of weld segment with respect to the line of action of applied force
$M_w =$ 1.00	– strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for Column-bfl 1 / SP1 - 2

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 75.3 kN ≥ $F_w =$ 59.6 kN

Where:

ϕ_w = 0.67 – resistance factor for welded connections

A_w = 275 mm^2 – effective throat area of weld critical element

X_u = 490.0 MPa – ultimate strength as rated by the electrode classification number

θ = 38.2 ° – angle of axis of weld segment with respect to the line of action of applied force

M_w = 1.00 – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for SP1 / Brace-w 3 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 35.9 kN ≥ $F_w =$ 19.8 kN

Where:

ϕ_w = 0.67 – resistance factor for welded connections

A_w = 114 mm^2 – effective throat area of weld critical element

X_u = 490.0 MPa – ultimate strength as rated by the electrode classification number

θ = 65.9 ° – angle of axis of weld segment with respect to the line of action of applied force

M_w = 1.00 – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for SP1 / Brace-w 3 - 2

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 37.3 kN ≥ $F_w =$ 19.9 kN

Where:

$\phi_w =$ 0.67 – resistance factor for welded connections

$A_w =$ 114 mm^2 – effective throat area of weld critical element

$X_u =$ 490.0 MPa – ultimate strength as rated by the electrode classification number

$\theta =$ 82.2 ° – angle of axis of weld segment with respect to the line of action of applied force

$M_w =$ 1.00 – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for SP1 / Brace-w 1 - 1

Weld resistance check (CSA S16-14: 13.13.2.2)

$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w =$ 32.8 kN ≥ $F_w =$ 25.0 kN

Where:

$\phi_w =$ 0.67 – resistance factor for welded connections

$A_w =$ 111 mm^2 – effective throat area of weld critical element

$X_u =$ 490.0 MPa – ultimate strength as rated by the electrode classification number

$\theta =$ 52.1 ° – angle of axis of weld segment with respect to the line of action of applied force

$M_w =$ 1.00 – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Detailed result for SP1 / Brace-w 1 - 2

Weld resistance check (CSA S16-14: 13.13.2.2)

$$V_r = 0.67 \cdot \phi_w \cdot A_w \cdot X_u \cdot (1 + 0.5 \cdot \sin^{1.5}\theta) \cdot M_w = \quad 32.3 \quad \text{kN} \quad \geq \quad F_w = \quad 24.5 \quad \text{kN}$$

Where:

$\phi_w = 0.67$ – resistance factor for welded connections

$A_w = 111\ \text{mm}^2$ – effective throat area of weld critical element

$X_u = 490.0$ MPa – ultimate strength as rated by the electrode classification number

$\theta = 49.0\ °$ – angle of axis of weld segment with respect to the line of action of applied force

$M_w = 1.00$ – strength reduction factor for multi-orientation fillet welds:

- $M_w = 1.0$ – for joints with a single weld orientation
- $M_w = \frac{0.85+\theta_1/600}{0.85+\theta_2/600}$ – for joints with multiple weld orientations, for each segment, where:
  - θ_1 – orientation of the weld segment under consideration
  - θ_2 – orientation of the weld segment in the joint that is nearest to 90°

Buckling

Loads	Shape	Factor [-]
Compression - Brace	1	5.82
	2	5.87
	3	6.47
	4	6.54
	5	7.02
	6	7.13

Bill of material

Manufacturing operations

Name	Plates [mm]	Shape	Nr.	Welds [mm]	Length [mm]	Bolts	Nr.
SP1	P19.0x775.0-610.0 (300W)		1	Double fillet: a = 7.1	750.0		

Welds

Type	Material	Throat thickness [mm]	Leg size [mm]	Length [mm]
Fillet	E49xx	4.0	5.7	1432.1
Double fillet	E49xx	7.1	10.0	2147.1

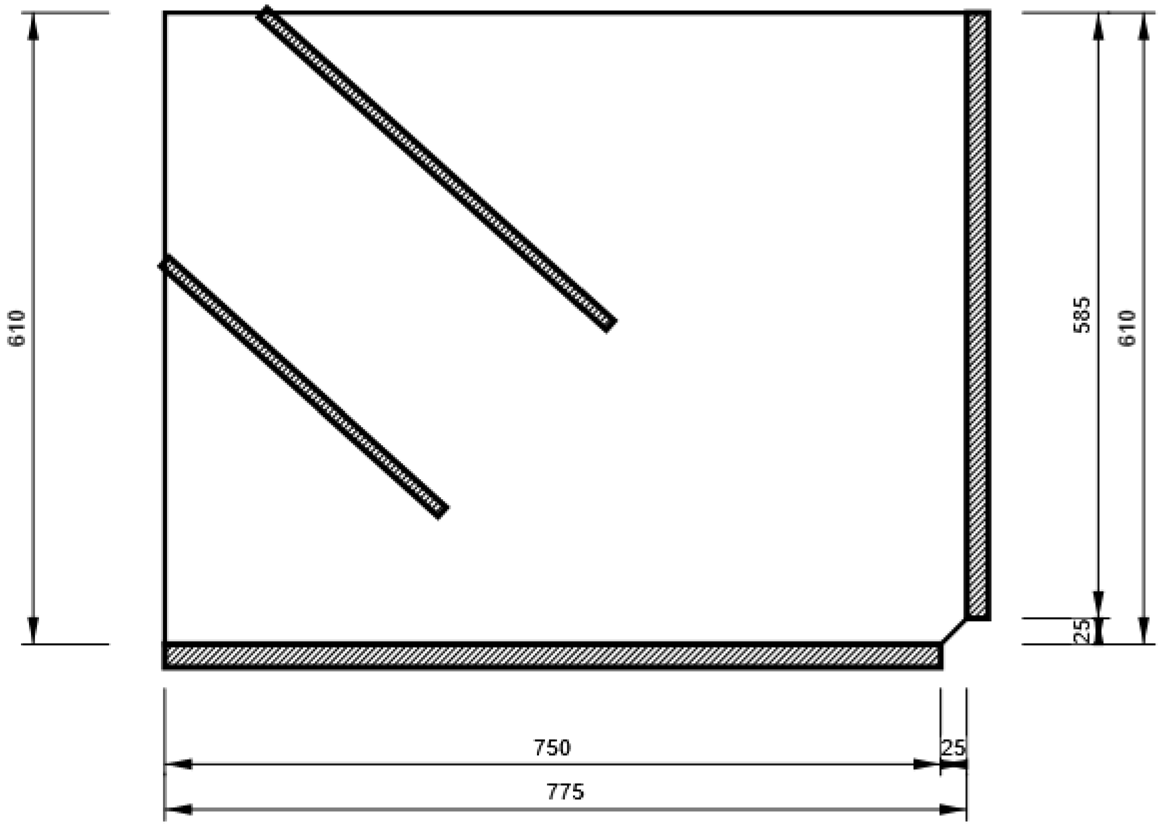
Bolts

Name	Grip length [mm]	Count
3/4 A325	29	7

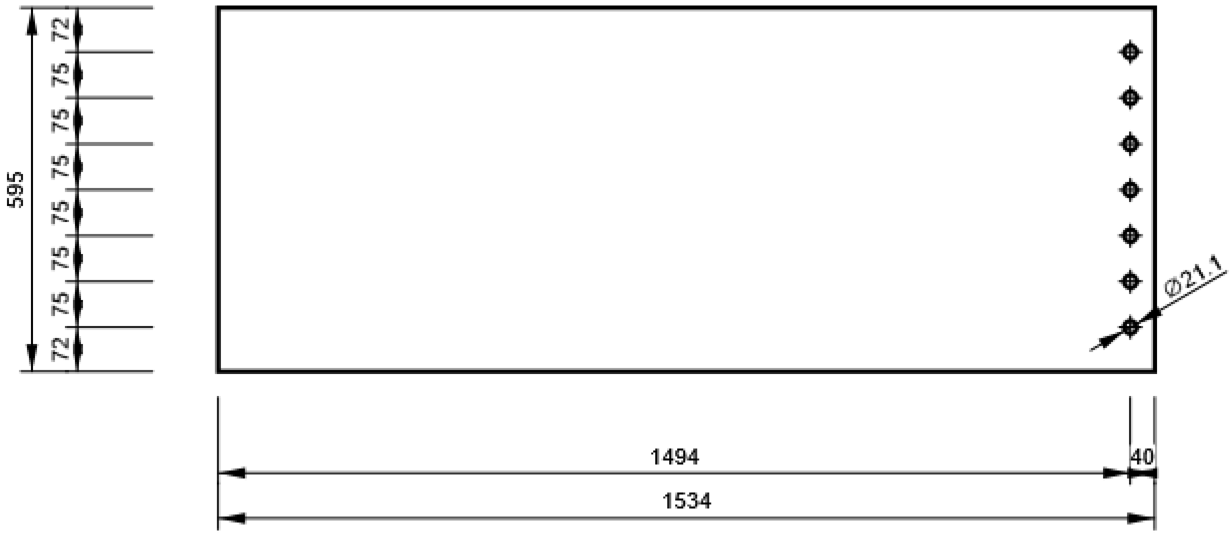
Drawing

SP1

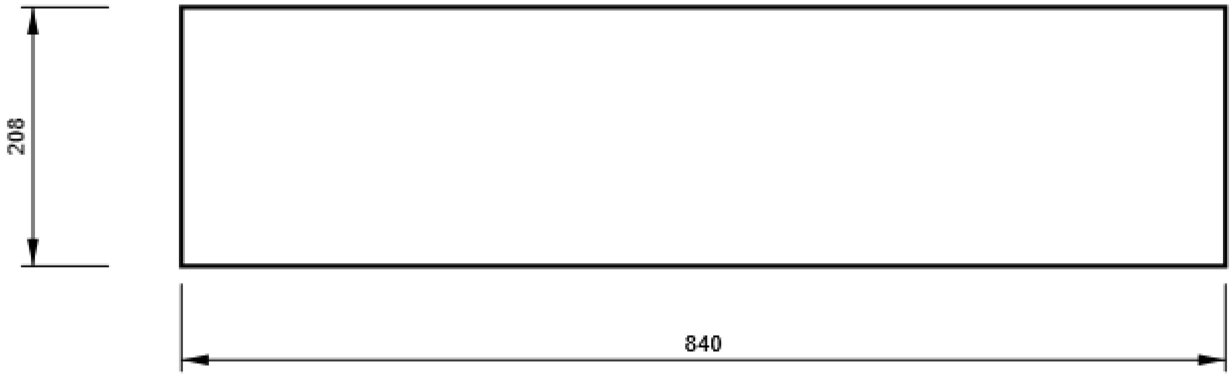
P19.0x610-775 (300W)



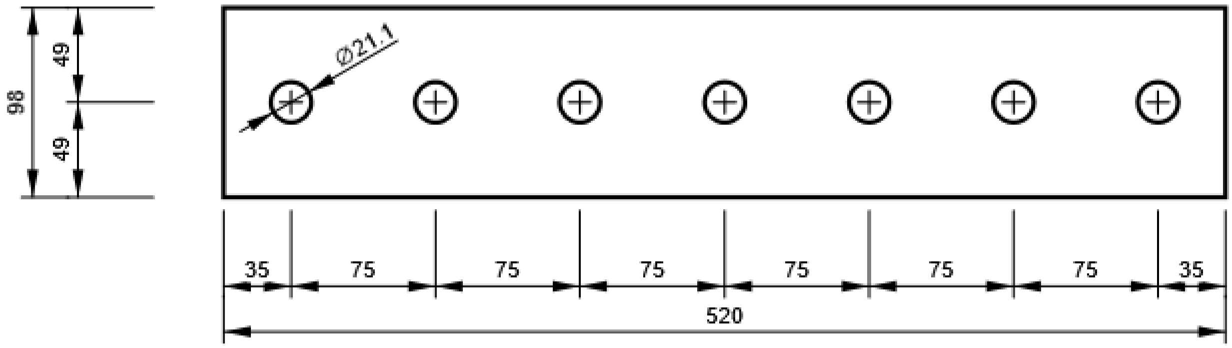
Beam, W24X94 - Web 1:



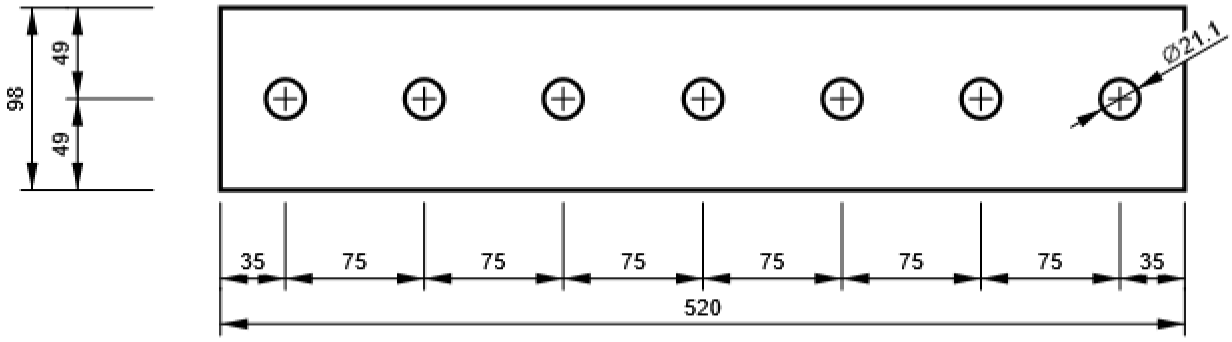
Brace, HSS10X4X.500 - Web 4:



CLEAT1 a, L102x102x7.9 - Bottom flange 1:



CLEAT1 b, L102x102x7.9 - Bottom flange 1:



Symbol explanation

Symbol	Symbol explanation
ε_{Pl}	Strain
f_y	Yield strength
ε_{lim}	Limit of plastic strain
T_f	Tension force
V	Resultant of shear forces Vy, Vz in bolt
B_r	Bearing resistance
$T_{r,bs}$	Tear-out resistance
Ut_t	Utilization in tension
Ut_s	Utilization in shear
UT_{ts}	Utilization in tension and shear
T_r	Tension resistance
V_r	Shear resistance
T_h	Throat thickness of weld
L_s	Leg size of weld
L	Length of weld
L_c	Length of critical weld element
F_w	Force in weld critical element
V_r	Weld resistance
Ut	Utilization

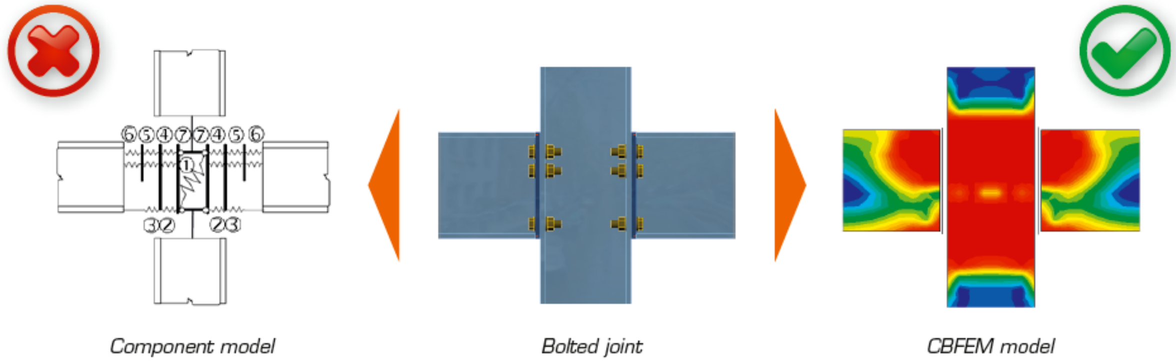
Code settings

Item	Value	Unit	Reference
Structural steel ϕ	0.90	-	CSA S16-14: 13.1
Bolts ϕb	0.80	-	CSA S16-14: 13.12.1.2
Weld ϕw	0.67	-	CSA S16-14: 13.13.1
Friction coefficient in slip-resistance	0.30	-	CSA S16-14: Table 3
Limit plastic strain	0.05	-	
Weld stress evaluation	Plastic redistribution		
Detailing	No		
Distance between bolts [d]	2.70	-	CSA S16-14: 22.3.1
Distance between bolts and edge [d]	1.25	-	CSA S16-14: Table 6
Base metal capacity check at weld fusion face	No		CSA S16-14: 13.13.2.2
Cracked concrete	Yes		
Local deformation check	No		
Local deformation limit	0.03	-	CIDECT DG 1, 3 - 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints

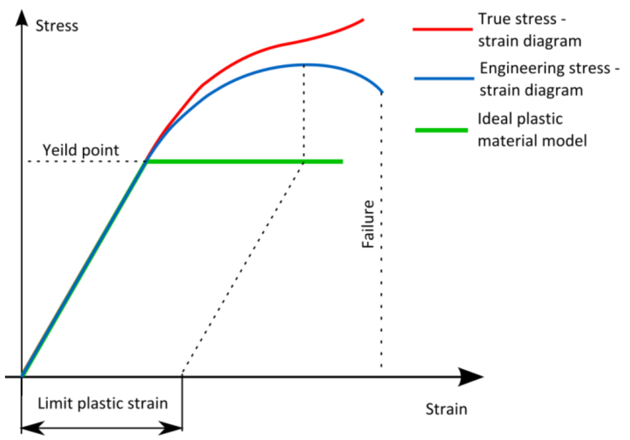
Theoretical Background

CBFEM versus Component method

The weak point of standard Component method is in analyzing of internal forces and stress in a joint. CBFEM replaces specific analysis of internal forces in joint with general FEA.

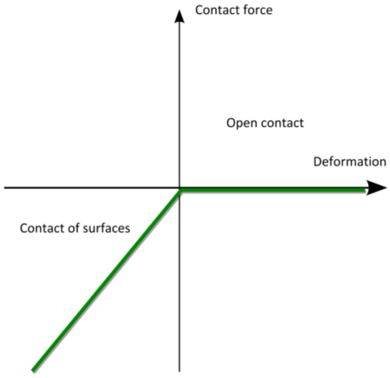


Check methods of specific components like bolts or welds are done according to standard Component method (Eurocode).
For the fasteners – bolts and welds – special FEM components had to be developed to model the welds and bolts behaviour in joint. All parts of 1D members and all additional plates are modelled as plate/walls. These elements are made of steel (metal in general) and the behaviour of this material is significantly nonlinear.
The real stress-strain diagram of steel is replaced by the ideal plastic material for design purposes in building practice. The advantage of ideal plastic material is, that only yield strength and modulus of elasticity must be known to describe the material curve. The granted ductility of construction steel is 15 %. The real usable value of limit plastic strain is 5% for ordinary design (1993-1-5 appendix C paragraph C.8 note 1).
The stress in steel cannot exceed the yield strength when using the ideal elastic-plastic stress-strain diagram.



Real tension curve and the ideal elastic-plastic diagram of material

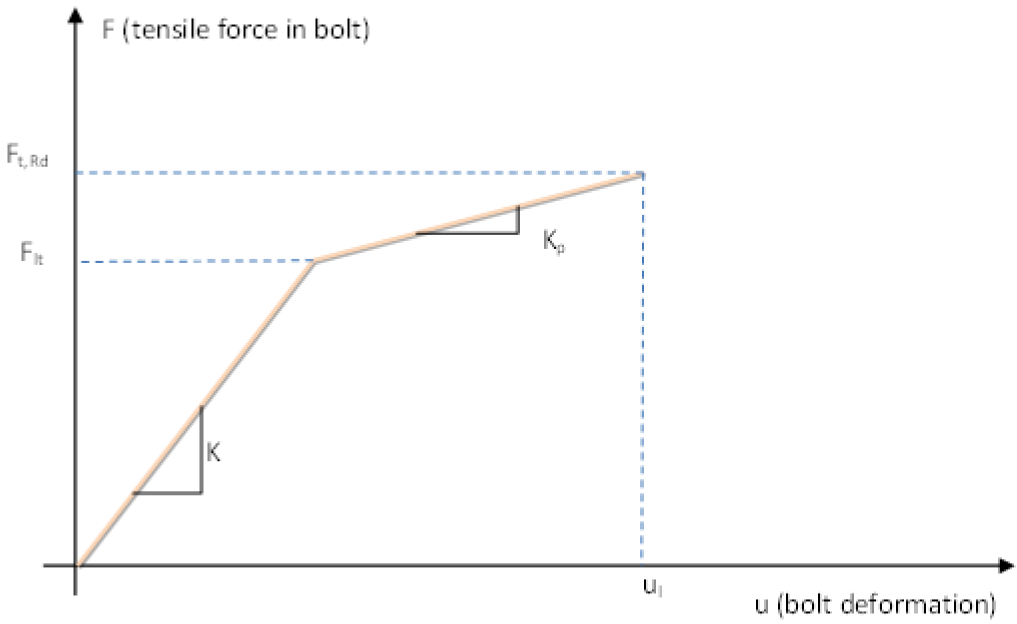
CBFEM method aims to model the real state precisely. Meshes of plates / walls are not merged, no intersections are generated between them, unlike it is used to when modelling structures and buildings. Mesh of finite elements is generated on each individual plate independently on mesh of other plates.
Between the meshes, special massless force interpolation constraints are added. They ensure the connection between the edge of one plate and the surface or edge of the other plate.
This unique calculation model provides very good results – both for the point of view of precision and of the analysis speed. The method is protected by patent.
The steel base plate is placed loosely on the concrete foundation. It is a contact element in the analysis model – the connection resists compression fully, but does not resist tension.



Stress-strain diagram of contact between the concrete block and the base plate

Welds are modelled using a special elastoplastic element, which is added to the interpolation links between the plates. The element respects the weld throat thickness, position and orientation. The plasticity state is controlled by stresses in the weld throat section. The plastic redistribution of stress in welds allows for stress peaks to be redistributed along the longer part of the weld.

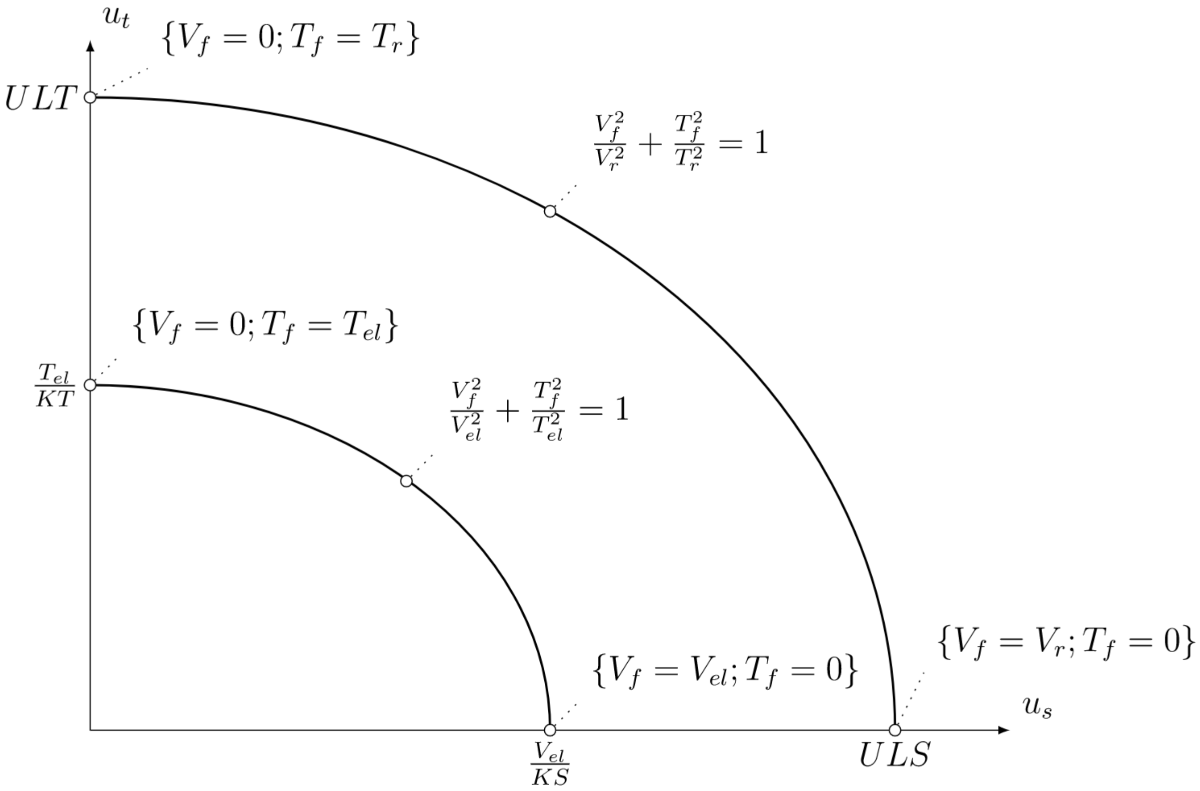
Bolted connection consists of two or more clasped plates and one or more bolts. Plates are placed loosely on each other. A contact element is inserted between plates in the analysis model, which acts only in compression. No forces are carried in tension. Shear force is taken by bearing. Special model for its transferring in the force direction only is implemented. IDEA StatiCa Connection can check bolts for interaction of shear and tension. The bolt behavior is implemented according to the following picture.



Bolt – tension

Symbol explanation:

- K – linear stiffness of bolt,
- K_p – stiffness of bolt at plastic branch,
- F_{lt} – limit force for linear behaviour of bolt,
- $F_{t,Rd}$ – limit bolt resistance,
- u_l – limit deformation of bolt.

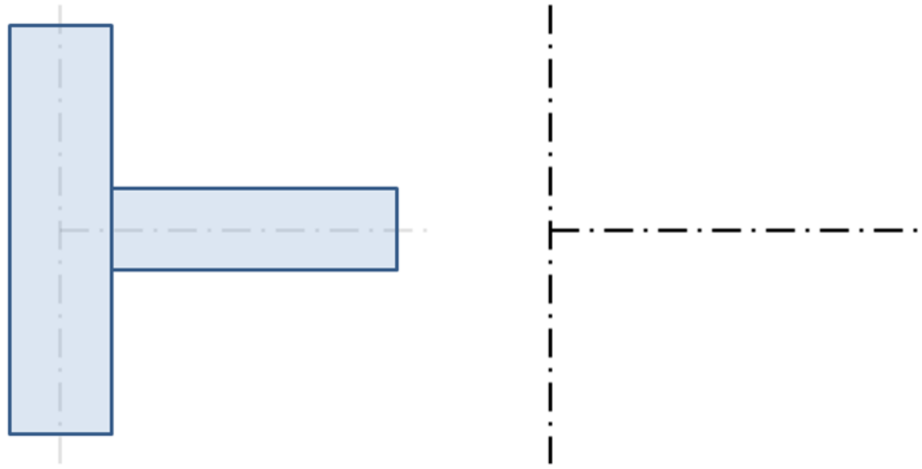


Bolt - interaction of shear and tension

The concrete block in CBFEM is modelled using Winkler-Pasternak subsoil model. The stiffness of subsoil is determined using modulus of elasticity of concrete and effective height of subsoil. The concrete block is not designed by CBFEM method.

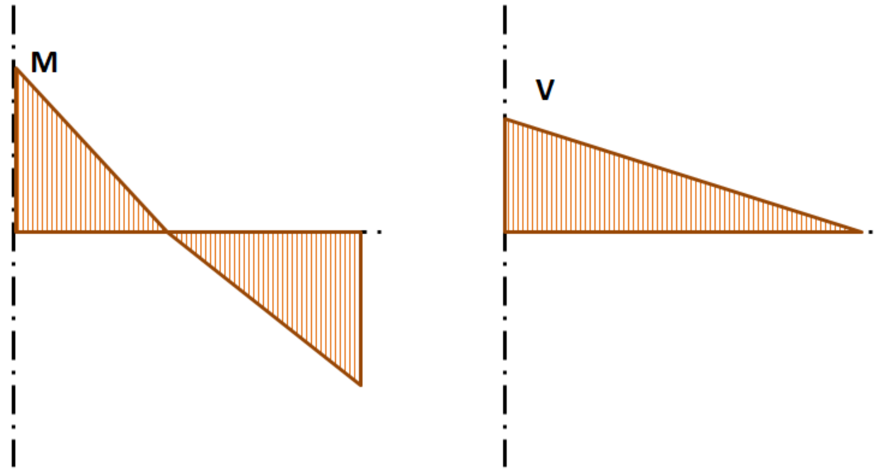
Loads

End forces of member of the frame analysis model are transferred to the ends of member segments. Eccentricities of members caused by the joint design are respected during load transfer.
The analysis model created by CBFEM method corresponds to the real joint very precisely, whereas the analysis of internal forces is performed on very idealised 3D FEM 1D model, where individual beams are modelled using centrelines and the joints are modelled using immaterial nodes.



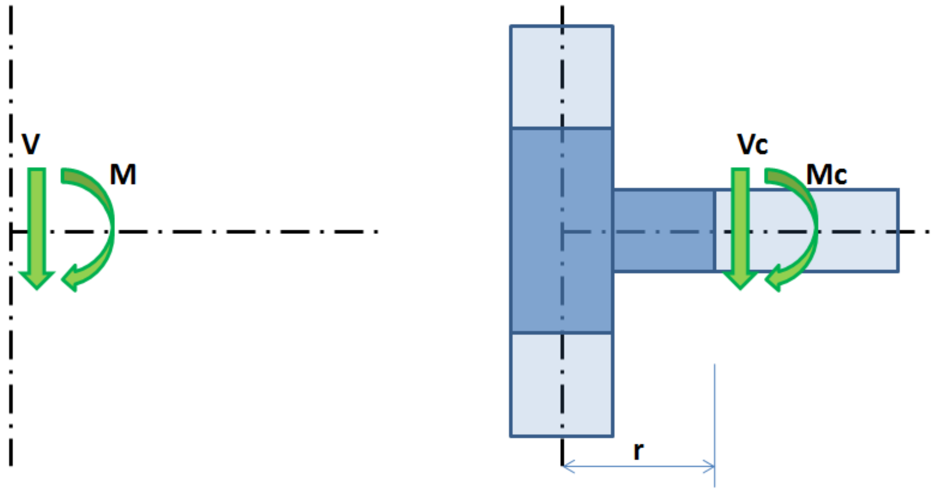
Joint of a vertical column and a horizontal beam

Internal forces are analysed using 1D members in 3D model. There is an example of courses of internal forces in the following picture.



Internal forces in horizontal beam. M and V are the end forces at joint.

The effects caused by member on the joint are important to design the joint (connection). The effects are illustrated in the following picture.



Effects of the member on the joint. CBFEM model is drawn in dark blue color.

Moment *M* and shear force *V* act in a theoretical joint. The point of theoretical joint does not exist in CBFEM model, thus the load cannot be applied here. The model must be loaded by actions *M* and *V*, which have to be transferred to the end of segment in the distance *r*.
$M_c = M - V \cdot r$
$V_c = V$
In CBFEM model, the end section of segment is loaded by moment M_c and force V_c.

Welds

Fillet welds

The resistance for direct shear and tension or compression induced shear is designed according to S16-14 – 13.13.2.2. Plastic redistribution in weld material is applied in Finite Element Modelling. M_w equals to 1.0 in IDEA and the resistance of multi-orientation welds is determined by FEA where the most stressed element is assessed. Base metal capacity at the fusion face is always assessed.

CJP groove welds

The resistance of Complete Joint Penetration (CJP) groove welds is assumed as that of the base metal.

Bolts

Tensile strength of bolts

The tensile resistance of a bolt is assessed according to Clause 13.12.1.3.

Shear strength of bolts

The shear resistance of a bolt is assessed according to Clause 13.12.1.2. Each shear plane of a bolt is checked separately. When the bolt threads are intercepted by a shear plane, the shear resistance is taken as $0.7V_r$.

Combined tension and shear in bearing type connection

The resistance of a bolt loaded by combined tension and shear is assessed according to Clause 13.12.1.4.

Bearing strength in bolt holes

The resistance developed at the bolt in a bolted joint subjected to bearing and shear is assessed according to Clause 13.12.1.2.

Hole tear-out of a bolt

The resistance of hole tear-out of a bolt is checked for individual bolts according to Clause 13.11.

Bolts in slip-critical connections

The slip resistance of a bolted joint is assessed according to Clause 13.12.2. When slotted holes are used in slip-critical connections, the slip resistance is multiplied by a factor of 0.75. A tension and shear interaction is assessed.

Concrete design bearing strength in compression

The compressive resistance of concrete is determined in accordance with S16-14 – 25.3.1 and CSA A23.3 – 10.8. The load is distributed upon the supporting surface (geometrically similar lower area of the frustum having its slopes of 1 vertical to 2 horizontal) of the concrete when the foundation block is larger than the base plate. The average stress under the base plate in contact with the foundation pad is compared to the concrete design bearing strength in compression.

Anchors

Anchor rods are designed according to A23.3-14 – Annex D. The following resistances of anchor bolts are evaluated:

- Steel strength of anchor in tension N_{sar}
- Concrete breakout strength in tension N_{cbr}
- Concrete pullout strength N_{pr}
- Concrete side-face blowout strength N_{sbr}
- Steel strength of anchor in shear V_{sar}
- Concrete breakout strength in shear V_{cbr}
- Concrete pryout strength of anchor in shear V_{cpr}

Steel resistance of anchor in tension

Steel strength of anchor in tension is determined according to CSA A23.3-14 – D.6.1.

Concrete breakout resistance of anchor in tension

Concrete breakout strength is designed according to the Concrete Capacity Design (CCD) in CSA A23.3-14 – D.6.2. In the CCD method, the concrete cone is considered to be formed at an angle of approximately 34° (1 vertical to 1.5 horizontal slope). For simplification, the cone is considered to be square rather than round in plan. The concrete breakout stress in the CCD method is considered to decrease with an increase in size of the breakout surface.
The modification factor for anchor groups loaded by an eccentric tension force is not taken into account because each anchor is assessed with the design force evaluated by finite element method.

Concrete pullout resistance of anchor in tension

Concrete pullout strength of anchor is defined in CSA A23.3-14 – D.6.3. Concrete pullout strength for other types of anchors than headed or hooked is not evaluated in the software and has to be specified by the manufacturer.

Concrete side-face blowout resistance

Concrete side-face blowout strength of headed anchor in tension is defined in CSA A23.3-14 – D.6.4.

Steel resistance of anchor in shear

The steel strength in shear is determined according to A23.3 – D.7.1. If mortar joint is selected, steel strength in shear V_{sa} is multiplied by 0.8 (A23.3 –D.7.1.3). The shear on lever arm, which is present in case of base plate with oversized holes and washers or plates added to the top of the base plate to transmit the shear force, is not considered.

Concrete breakout resistance of anchor in shear

Concrete breakout strength of an anchor in shear is designed according to A23.3 –D.7.2. The modification factor for anchor groups loaded by an eccentric tension force is not taken into account because each anchor is assessed with the design force evaluated by finite element method.

Concrete pryout resistance of an anchor in shear

Concrete pryout strength is designed according to A23.3 – D.7.3.

Interaction of tensile and shear forces

Interaction of tensile and shear forces is assessed according to A23.3 – Figure D.18.

$$\left(\frac{N_f}{N_r}\right)^{5/3} + \left(\frac{V_f}{V_r}\right)^{5/3} \leq 1.0$$

where:

- N_f and V_f are design forces acting on an anchor
- N_r and V_r are the lowest design strengths determined from all appropriate failure modes

Anchors with stand-off

Anchor with stand-off is designed as a bar element loaded by shear force, bending moment and compressive or tensile force. These internal forces are determined by finite element model. The anchor is fixed on both sides, one side is 0.5×d below the concrete level, the other side is in the middle of the thickness of the plate. The buckling length is conservatively assumed as twice the length of the bar element. Plastic section modulus is used. The bar element is designed according to CSA S16-14. Interaction of shear force is neglected because the minimum length of the anchor to fit the nut under the base plate ensures that the anchor fails in bending before the shear force reaches half the shear resistance and the shear interaction is negligible (up to 7 %). Interaction of bending moment and compressive or tensile force is conservatively assumed as linear. Second order effects are not taken into account.
Shear resistance is checked according to CSA S16-14 – 13.4.4
Tensile resistance is checked according to CSA S16-14 – 13.2
Compressive resistance is checked according to CSA S16-14 – 13.3.1
Bending resistance is checked according to CSA S16-14 – 13.5
Linear interaction for combined bending moment and axial force is used.

Software info

Application	IDEA StatiCa Connection
Version	22.0.0.3013
Developed by	IDEA StatiCa