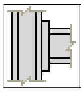
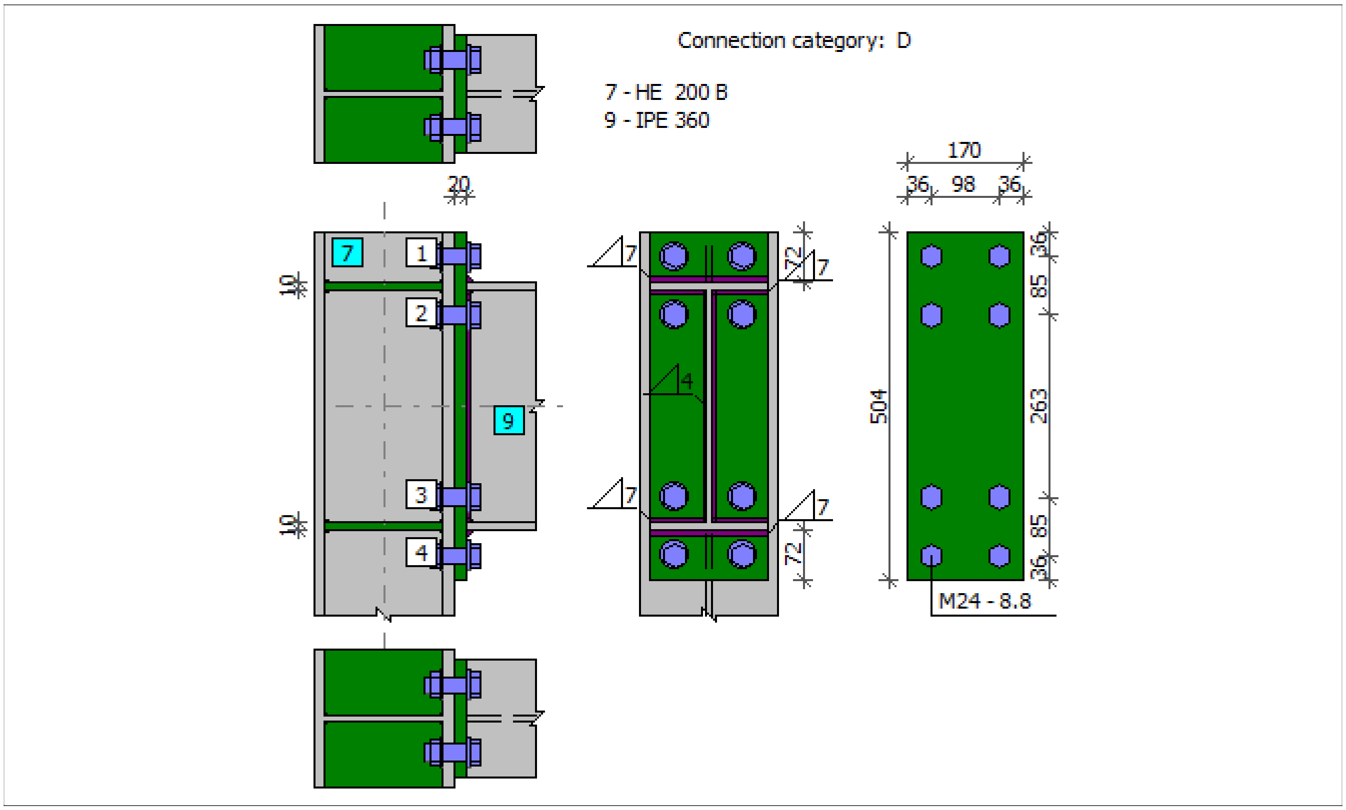
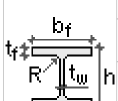
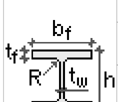
	Beam - column (front plate) EC3 1991-1-8: 2008	Ratio : 0.81	✓

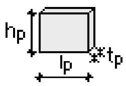
Structure node: 14
Structure bars: 7, 9



Data

Column HE 200 B					
	h_c	b_{fc}	t_{fc}	t_{wc}	R_c
	200.00mm	200.00mm	15.00mm	9.00mm	0.00mm
	A_c	J_{y0c}	J_{z0c}	y_{0c}	z_{0c}
	78.08cm^2	5696.17cm^4	2003.37cm^4	100.00mm	100.00mm
Material	Grade	f_y	f_u		
	S 355	355.00MPa	510.00MPa		

Beam IPE 360					
	h_b	b_{fb}	t_{fb}	t_{wb}	R_b
	360.00mm	170.00mm	12.70mm	8.00mm	0.00mm
	A_b	J_{y0b}	J_{z0b}	y_{0b}	z_{0b}
	72.73cm^2	16270.00cm^4	1043.45cm^4	85.00mm	180.00mm
Material	Grade	f_y	f_u		
	S 355	355.00MPa	510.00MPa		

Front plate			
	l_p	h_p	t_p
	$170.00mm$	$504.00mm$	$20.00mm$
Material	Grade	f_y	f_u
	S 355	$355.00MPa$	$510.00MPa$

Bolts connecting front plate and column flange

Grade		8.8
Yield point	$f_y =$	$640.00MPa$
Resistance on tension	$f_u =$	$800.00MPa$
Bolt diameter	$d =$	$24.00mm$
Bolt opening diameter	$d_0 =$	$27.00mm$
Area of bolt section	$A =$	$4.52cm^2$
Effective section area of a bolt	$A_s =$	$3.53cm^2$
Number of rows	$w =$	$4.00mm$
Distance from horizontal edge	$e_1 =$	$36.00mm$
Horizontal spacing	$w_1 =$	$98.00mm$
Number of bolts in rows		$m_1 = 2; m_2 = 2; m_3 = 2; m_4 = 2$
Vertical spacing of rows		$p_1 = 84.70mm; p_2 = 262.60mm; p_3 = 84.70mm$

Welds

Thickness of fillet welds connecting beam flanges and front plate	$a_f =$	$7.00mm$
Thickness of fillet welds connecting beam web and front plate	$a_w =$	$4.00mm$

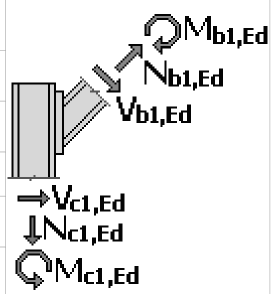
Materials coeffs

Coefficient	$\gamma_{M0} =$	1.00
Coefficient	$\gamma_{M1} =$	1.00
Coefficient	$\gamma_{M2} =$	1.25

Forces

Design loads Co #2

Right beam		
Axial force	$N_{b1,Ed} =$	$-44.28kN$
Shear force	$V_{b1,Ed} =$	$62.88kN$
Bending moment	$M_{b1,Ed} =$	$113.42kNm$
Lower column		
Axial force	$N_{c1,Ed} =$	$-85.29kN$
Shear force	$V_{c1,Ed} =$	$44.44kN$
Bending moment	$M_{c1,Ed} =$	$113.34kNm$



Results

Column web panel in shear

The section area of column web panel

$$A_{vc} = A_c - 2 \cdot b_{fc} \cdot t_{fc} + (t_{wc} + 2 \cdot r_c) \cdot t_{fc} = 78.08cm^2 - 2 \cdot 200.00mm \cdot 15.00mm + (9.00mm + 2 \cdot 0.00mm) \cdot 15.00mm = 19.43cm^2$$

The plastic moment resistance of a column flange

$$M_{pl,fc,Rd} = \frac{0.25 \cdot b_{fc} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 200.00mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 3.99kNm$$

The distance between the centrelines of the stiffeners

$$d_s = 347.30mm$$

The plastic moment resistance of a stiffener-top flange level of beam

$$M_{pl,stu,Rd} = \frac{0.25 \cdot b_{fc} \cdot t_{sfu}^2 \cdot f_{ys}}{\gamma_{M0}} = \frac{0.25 \cdot 200.00mm \cdot (10.00mm)^2 \cdot 355.00MPa}{1.00} = 0.17kNm$$

The plastic moment resistance of a stiffener-bottom flange level of beam

$$M_{pl,stl,Rd} = \frac{0.25 \cdot b_{fc} \cdot t_{sfl}^2 \cdot f_{ys}}{\gamma_{M0}} = \frac{0.25 \cdot 200.00mm \cdot (10.00mm)^2 \cdot 355.00MPa}{1.00} = 0.17kNm$$

The additional shear resistance due to stiffeners

$$V_{wp,add,Rd} = min\left(\frac{4 \cdot M_{pl,fc,Rd}}{d_s} ; \frac{2 \cdot M_{pl,fc,Rd} + 2 \cdot M_{pl,st,Rd}}{d_s}\right) = \min\left(\frac{4 \cdot 3.99kNm}{347.30mm} ; \frac{2 \cdot 3.99kNm + 2 \cdot 0.34kNm}{347.30mm}\right) = 24.95kN$$

The plastic shear resistance of a column web panel

$$V_{wp,Rd} = \frac{0.9 \cdot A_{vc} \cdot f_{ywc}}{\sqrt{3} \cdot \gamma_{M0}} + V_{wp,add,Rd} = \frac{0.9 \cdot 19.43cm^2 \cdot 355.00MPa}{\sqrt{3} \cdot 1.00} + 24.95kN = 383.36kN$$

The resulting shear force in the web panel

$$V_{wp,Ed} = \frac{M_{b1,Ed} - M_{b2,Ed}}{z} - 0.5 \cdot (V_{c1,Ed} - V_{c2,Ed}) = \frac{113.42kNm - 0.00kNm}{347.30mm} - 0.5 \cdot (44.44kN - 0.00kN) = 304.35kN$$

$\lvert V_{wp,Ed} \rvert \le V_{wp,Rd}$	$\lvert 304.35kN \rvert < 383.36kN$	0.79	✓

Column web in transverse compression

Calculation parameter

$$s_p = min(t_p + c ; 2 \cdot t_p) = \min(20.00mm + 72.00mm ; 2 \cdot 20.00mm) = 40.00 \text{ mm}$$

The effective width of the column web in compression

$b_{eff,c,wc} = t_{fb} + 2\cdot\sqrt{2}\cdot a_f + 5\cdot(t_{fc} + r_c) + s_p = 12.70mm + 2\cdot\sqrt{2}\cdot 7.00mm + 5\cdot(15.00mm + 0.00mm) + 40.00mm = 147.50mm$

Reduction factor

$$\omega_1 = \frac{1}{\sqrt{1 + 1.3\cdot\left(\frac{b_{eff,c,wc}\cdot t_{wc}}{A_{vc}}\right)^2}} = \frac{1}{\sqrt{1 + 1.3\cdot\left(\frac{147.50\cdot 9.00mm}{19.43cm^2}\right)^2}} = 0.79$$

$\omega = \omega_1 = 0.79$

Design resistance of column web subject to transverse compression

$$F_{c,wc,Rd1} = \frac{\omega\cdot k_{wc}\cdot b_{eff,c,wc}\cdot t_{wc}\cdot f_{y,wc}}{\gamma_{M0}} = \frac{0.79\cdot 1.00\cdot 147.50mm\cdot 9.00mm\cdot 355.00MPa}{1.00} = 371.77kN$$

The depth of the column web

$d_{wc} = h_c - 2\cdot(t_{fc} + r_c) = 200.00mm - 2\cdot(15.00mm + 0.00mm) = 170.00mm$

Plate slenderness

$$\lambda_p = 0.932\cdot\sqrt{\frac{b_{eff,c,wc}\cdot d_{wc}\cdot f_{y,wc}}{E\cdot t_{wc}^2}} = 0.932\cdot\sqrt{\frac{147.50mm\cdot 170.00mm\cdot 355.00MPa}{210000.00MPa\cdot(9.00mm)^2}} = 0.67$$

The reduction factor for plate buckling

$$\rho = \frac{\lambda_p - 0.22}{\lambda_p^2} = \frac{0.67 - 0.22}{(0.67)^2} = 1.00$$

$$F_{c,wc,Rd2} = \frac{\omega\cdot k_{wc}\cdot\rho\cdot b_{eff,c,wc}\cdot t_{wc}\cdot f_{y,wc}}{\gamma_{M1}} = \frac{0.79\cdot 1.00\cdot 1.00\cdot 147.50mm\cdot 9.00mm\cdot 355.00MPa}{1.00} = 371.77kN$$

$$F_{c,wc,Rd,st} = \frac{(b_{fc} - t_{wc})\cdot t_s\cdot f_{y,s}}{\gamma_{M0}} = \frac{(200.00mm\cdot 9.00mm)\cdot 10.00mm\cdot 355.00MPa}{1.00} = 678.05kN$$

Design resistance of column web subject to transverse compression

$F_{c,wc,Rd} = min(F_{c,wc,Rd1};\ F_{c,wc,Rd2}) + F_{c,wc,Rd,st} = min(371.77kN;\ 371.77kN)$ + 678.05 kN = 1049.82 kN

Beam flange and web in compression

Plastic section modulus

$W_{pl} = 973.74cm^3$

The design resistance for bending of cross-section

$$M_{c,Rd} = \frac{W_{pl}\cdot f_{yb}}{\gamma_{M0}} = \frac{973.74cm^3\cdot 355.00MPa}{1.00} = 345.68kNm$$

Distance between beam flanges

$h_f = 347.30mm$

Design resistance of flange beam subject compression

$$F_{c,fb,Rd} = \frac{M_{c,Rd}}{h_f} = \frac{345.68kNm}{347.30mm} = 995.32kN$$

Bolts connecting front plate and column flange

Tensile resistance of a bolt

$$F_{t,Rd} = \frac{k_2 \cdot f_{ub} \cdot A_s}{\gamma_{M2}} = \frac{0.90 \cdot 800.00 MPa \cdot 3.53 cm^2}{1.25} = 203.33 kN$$

Shear section area of bolt

$$A = 0.25 \cdot \pi \cdot d^2 = 0.25 \cdot \pi \cdot (24.00 mm)^2 = 4.52 cm^2$$

Shear resistance of bolt in one surface

$$F_{v,Rd} = \frac{\alpha_v \cdot m \cdot f_{ub} \cdot A}{\gamma_{M2}} = \frac{0.60 \cdot 1 \cdot 800.00 MPa \cdot 4.52 cm^2}{1.25} = 173.72 kN$$

Punching shear resistance of a bolt

$$B_{p,Rd} = \frac{0.6 \cdot \pi \cdot d_m \cdot t_{fc} \cdot f_{uc}}{\gamma_{M2}} = \frac{0.6 \cdot \pi \cdot 37.99 mm \cdot 15.00 mm \cdot 510.00 MPa}{1.25} = 438.25 kN$$

Tension zone

BOLTS ROW 1

Column flange in bending

Geometrical parameters

Bolt distance from upper edge column

$$e_{1fc} = e_c + e_1 = 0.00 mm + 36.00 mm = 36.00 mm$$

Bolt distance from outer edge

$$e_{fc} = 51.00 mm$$

Bolt distance from column web

$$m_{fc} = 0.5 \cdot (w - t_{wc}) - 0.8 \cdot r_c = 0.5 \cdot (98.00 mm - 9.00 mm) - 0.8 \cdot 0.00 mm = 44.50 mm$$

Distance e{min}

$$e_{min} = 36.00 mm$$

Calculation parameter n

$$n = min(e_{min} ;\ 1.25 \cdot m_{fc}) = \min(36.00 mm ;\ 1.25 \cdot 44.50 mm) = 51.00 mm$$

Calculation parameter

$$m_{2fc} = p_1 + e_1 - e_{p1} - t_{fb} - 0.8 \cdot a_f \cdot \sqrt{2} = 84.70 mm + 36.00 mm - 72.00 mm - 15.00 mm - 0.8 \cdot 7.00 mm \cdot \sqrt{2} = 383.99 mm$$

$$\lambda_1 = \frac{m_{fc}}{m_{fc} + e_{fc}} = \frac{44.50 mm}{44.50 mm + 51.00 mm} = 0.47$$

$$\lambda_2 = \frac{m_{2fc}}{m_{fc} + e_{fc}} = \frac{383.99 mm}{44.50 mm + 51.00 mm} = 4.02$$

$$\alpha = 5.44$$

Effective length for one bolt in circular patterns

$$l_{eff,cp,1} = 2 \cdot \pi \cdot m_{fc} = 2 \cdot \pi \cdot 44.50 mm = 279.60 mm$$

$$l_{eff,cp,2} = \pi \cdot m_{fc} + 2 \cdot e_1 = \pi \cdot 44.50 mm + 2 \cdot 51.00 mm = 211.80 mm$$

$$l_{eff,cp} = min(l_{eff,cp,1} ;\ l_{eff,cp,2}) = \min(279.60 mm ;\ 211.80 mm) = 211.80 mm$$

Effective length for one bolt in non-circular patterns

$$l_{eff,nc} = e_1 + \alpha \cdot m_{fc} - (2 \cdot m_{fc} + 0.625 \cdot e) = 36.00 mm + 5.44 \cdot 44.50 mm - (2 \cdot 44.50 mm + 0.625 \cdot 51.00 mm) = 157.21 mm$$

Effective length for one bolt for 1 mode

$$l_{eff,1} = min(l_{eff,cp} ;\ l_{eff,nc}) = \min(211.80 mm ;\ 157.21 mm) = 157.21 mm$$

Effective length for one bolt for 2 mode

$l_{eff,2} = l_{eff,nc} = 157.21mm$

Model 1: Complete yielding of the column flange

$$M_{pl,1,Rd} = \frac{0.25 \cdot l_{eff,1} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 157.21mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 3.14kNm$$

Method 1

$$F_{T,1,Rd1} = \frac{4 \cdot M_{pl,1,Rd}}{m_{fc}} = \frac{4 \cdot 3.14kNm}{44.50mm} = 282.18kN$$

Method 2 (alternative method)

Parameter for bearing zone

$e_w = 0.25 \cdot d_w = 0.25 \cdot 44.00mm = 11.00mm$

$$F_{T,1,Rd2} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m_{fc} \cdot n - e_w \cdot (m_{fc} + n)} = \frac{(8 \cdot 51.00mm - 2 \cdot 11.00mm) \cdot 3.14kNm}{2 \cdot 44.50mm \cdot 51.00mm - 11.00mm \cdot (44.50mm + 51.00mm)} = 347.35kN$$

$F_{T,1,Rd} = min(F_{T,1,Rd1}; F_{T,1,Rd2}) = \min(282.18kN; 347.35kN) = 282.18$ kN

Model 2: Bolt failure with yielding of the column flange

$$M_{pl,2,Rd} = \frac{0.25 \cdot l_{eff,2} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 157.21mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 3.14kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum F_{t,Rd}}{m_{fc} + n} = \frac{2 \cdot 3.14kNm + 51.00mm \cdot 2 \cdot 203.33kN}{44.50mm + 51.00mm} = 282.91kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 2 \cdot 203.33kN = 406.66kN$$

Component resistance

$F_{t,fc,Rd(1)} = min(F_{T,1,Rd}; F_{T,2,Rd}; F_{T,3,Rd}) = \min(282.18kN; 282.91kN; 406.66kN) = 282.18$ kN

Column web in transverse tension

The section area of column web panel

$$A_{vc} = A_c - 2 \cdot b_{fc} \cdot t_{fc} + (t_{wc} + r_c) \cdot t_{fc} = 78.08cm^2 - 2 \cdot 200.00mm \cdot 15.00mm + (9.00mm + 0.00mm) \cdot 15.00mm = 19.43cm^2$$

The effective width of the column web in tension

$b_{eff,t,wc} = l_{eff,1(1)} = 157.21mm$

Reduction factor

$$\omega_1 = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{b_{eff,t,wc} \cdot t_{wc}}{A_{vc}}\right)^2}} = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{157.21 \cdot 9.00mm}{19.43cm^2}\right)^2}} = 0.77$$

$\omega = \omega_1 = 0.77$

$$F_{t,wc,Rd,st} = \frac{(b_{fc} - t_{wc}) \cdot t_s \cdot f_{y,s}}{\gamma_{M0}} = \frac{(200.00mm - 9.00mm) \cdot 10.00mm \cdot 355.00MPa}{1.00} = 678.05kN$$

Design resistance of column web subject to transverse tension

$$F_{t,wc,Rd(1)} = \frac{\omega \cdot b_{eff,t,wc} \cdot t_{wc} \cdot f_{y,wc}}{\gamma_{M0}} + F_{t,wc,Rd,st} = \frac{0.77 \cdot 157.21mm \cdot 9.00mm \cdot 355.00MPa}{1.00} + 678.05kN = 1064.49kN$$

End plate in bending

Geometrical parameters

Bolt distance from outer edge

$e_{ep} = 36.00mm$

Bolt distance from beam web

$m_{ep} = 0.5 \cdot (w - t_{wb}) - 0.8 \cdot \sqrt{2} \cdot a_w = 0.5 \cdot (98.00mm - 8.00mm) - 0.8 \cdot \sqrt{2} \cdot 4.00mm = 40.47mm$

Distance e{min}

$e_{min} = min(e_x ; e_{ep}) = \min(36.00mm ; 36.00mm) = 36.00mm$

Calculation parameter n

$n = min(e_{min} ; 1.25 \cdot m_{ep}) = \min(36.00mm ; 1.25 \cdot 40.47mm) = 35.10mm$

Bolt distance from beam flange

$m_x = e_{p1} - e_1 - 0.8 \cdot a_f \cdot \sqrt{2} = 72.00mm - 36.00mm - 0.8 \cdot 7.00mm \cdot \sqrt{2} = 28.08mm$

Bolt distance from outer horizontal edge plate

$e_x = e_1 = 36.00mm$

Effective length for one bolt in circular patterns

$l_{eff,cp,1} = 2 \cdot \pi \cdot m_x = 2 \cdot \pi \cdot 28.08mm = 176.43mm$

$l_{eff,cp,2} = \pi \cdot m_x + w = \pi \cdot 28.08mm + 98.00mm = 186.22mm$

$l_{eff,cp,3} = \pi \cdot m_x + 2 \cdot e = \pi \cdot 28.08mm + 2 \cdot 36.00mm = 160.22mm$

$l_{eff,cp} = min(l_{eff,cp,1} ; l_{eff,cp,2} ; l_{eff,cp,3}) = \min(176.43mm ; 186.22mm ; 160.22mm) = 160.22mm$

Effective length for one bolt in non-circular patterns

$l_{eff,nc,1} = 4 \cdot m_x + 1.25 \cdot e_x = 4 \cdot 28.08mm + 1.25 \cdot 36.00mm = 157.32mm$

$l_{eff,nc,2} = e + 2 \cdot m_x + 0.625 \cdot e_x = 36.00mm + 2 \cdot 28.08mm + 0.625 \cdot 36.00mm = 114.66mm$

$l_{eff,nc,3} = 0.5 \cdot b_p = 0.5 \cdot 170.00mm = 85.00mm$

$l_{eff,nc,4} = 0.5 \cdot w + 2 \cdot m_x + 0.625 \cdot e_x = 0.5 \cdot 98.00mm + 2 \cdot 28.08mm + 0.625 \cdot 36.00mm = 127.66mm$

$l_{eff,nc} = min(l_{eff,nc,1} ; l_{eff,nc,2} ; l_{eff,nc,3} ; l_{eff,nc,4}) = \min(157.32mm ; 114.66mm ; 85.00mm ; 127.66mm) = 85.00mm$

Effective length for one bolt for 1 mode

$l_{eff,1} = min(l_{eff,cp} ; l_{eff,nc}) = \min(160.22mm ; 85.00mm) = 85.00mm$

Effective length for one bolt for 2 mode

$l_{eff,2} = l_{eff,nc} = 85.00mm$

Model 1: Complete yielding of the end plate

$$M_{pl,1,Rd} = \frac{0.25 \cdot l_{eff,1} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 85.00mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 3.02kNm$$

Method 1

$$F_{T,1,Rd1} = \frac{4 \cdot M_{pl,1,Rd}}{m_x} = \frac{4 \cdot 3.02kNm}{28.08mm} = 429.84kN$$

Method 2 (alternative method)

Parameter for bearing zone

$e_w = 0.25 \cdot d_w = 0.25 \cdot 44.00mm = 11.00mm$

$$F_{T,1,Rd2} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m_x \cdot n - e_w \cdot (m_x + n)} = \frac{(8 \cdot 35.10mm - 2 \cdot 11.00mm) \cdot 3.02kNm}{2 \cdot 28.08mm \cdot 35.10mm - 11.00mm \cdot (28.08mm + 35.10mm)} = 611.89kN$$

$F_{T,1,Rd} = min(F_{T,1,Rd1}\ ;\ F_{T,1,Rd2}) = \min(429.84kN\ ;\ 611.89kN) = 429.84\ \text{kN}$

Model 2: Bolt failure with yielding of the end plate

$$M_{pl,2,Rd} = \frac{0.25 \cdot l_{eff,2} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 85.00mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 3.02kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum F_{t,Rd}}{m_x + n} = \frac{2 \cdot 3.02kNm + 35.10mm \cdot 2 \cdot 203.33kN}{28.08mm + 35.10mm} = 321.44kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 2 \cdot 203.33kN = 406.66kN$$

Component resistance

$F_{t,ep,Rd(1)} = min(F_{T,1,Rd}\ ;\ F_{T,2,Rd}\ ;\ F_{T,3,Rd}) = \min(429.84kN\ ;\ 321.44kN\ ;\ 406.66kN) = 321.44\ \text{kN}$

Resistance of the bolt row 1

$F_{t,Rd(1)M} = min$			
.	$F_{t,fc,Rd(1)} =$	$282.18kN$	
.	$F_{t,wc,Rd(1)} =$	$1064.49kN$	
.	$F_{t,ep,Rd(1)} =$	$321.44kN$	
.	$\frac{V_{wp,Rd}}{\beta} =$	$\frac{383.36kN}{1.00} =$	$383.36kN$
.	$F_{cwc,Rd} =$	$1049.82kN$	
.	$F_{cfb,Rd} =$	$995.32kN$	
$= 282.18kN$			

BOLTS ROW 2

Column flange in bending

Geometrical parameters

Bolt distance from outer edge

$e_{fc} = 51.00mm$

Bolt distance from column web

$m_{fc} = 0.5 \cdot (w - t_{wc}) - 0.8 \cdot r_c = 0.5 \cdot (98.00mm - 9.00mm) - 0.8 \cdot 0.00mm = 44.50mm$

Distance e{min}

$e_{min} = 36.00mm$

Calculation parameter n

$n = min(e_{min}\ ;\ 1.25 \cdot m_{fc}) = \min(36.00mm\ ;\ 1.25 \cdot 44.50mm) = 51.00mm$

Effective length for one bolt in circular patterns

$l_{eff,cp} = 2 \cdot \pi \cdot m_{fc} = 2 \cdot \pi \cdot 44.50mm = 279.60mm$

Effective length for one bolt in non-circular patterns

$l_{eff,nc} = 4 \cdot m_{fc} + 1.25 \cdot e = 4 \cdot 44.50mm + 1.25 \cdot 51.00mm = 241.75mm$

Effective length for one bolt for 1 mode

$l_{eff,1} = min(l_{eff,cp}\ ;\ l_{eff,nc}) = \min(279.60mm\ ;\ 241.75mm) = 241.75mm$

Effective length for one bolt for 2 mode

$l_{eff,2} = l_{eff,nc} = 241.75mm$

Model 1: Complete yielding of the column flange

$$M_{pl,1,Rd} = \frac{0.25 \cdot l_{eff,1} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 241.75mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 4.83kNm$$

Method 1

$$F_{T,1,Rd1} = \frac{4 \cdot M_{pl,1,Rd}}{m_{fc}} = \frac{4 \cdot 4.83kNm}{44.50mm} = 433.93kN$$

Method 2 (alternative method)

Parameter for bearing zone

$e_w = 0.25 \cdot d_w = 0.25 \cdot 44.00mm = 11.00mm$

$$F_{T,1,Rd2} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m_{fc} \cdot n - e_w \cdot (m_{fc} + n)} = \frac{(8 \cdot 51.00mm - 2 \cdot 11.00mm) \cdot 4.83kNm}{2 \cdot 44.50mm \cdot 51.00mm - 11.00mm \cdot (44.50mm + 51.00mm)} = 534.15kN$$

$F_{T,1,Rd} = min(F_{T,1,Rd1} ; F_{T,1,Rd2})$ = min (433.93kN ; 534.15kN) = 433.93 kN

Model 2: Bolt failure with yielding of the column flange

$$M_{pl,2,Rd} = \frac{0.25 \cdot l_{eff,2} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 241.75mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 4.83kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum F_{t,Rd}}{m_{fc} + n} = \frac{2 \cdot 4.83kNm + 51.00mm \cdot 2 \cdot 203.33kN}{44.50mm + 51.00mm} = 318.27kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 2 \cdot 203.33kN = 406.66kN$$

Component resistance

$F_{t,fc,Rd(1)} = min(F_{T,1,Rd} ; F_{T,2,Rd} ; F_{T,3,Rd})$ = min (433.93kN ; 318.27kN ; 406.66kN) = 318.27 kN

Column web in transverse tension

The section area of column web panel

$$A_{vc} = A_c - 2 \cdot b_{fc} \cdot t_{fc} + (t_{wc} + r_c) \cdot t_{fc} = 78.08cm^2 - 2 \cdot 200.00mm \cdot 15.00mm + (9.00mm + 0.00mm) \cdot 15.00mm = 19.43cm^2$$

The effective width of the column web in tension

$b_{eff,t,wc} = l_{eff,1(2)} = 241.75mm$

Reduction factor

$$\omega_1 = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{b_{eff,t,wc} \cdot t_{wc}}{A_{vc}}\right)^2}} = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{241.75 \cdot 9.00mm}{19.43cm^2}\right)^2}} = 0.62$$

$\omega = \omega_1 = 0.62$

$$F_{t,wc,Rd,st} = \frac{(b_{fc} - t_{wc}) \cdot t_s \cdot f_{y,s}}{\gamma_{M0}} = \frac{(200.00mm - 9.00mm) \cdot 10.00mm \cdot 355.00MPa}{1.00} = 678.05kN$$

Design resistance of column web subject to transverse tension

$$F_{t,wc,Rd(2)} = \frac{\omega \cdot b_{eff,t,wc} \cdot t_{wc} \cdot f_{y,wc}}{\gamma_{M0}} + F_{t,wc,Rd,st} = \frac{0.62 \cdot 241.75mm \cdot 9.00mm \cdot 355.00MPa}{1.00} + 678.05kN = 1154.32kN$$

End plate in bending

Geometrical parameters

Bolt distance from outer edge

$e_{ep} = 36.00mm$

Bolt distance from beam web

$m_{ep} = 0.5 \cdot (w - t_{wb}) - 0.8 \cdot \sqrt{2} \cdot a_w = 0.5 \cdot (98.00mm - 8.00mm) - 0.8 \cdot \sqrt{2} \cdot 4.00mm = 40.47mm$

Distance e{min}

$e_{min} = 36.00mm$

Calculation parameter n

$n = min(e_{min} ;\ 1.25 \cdot m_{ep}) = \min(36.00mm ;\ 1.25 \cdot 40.47mm) = 36.00mm$

Calculation parameter

$m_{2ep} = p_1 + e_1 - e_{p1} - t_{fb} - 0.8 \cdot a_f \cdot \sqrt{2} = 84.70mm + 36.00mm - 72.00mm - 12.70mm - 0.8 \cdot 7.00mm \cdot \sqrt{2} = 28.08mm$

$$\lambda_1 = \frac{m_{ep}}{m_{ep} + e_{ep}} = \frac{40.47mm}{40.47mm + 36.00mm} = 0.53$$

$$\lambda_2 = \frac{m_{2ep}}{m_{ep} + e_{ep}} = \frac{28.08mm}{40.47mm + 36.00mm} = 0.37$$

$\alpha = 5.88$

Effective length for one bolt in circular patterns

$l_{eff,cp} = 2 \cdot \pi \cdot m_{ep} = 2 \cdot \pi \cdot 40.47mm = 254.31mm$

Effective length for one bolt in non-circular patterns

$l_{eff,nc} = \alpha \cdot m_{ep} = 5.88 \cdot 40.47mm = 238.05mm$

Effective length for one bolt for 1 mode

$l_{eff,1} = min(l_{eff,cp} ;\ l_{eff,nc}) = \min(254.31mm ;\ 238.05mm) = 238.05mm$

Effective length for one bolt for 2 mode

$l_{eff,2} = l_{eff,nc} = 238.05mm$

Model 1: Complete yielding of the end plate

$$M_{pl,1,Rd} = \frac{0.25 \cdot l_{eff,1} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 238.05mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 8.45kNm$$

Method 1

$$F_{T,1,Rd1} = \frac{4 \cdot M_{pl,1,Rd}}{m_{ep}} = \frac{4 \cdot 8.45kNm}{40.47mm} = 835.18kN$$

Method 2 (alternative method)

Parameter for bearing zone

$e_w = 0.25 \cdot d_w = 0.25 \cdot 44.00mm = 11.00mm$

$$F_{T,1,Rd2} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m_{ep} \cdot n - e_w \cdot (m_{ep} + n)} = \frac{(8 \cdot 36.00mm - 2 \cdot 11.00mm) \cdot 8.45kNm}{2 \cdot 40.47mm \cdot 36.00mm - 11.00mm \cdot (40.47mm + 36.00mm)} = 1084.42kN$$

$F_{T,1,Rd} = min(F_{T,1,Rd1} ;\ F_{T,1,Rd2}) = \min(835.18kN ;\ 1084.42kN) = 835.18$ kN

Model 2: Bolt failure with yielding of the end plate

$$M_{pl,2,Rd} = \frac{0.25 \cdot l_{eff,2} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 238.05mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 8.45kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum F_{t,Rd}}{m_{ep} + n} = \frac{2 \cdot 8.45kNm + 36.00mm \cdot 2 \cdot 203.33kN}{40.47mm + 36.00mm} = 412.44kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 2 \cdot 203.33kN = 406.66kN$$

Component resistance

$F_{t,ep,Rd(1)} = min(F_{T,1,Rd} ;\ F_{T,2,Rd} ;\ F_{T,3,Rd})$ = min (835.18kN ; 412.44kN ; 406.66kN) = 406.66 kN

Beam web in tension

Effective width of beam web in tension

$b_{eff,t,wb} = l_{eff1(2)} = 238.05mm$

Component resistance

$$F_{t,wb,Rd(2)} = \frac{b_{eff,t,wb} \cdot t_{wb} \cdot f_{yb}}{\gamma_{M0}} = \frac{238.05mm \cdot 8.00mm \cdot 355.00MPa}{1.00} = 676.07kN$$

Resistance of the bolt row 2

$F_{t,Rd(2)M} = min$			
.	$F_{t,fc,Rd(2)} =$	$318.27kN$	
.	$F_{t,wc,Rd(2)} =$	$1154.32kN$	
.	$F_{t,ep,Rd(2)} =$	$406.66kN$	
.	$F_{t,wb,Rd(2)} =$	$676.07kN$	
.	$\frac{V_{wp,Rd}}{\beta} - F_{t,Rd(1)M} =$	$\frac{383.36kN}{1.00} - 282.18kN =$	$101.19kN$
.	$F_{cwc,Rd} - F_{t,Rd(1)M} =$	$1049.82kN - 282.18kN =$	$767.65kN$
.	$F_{cfb,Rd} - F_{t,Rd(1)M} =$	$995.32kN - 282.18kN =$	$713.15kN$
	$= 101.19kN$		

BOLTS ROW 3

Column flange in bending

Geometrical parameters

Bolt distance from outer edge

$e_{fc} = 51.00mm$

Bolt distance from column web

$m_{fc} = 0.5 \cdot (w - t_{wc}) - 0.8 \cdot r_c = 0.5 \cdot (98.00mm - 9.00mm) - 0.8 \cdot 0.00mm = 44.50mm$

Distance e{min}

$e_{min} = 36.00mm$

Calculation parameter n

$n = min(e_{min} ;\ 1.25 \cdot m_{fc})$ = min (36.00mm ; 1.25·44.50mm) = 51.00mm

Effective length for one bolt in circular patterns

$l_{eff,cp} = 2 \cdot \pi \cdot m_{fc} = 2 \cdot \pi \cdot 44.50mm = 279.60mm$

Effective length for one bolt in non-circular patterns

$l_{eff,nc} = 4 \cdot m_{fc} + 1.25 \cdot e = 4 \cdot 44.50mm + 1.25 \cdot 51.00mm = 241.75mm$

Effective length for one bolt for 1 mode

$l_{eff,1} = min(l_{eff,cp}\ ;\ l_{eff,nc}) = \min(279.60mm\ ;\ 241.75mm) = 241.75mm$

Effective length for one bolt for 2 mode

$l_{eff,2} = l_{eff,nc} = 241.75mm$

Model 1: Complete yielding of the column flange

$$M_{pl,1,Rd} = \frac{0.25 \cdot l_{eff,1} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 241.75mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 4.83kNm$$

Method 1

$$F_{T,1,Rd1} = \frac{4 \cdot M_{pl,1,Rd}}{m_{fc}} = \frac{4 \cdot 4.83kNm}{44.50mm} = 433.93kN$$

Method 2 (alternative method)

Parameter for bearing zone

$e_w = 0.25 \cdot d_w = 0.25 \cdot 44.00mm = 11.00mm$

$$F_{T,1,Rd2} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m_{fc} \cdot n - e_w \cdot (m_{fc} + n)} = \frac{(8 \cdot 51.00mm - 2 \cdot 11.00mm) \cdot 4.83kNm}{2 \cdot 44.50mm \cdot 51.00mm - 11.00mm \cdot (44.50mm + 51.00mm)} = 534.15kN$$

$F_{T,1,Rd} = min(F_{T,1,Rd1}\ ;\ F_{T,1,Rd2}) = \min(433.93kN\ ;\ 534.15kN) = 433.93\ \text{kN}$

Model 2: Bolt failure with yielding of the column flange

$$M_{pl,2,Rd} = \frac{0.25 \cdot l_{eff,2} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 241.75mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 4.83kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum F_{t,Rd}}{m_{fc} + n} = \frac{2 \cdot 4.83kNm + 51.00mm \cdot 2 \cdot 203.33kN}{44.50mm + 51.00mm} = 318.27kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 2 \cdot 203.33kN = 406.66kN$$

Component resistance

$F_{t,fc,Rd(1)} = min(F_{T,1,Rd}\ ;\ F_{T,2,Rd}\ ;\ F_{T,3,Rd}) = \min(433.93kN\ ;\ 318.27kN\ ;\ 406.66kN) = 318.27\ \text{kN}$

Column web in transverse tension

The section area of column web panel

$A_{vc} = A_c - 2 \cdot b_{fc} \cdot t_{fc} + (t_{wc} + r_c) \cdot t_{fc} = 78.08cm^2 - 2 \cdot 200.00mm \cdot 15.00mm + (9.00mm + 0.00mm) \cdot 15.00mm = 19.43cm^2$

The effective width of the column web in tension

$b_{eff,t,wc} = l_{eff,1(3)} = 241.75mm$

Reduction factor

$$\omega_1 = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{b_{eff,t,wc} \cdot t_{wc}}{A_{vc}}\right)^2}} = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{241.75 \cdot 9.00mm}{19.43cm^2}\right)^2}} = 0.62$$

$\omega = \omega_1 = 0.62$

$$F_{t,wc,Rd,st} = \frac{(b_{fc} - t_{wc}) \cdot t_s \cdot f_{y,s}}{\gamma_{M0}} = \frac{(200.00mm - 9.00mm) \cdot 10.00mm \cdot 355.00MPa}{1.00} = 678.05kN$$

Design resistance of column web subject to transverse tension

$$F_{t,wc,Rd(3)} = \frac{\omega \cdot b_{eff,t,wc} \cdot t_{wc} \cdot f_{y,wc}}{\gamma_{M0}} + F_{t,wc,Rd,st} = \frac{0.62 \cdot 241.75mm \cdot 9.00mm \cdot 355.00MPa}{1.00} + 678.05kN = 1154.32kN$$

End plate in bending

Geometrical parameters

Bolt distance from outer edge

$e_{ep} = 36.00mm$

Bolt distance from beam web

$m_{ep} = 0.5 \cdot (w - t_{wb}) - 0.8 \cdot \sqrt{2} \cdot a_w = 0.5 \cdot (98.00mm - 8.00mm) - 0.8 \cdot \sqrt{2} \cdot 4.00mm = 40.47mm$

Distance e{min}

$e_{min} = 36.00mm$

Calculation parameter n

$n = min(e_{min} ;\ 1.25 \cdot m_{ep}) = \min(36.00mm ;\ 1.25 \cdot 40.47mm) = 36.00mm$

Effective length for one bolt in circular patterns

$l_{eff,cp} = 2 \cdot \pi \cdot m_{ep} = 2 \cdot \pi \cdot 40.47mm = 254.31mm$

Effective length for one bolt in non-circular patterns

$l_{eff,nc} = 4 \cdot m_{ep} + 1.25 \cdot e = 4 \cdot 40.47mm + 1.25 \cdot 36.00mm = 206.90mm$

Effective length for one bolt for 1 mode

$l_{eff,1} = min(l_{eff,cp} ;\ l_{eff,nc}) = \min(254.31mm ;\ 206.90mm) = 206.90mm$

Effective length for one bolt for 2 mode

$l_{eff,2} = l_{eff,nc} = 206.90mm$

Model 1: Complete yielding of the end plate

$$M_{pl,1,Rd} = \frac{0.25 \cdot l_{eff,1} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 206.90mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 7.34kNm$$

Method 1

$$F_{T,1,Rd1} = \frac{4 \cdot M_{pl,1,Rd}}{m_{ep}} = \frac{4 \cdot 7.34kNm}{40.47mm} = 725.88kN$$

Method 2 (alternative method)

Parameter for bearing zone

$e_w = 0.25 \cdot d_w = 0.25 \cdot 44.00mm = 11.00mm$

$$F_{T,1,Rd2} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m_{ep} \cdot n - e_w \cdot (m_{ep} + n)} = \frac{(8 \cdot 36.00mm - 2 \cdot 11.00mm) \cdot 7.34kNm}{2 \cdot 40.47mm \cdot 36.00mm - 11.00mm \cdot (40.47mm + 36.00mm)} = 942.49kN$$

$F_{T,1,Rd} = min(F_{T,1,Rd1} ;\ F_{T,1,Rd2}) = \min(725.88kN ;\ 942.49kN) = 725.88$ kN

Model 2: Bolt failure with yielding of the end plate

$$M_{pl,2,Rd} = \frac{0.25 \cdot l_{eff,2} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 206.90mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 7.34kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum F_{t,Rd}}{m_{ep} + n} = \frac{2 \cdot 7.34kNm + 36.00mm \cdot 2 \cdot 203.33kN}{40.47mm + 36.00mm} = 383.52kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 2 \cdot 203.33kN = 406.66kN$$

Component resistance

$$F_{t,ep,Rd(1)} = min(F_{T,1,Rd};\ F_{T,2,Rd};\ F_{T,3,Rd}) = \min(725.88kN;\ 383.52kN;\ 406.66kN) = 383.52\text{ kN}$$

Beam web in tension

Effective width of beam web in tension

$$b_{eff,t,wb} = l_{eff1(3)} = 206.90mm$$

Component resistance

$$F_{t,wb,Rd(3)} = \frac{b_{eff,t,wb} \cdot t_{wb} \cdot f_{yb}}{\gamma_{M0}} = \frac{206.90mm \cdot 8.00mm \cdot 355.00MPa}{1.00} = 587.59kN$$

Column flange in bending

Row 2+3 considered as group

Circular patterns

Bolts row 2

$$l_{eff,cp(2,g)} = \pi \cdot m_{fc} + p = \pi \cdot 44.50mm + 262.60mm = 402.40mm$$

Bolts row 3

$$l_{eff,cp(3,g)} = \pi \cdot m_{fc} + p = \pi \cdot 44.50mm + 262.60mm = 402.40mm$$

$$\sum l_{eff(2+3)} = l_{eff,cp(2,g)} + l_{eff,cp(3,g)} = 402.40mm + 402.40mm = 804.80mm$$

Non-circular patterns

Bolts row 2

$$l_{eff,nc(2,g)} = 2 \cdot m_{fc} + 0.625 \cdot e + 0.5 \cdot p = 2 \cdot 44.50mm + 0.625 \cdot 51.00mm + 0.5 \cdot 262.60mm = 252.18mm$$

Bolts row 3

$$l_{eff,nc(3,g)} = 2 \cdot m_{fc} + 0.625 \cdot e + 0.5 \cdot p = 2 \cdot 44.50mm + 0.625 \cdot 51.00mm + 0.5 \cdot 262.60mm = 252.18mm$$

$$\sum l_{eff,nc(2+3)} = l_{eff,nc(2,g)} + l_{eff,nc(3,g)} = 252.18mm + 252.18mm = 504.35mm$$

Model 1: Complete yielding of the column flange

Effective length for one bolt for 1 mode

$$\sum l_{eff,1(2+3)} = min(\sum l_{eff,cp(2+3)};\ \sum l_{eff,nc(2+3)}) = \min(804.80mm;\ 504.35mm) = 504.35mm$$

$$M_{pl,1,Rd} = \frac{0.25 \cdot \sum l_{eff,1(2+3)} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 504.35mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 10.07kNm$$

$$F_{T,1,Rd} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m \cdot n - e_w \cdot (m + n)} = \frac{(8 \cdot 51.00mm - 2 \cdot 11.00mm) \cdot 10.07kNm}{2 \cdot 44.50mm \cdot 51.00mm - 11.00mm \cdot (44.50mm + 51.00mm)} = 1114.38kN$$

Model 2: Bolt failure with yielding of the column flange

Effective length for one bolt for 2 mode

$$\sum l_{eff,2(2+3)} = \sum l_{eff,nc(2+3)} = 504.35mm$$

$$M_{pl,2,Rd} = \frac{0.25 \cdot \sum l_{eff,2(2+3)} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 504.35mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 10.07kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum B_{p,Rd}}{m_{fc} + n} = \frac{2 \cdot 10.07kNm + 51.00mm \cdot 4 \cdot 203.33kN}{44.50mm + 51.00mm} = 645.25kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 4 \cdot 203.33kN = 813.31kN$$

Resistance of group

$F_{t,fc(2+3)} = min(F_{T,1,Rd};\ F_{T,2,Rd};\ F_{T,3,Rd})$ = min (905.28kN ; 645.25kN ; 813.31kN) = 645.25 kN

Column web in transverse tension

The section area of column web panel

$$A_{vc} = A_c - 2 \cdot b_{fc} \cdot t_{fc} + (t_{wc} + r_c) \cdot t_{fc} = 78.08cm^2 - 2 \cdot 200.00mm \cdot 15.00mm + (9.00mm + 0.00mm) \cdot 15.00mm = 19.43cm^2$$

The effective width of the column web in tension

$$b_{eff,t,wc} = \sum l_{eff,1(2+3)} = 504.35mm$$

Reduction factor

$$\omega_1 = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{b_{eff,t,wc} \cdot t_{wc}}{A_{vc}}\right)^2}} = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{504.35 \cdot 9.00mm}{19.43cm^2}\right)^2}} = 0.35$$

$$\omega = \omega_1 = 0.35$$

$$F_{t,wc,Rd,st} = \frac{(b_{fc} - t_{wc}) \cdot t_s \cdot f_{y,s}}{\gamma_{M0}} = \frac{(200.00mm - 9.00mm) \cdot 10.00mm \cdot 355.00MPa}{1.00} = 678.05kN$$

Design resistance of column web subject to transverse tension

$$F_{t,wc,Rd(2+3)} = \frac{\omega \cdot b_{eff,t,wc} \cdot t_{wc} \cdot f_{y,wc}}{\gamma_{M0}} + F_{t,wc,Rd,st} = \frac{0.35 \cdot 504.35mm \cdot 9.00mm \cdot 355.00MPa}{1.00} + 678.05kN = 1244.42kN$$

End plate in bending

Row 2+3 considered as group

Circular patterns

Bolts row 2

$$l_{eff,cp(2,g)} = \pi \cdot m_{ep} + p = \pi \cdot 40.47mm + 262.60mm = 389.75mm$$

Bolts row 3

$$l_{eff,cp(3,g)} = \pi \cdot m_{ep} + p = \pi \cdot 40.47mm + 262.60mm = 389.75mm$$

$$\sum l_{eff(2+3)} = l_{eff,cp(2,g)} + l_{eff,cp(3,g)} = 389.75mm + 389.75mm = 779.51mm$$

Non-circular patterns

Bolts row 2

$$l_{eff,nc(2,g)} = 0.5 \cdot p + \alpha \cdot m_{ep} - (2 \cdot m_{ep} + 0.625 \cdot e) = 0.5 \cdot 262.60mm + 0.00 \cdot 40.47mm - (2 \cdot 40.47mm + 0.625 \cdot 36.00mm) = 265.91mm$$

Bolts row 3

$$l_{eff,nc(3,g)} = 2 \cdot m_{ep} + 0.625 \cdot e + 0.5 \cdot p = 2 \cdot 40.47mm + 0.625 \cdot 36.00mm + 0.5 \cdot 262.60mm = 234.75mm$$

$$\sum l_{eff,nc(2+3)} = l_{eff,nc(2,g)} + l_{eff,nc(3,g)} = 265.91mm + 234.75mm = 500.65mm$$

Model 1: Complete yielding of the end plate

Effective length for one bolt for 1 mode

$$\sum l_{eff,1(2+3)} = min(\sum l_{eff,cp(2+3)}\ ;\ \sum l_{eff,nc(2+3)}) = \min(779.51mm\ ;\ 500.65mm) = 500.65mm$$

$$M_{pl,1,Rd} = \frac{0.25 \cdot \sum l_{eff,1(2+3)} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 500.65mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 17.77kNm$$

Method 1

$$F_{T,1,Rd1} = \frac{4 \cdot M_{pl,1,Rd}}{m_{ep}} = \frac{4 \cdot 17.77kNm}{40.47mm} = 1756.49kN$$

Method 2 (alternative method)

$$F_{T,1,Rd2} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m_{ep} \cdot n - e_w \cdot (m_{ep} + n)} = \frac{(8 \cdot 36.00mm - 2 \cdot 11.00mm) \cdot 17.77kNm}{2 \cdot 40.47mm \cdot 36.00mm - 11.00mm \cdot (40.47mm + 36.00mm)} = 2280.66kN$$

$$F_{T,1,Rd} = min(F_{T,1,Rd1}\ ;\ F_{T,1,Rd2}) = \min(1756.49kN\ ;\ 2280.66kN) = 1756.49\ \text{kN}$$

Model 2: Bolt failure with yielding of the end plate

Effective length for one bolt for 2 mode

$$\sum l_{eff,2(2+3)} = \sum l_{eff,nc(2+3)} = 500.65mm$$

$$M_{pl,2,Rd} = \frac{0.25 \cdot \sum l_{eff,2(2+3)} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 500.65mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 17.77kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum B_{p,Rd}}{m_{ep} + n} = \frac{2 \cdot 17.77kNm + 36.00mm \cdot 4 \cdot 203.33kN}{40.47mm + 36.00mm} = 847.68kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 4 \cdot 203.33kN = 813.31kN$$

Resistance of group

$$F_{t,ep(2+3)} = min(F_{T,1,Rd}\ ;\ F_{T,2,Rd}\ ;\ F_{T,3,Rd}) = \min(1756.49kN\ ;\ 847.68kN\ ;\ 813.31kN) = 813.31\ \text{kN}$$

Beam web in tension

Effective width of beam web in tension

$$b_{eff,t,wb} = \sum l_{eff1(2+3)} = 500.65mm$$

Component resistance

$$F_{t,wb,Rd(2+3)} = \frac{b_{eff,t,wb} \cdot t_{wb} \cdot f_{yb}}{\gamma_{M0}} = \frac{500.65mm \cdot 8.00mm \cdot 355.00MPa}{1.00} = 1421.86kN$$

Resistance of the bolt row 3

$F_{t,Rd(3)M} = min$		
.	$F_{t,fc,Rd(3)} =$	$318.27kN$
.	$F_{t,wc,Rd(3)} =$	$1154.32kN$

.	$F_{t,ep,Rd(3)} =$	$383.52kN$	
.	$F_{t,wb,Rd(3)} =$	$587.59kN$	
.	$F_{t,fc,Rd(2+3)} - F_{t,Rd(2)M} =$	$645.25kN - 101.19kN =$	$544.06kN$
.	$F_{t,wc,Rd(2+3)} - F_{t,Rd(2)M} =$	$1244.42kN - 101.19kN =$	$1143.23kN$
.	$F_{t,ep,Rd(2+3)} - F_{t,Rd(2)M} =$	$813.31kN - 101.19kN =$	$712.12kN$
.	$F_{t,wb,Rd(2+3)} - F_{t,Rd(2)M} =$	$1421.86kN - 101.19kN =$	$1320.67kN$
.	$\frac{V_{wp,Rd}}{\beta} - F_{t,Rd(1)M} - F_{t,Rd(2)M} =$	$\frac{383.36kN}{1.00} - 282.18kN - 101.19kN =$	$0.00kN$
.	$F_{cwc,Rd} - F_{t,Rd(1)M} - F_{t,Rd(2)M} =$	$1049.82kN - 282.18kN - 101.19kN =$	$666.46kN$
.	$F_{cfb,Rd} - F_{t,Rd(1)M} - F_{t,Rd(2)M} =$	$995.32kN - 282.18kN - 101.19kN =$	$611.96kN$
$= 0.00kN$			

BOLTS ROW 4

Column flange in bending

Geometrical parameters

Bolt distance from upper edge column

$e_{1fc} = e_c + e_1 = 0.00mm + 36.00mm = 36.00mm$

Bolt distance from outer edge

$e_{fc} = 51.00mm$

Bolt distance from column web

$m_{fc} = 0.5 \cdot (w - t_{wc}) - 0.8 \cdot r_c = 0.5 \cdot (98.00mm - 9.00mm) - 0.8 \cdot 0.00mm = 44.50mm$

Distance e{min}

$e_{min} = 36.00mm$

Calculation parameter n

$n = min(e_{min}\ ;\ 1.25 \cdot m_{fc}) = \min(36.00mm\ ;\ 1.25 \cdot 44.50mm) = 51.00mm$

Calculation parameter

$m_{2fc} = p_1 + e_1 - e_{p1} - t_{fb} - 0.8 \cdot a_f \cdot \sqrt{2} = 84.70mm + 36.00mm - 72.00mm - 15.00mm - 0.8 \cdot 7.00mm \cdot \sqrt{2} = 48.01mm$

$$\lambda_1 = \frac{m_{fc}}{m_{fc} + e_{fc}} = \frac{44.50mm}{44.50mm + 51.00mm} = 0.47$$

$$\lambda_2 = \frac{m_{2fc}}{m_{fc} + e_{fc}} = \frac{48.01mm}{44.50mm + 51.00mm} = 0.50$$

$\alpha = 5.90$

Effective length for one bolt in circular patterns

$l_{eff,cp,1} = 2 \cdot \pi \cdot m_{fc} = 2 \cdot \pi \cdot 44.50mm = 279.60mm$

$l_{eff,cp,2} = \pi \cdot m_{fc} + 2 \cdot e_1 = \pi \cdot 44.50mm + 2 \cdot 51.00mm = 211.80mm$

$l_{eff,cp} = min(l_{eff,cp,1}\ ;\ l_{eff,cp,2}) = \min(279.60mm\ ;\ 211.80mm) = 211.80mm$

Effective length for one bolt in non-circular patterns

$l_{eff,nc} = e_1 + \alpha \cdot m_{fc} - (2 \cdot m_{fc} + 0.625 \cdot e) = 36.00mm + 5.90 \cdot 44.50mm - (2 \cdot 44.50mm + 0.625 \cdot 51.00mm) = 177.59mm$

Effective length for one bolt for 1 mode

$l_{eff,1} = min(l_{eff,cp}\ ;\ l_{eff,nc}) = \min(211.80mm\ ;\ 177.59mm) = 177.59mm$

Effective length for one bolt for 2 mode

$l_{eff,2} = l_{eff,nc} = 177.59mm$

Model 1: Complete yielding of the column flange

$$M_{pl,1,Rd} = \frac{0.25 \cdot l_{eff,1} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 177.59mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 3.55kNm$$

Method 1

$$F_{T,1,Rd1} = \frac{4 \cdot M_{pl,1,Rd}}{m_{fc}} = \frac{4 \cdot 3.55kNm}{44.50mm} = 318.77kN$$

Method 2 (alternative method)

Parameter for bearing zone

$e_w = 0.25 \cdot d_w = 0.25 \cdot 44.00mm = 11.00mm$

$$F_{T,1,Rd2} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m_{fc} \cdot n - e_w \cdot (m_{fc} + n)} = \frac{(8 \cdot 51.00mm - 2 \cdot 11.00mm) \cdot 3.55kNm}{2 \cdot 44.50mm \cdot 51.00mm - 11.00mm \cdot (44.50mm + 51.00mm)} = 392.39kN$$

$F_{T,1,Rd} = min(F_{T,1,Rd1}\ ;\ F_{T,1,Rd2}) = \min(318.77kN\ ;\ 392.39kN) = 318.77\ \text{kN}$

Model 2: Bolt failure with yielding of the column flange

$$M_{pl,2,Rd} = \frac{0.25 \cdot l_{eff,2} \cdot t_{fc}^2 \cdot f_{yc}}{\gamma_{M0}} = \frac{0.25 \cdot 177.59mm \cdot (15.00mm)^2 \cdot 355.00MPa}{1.00} = 3.55kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum F_{t,Rd}}{m_{fc} + n} = \frac{2 \cdot 3.55kNm + 51.00mm \cdot 2 \cdot 203.33kN}{44.50mm + 51.00mm} = 291.43kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 2 \cdot 203.33kN = 406.66kN$$

Component resistance

$F_{t,fc,Rd(1)} = min(F_{T,1,Rd}\ ;\ F_{T,2,Rd}\ ;\ F_{T,3,Rd}) = \min(318.77kN\ ;\ 291.43kN\ ;\ 406.66kN) = 291.43\ \text{kN}$

Column web in transverse tension

The section area of column web panel

$A_{vc} = A_c - 2 \cdot b_{fc} \cdot t_{fc} + (t_{wc} + r_c) \cdot t_{fc} = 78.08cm^2 - 2 \cdot 200.00mm \cdot 15.00mm + (9.00mm + 0.00mm) \cdot 15.00mm = 19.43cm^2$

The effective width of the column web in tension

$b_{eff,t,wc} = l_{eff,1(4)} = 177.59mm$

Reduction factor

$$\omega_1 = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{b_{eff,t,wc} \cdot t_{wc}}{A_{vc}}\right)^2}} = \frac{1}{\sqrt{1 + 1.3 \cdot \left(\frac{177.59 \cdot 9.00mm}{19.43cm^2}\right)^2}} = 0.73$$

$\omega = \omega_1 = 0.73$

$$F_{t,wc,Rd,st} = \frac{(b_{fc} - t_{wc}) \cdot t_s \cdot f_{y,s}}{\gamma_{M0}} = \frac{(200.00mm - 9.00mm) \cdot 10.00mm \cdot 355.00MPa}{1.00} = 678.05kN$$

Design resistance of column web subject to transverse tension

$$F_{t,wc,Rd(4)} = \frac{\omega \cdot b_{eff,t,wc} \cdot t_{wc} \cdot f_{y,wc}}{\gamma_{M0}} + F_{t,wc,Rd,st} = \frac{0.73 \cdot 177.59mm \cdot 9.00mm \cdot 355.00MPa}{1.00} + 678.05kN = 1091.91kN$$

End plate in bending

Geometrical parameters

Bolt distance from outer edge

$e_{ep} = 36.00mm$

Bolt distance from beam web

$m_{ep} = 0.5 \cdot (w - t_{wb}) - 0.8 \cdot \sqrt{2} \cdot a_w = 0.5 \cdot (98.00mm - 8.00mm) - 0.8 \cdot \sqrt{2} \cdot 4.00mm = 40.47mm$

Distance e{min}

$e_{min} = min(e_x ; e_{ep}) = \min(36.00mm ; 36.00mm) = 36.00mm$

Calculation parameter n

$n = min(e_{min} ; 1.25 \cdot m_{ep}) = \min(36.00mm ; 1.25 \cdot 40.47mm) = 35.10mm$

Bolt distance from beam flange

$m_x = e_{p1} - e_1 - 0.8 \cdot a_f \cdot \sqrt{2} = 72.00mm - 36.00mm - 0.8 \cdot 7.00mm \cdot \sqrt{2} = 28.08mm$

Bolt distance from outer horizontal edge plate

$e_x = e_1 = 36.00mm$

Effective length for one bolt in circular patterns

$l_{eff,cp,1} = 2 \cdot \pi \cdot m_x = 2 \cdot \pi \cdot 28.08mm = 176.43mm$

$l_{eff,cp,2} = \pi \cdot m_x + w = \pi \cdot 28.08mm + 98.00mm = 186.22mm$

$l_{eff,cp,3} = \pi \cdot m_x + 2 \cdot e = \pi \cdot 28.08mm + 2 \cdot 36.00mm = 160.22mm$

$l_{eff,cp} = min(l_{eff,cp,1} ; l_{eff,cp,2} ; l_{eff,cp,3}) = \min(176.43mm ; 186.22mm ; 160.22mm) = 160.22mm$

Effective length for one bolt in non-circular patterns

$l_{eff,nc,1} = 4 \cdot m_x + 1.25 \cdot e_x = 4 \cdot 28.08mm + 1.25 \cdot 36.00mm = 157.32mm$

$l_{eff,nc,2} = e + 2 \cdot m_x + 0.625 \cdot e_x = 36.00mm + 2 \cdot 28.08mm + 0.625 \cdot 36.00mm = 114.66mm$

$l_{eff,nc,3} = 0.5 \cdot b_p = 0.5 \cdot 170.00mm = 85.00mm$

$l_{eff,nc,4} = 0.5 \cdot w + 2 \cdot m_x + 0.625 \cdot e_x = 0.5 \cdot 98.00mm + 2 \cdot 28.08mm + 0.625 \cdot 36.00mm = 127.66mm$

$l_{eff,nc} = min(l_{eff,nc,1} ; l_{eff,nc,2} ; l_{eff,nc,3} ; l_{eff,nc,4}) = \min(157.32mm ; 114.66mm ; 85.00mm ; 127.66mm) = 85.00mm$

Effective length for one bolt for 1 mode

$l_{eff,1} = min(l_{eff,cp} ; l_{eff,nc}) = \min(160.22mm ; 85.00mm) = 85.00mm$

Effective length for one bolt for 2 mode

$l_{eff,2} = l_{eff,nc} = 85.00mm$

Model 1: Complete yielding of the end plate

$$M_{pl,1,Rd} = \frac{0.25 \cdot l_{eff,1} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 85.00mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 3.02kNm$$

Method 1

$$F_{T,1,Rd1} = \frac{4 \cdot M_{pl,1,Rd}}{m_x} = \frac{4 \cdot 3.02kNm}{28.08mm} = 429.84kN$$

Method 2 (alternative method)

Parameter for bearing zone

$e_w = 0.25 \cdot d_w = 0.25 \cdot 44.00mm = 11.00mm$

$$F_{T,1,Rd2} = \frac{(8 \cdot n - 2 \cdot e_w) \cdot M_{pl,1,Rd}}{2 \cdot m_x \cdot n - e_w \cdot (m_x + n)} = \frac{(8 \cdot 35.10mm - 2 \cdot 11.00mm) \cdot 3.02kNm}{2 \cdot 28.08mm \cdot 35.10mm - 11.00mm \cdot (28.08mm + 35.10mm)} = 611.89kN$$

$F_{T,1,Rd} = min(F_{T,1,Rd1}\ ;\ F_{T,1,Rd2}) = \min(429.84kN\ ;\ 611.89kN) = 429.84\ \text{kN}$

Model 2: Bolt failure with yielding of the end plate

$$M_{pl,2,Rd} = \frac{0.25 \cdot l_{eff,2} \cdot t_p^2 \cdot f_{yp}}{\gamma_{M0}} = \frac{0.25 \cdot 85.00mm \cdot (20.00mm)^2 \cdot 355.00MPa}{1.00} = 3.02kNm$$

$$F_{T,2,Rd} = \frac{2 \cdot M_{pl,2,Rd} + n \cdot \sum F_{t,Rd}}{m_x + n} = \frac{2 \cdot 3.02kNm + 35.10mm \cdot 2 \cdot 203.33kN}{28.08mm + 35.10mm} = 321.44kN$$

Model 3: Bolt failure

$$F_{T,3,Rd} = \sum F_{t,Rd} = 2 \cdot 203.33kN = 406.66kN$$

Component resistance

$F_{t,ep,Rd(1)} = min(F_{T,1,Rd}\ ;\ F_{T,2,Rd}\ ;\ F_{T,3,Rd}) = \min(429.84kN\ ;\ 321.44kN\ ;\ 406.66kN) = 321.44\ \text{kN}$

Resistance of the bolt row 4

Bending resistance

Real bending moment

$$M_0 = M_{b1,Ed} = 113.42kNm$$

The design moment resistance of the joint, assuming no axial force

$$M_{j,Rd} = F_{t,Rd(1)M} \cdot h_1 + F_{t,Rd(2)M} \cdot h_2 + F_{t,Rd(3)M} \cdot h_3 = 282.18kN \cdot 389.65mm + 101.19kN \cdot 304.95mm + 0.00kN \cdot 42.35mm = 140.81kNm$$

$\frac{\lvert M_0 \rvert}{M_{j,Rd}} \le 1$	0.81 < 1.00	0.81	✔

Shear resistance

Shear force

$$V_0 = -N_{b1,Ed} \cdot sin(\alpha) + V_{b1,Ed} \cdot cos(\alpha) = -((-44.28kN)) \cdot sin(0.00Deg) + 62.88kN \cdot cos(0.00Deg) = 62.88kN$$

BOLTS ROW 1

Bolt bearing on the column flange

Coefficient determined by bolt spacing

$$\alpha_{ep} = min(1.0\ ;\ \frac{f_{ub}}{f_{uc}}\ ;\ \frac{e_1}{d_0}) = \min(1.0\ ;\ \frac{800.00MPa}{510.00MPa}\ ;\ \frac{36.00mm}{27.00mm}) = 0.44$$

Coefficient determined by bolt spacing

$$k_1 = min(2.5\ ;\ 2.8 \cdot \frac{e_2}{d_0}) = \min(2.5\ ;\ 2.8 \cdot \frac{51.00mm}{27.00mm}) = 2.50$$

Bearing resistance of a bolt

$$F_{b,Rdfc} = \frac{k_1 \cdot \alpha_b \cdot f_{uc} \cdot d \cdot t_{fc}}{\gamma_{M2}} = \frac{2.50 \cdot 0.44 \cdot 510.00MPa \cdot 24.00mm \cdot 15.00mm}{1.25} = 163.20kN$$

Bolt bearing on the plate

Coefficient determined by bolt spacing

$$\alpha_{ep} = min(1.0\ ;\ \frac{f_{ub}}{f_{up}}\ ;\ \frac{e_1}{d_0}) = \min(1.0\ ;\ \frac{800.00MPa}{510.00MPa}\ ;\ \frac{36.00mm}{27.00mm}) = 0.44$$

Coefficient determined by bolt spacing

$$k_1 = min(2.5\ ;\ 2.8\cdot\frac{e_2}{d_0}) = \min(2.5\ ;\ 2.8\cdot\frac{36.00mm}{27.00mm}) = 2.03$$

Bearing resistance of a bolt

$$F_{b,Rdep} = \frac{k_1\cdot\alpha_b\cdot f_{up}\cdot d\cdot t_p}{\gamma_{M2}} = \frac{2.03\cdot 0.44\cdot 510.00MPa\cdot 24.00mm\cdot 20.00mm}{1.25} = 176.98kN$$

Resistance of the bolt row 1

$$V_{Rd(1)} = m_1\cdot min(F_{b,Rdfc}\ ;\ F_{b,Rdep}\ ;\ F_{v,Rd}) = 2 * \min(163.20kN\ ;\ 176.98kN\ ;\ 173.72kN) = 326.40\ \text{kN}$$

BOLTS ROW 2

Bolt bearing on the column flange

Coefficient determined by bolt spacing

$$\alpha_{ep} = min(1.0\ ;\ \frac{f_{ub}}{f_{uc}}\ ;\ \frac{p_1}{3\cdot d_0} - 0.25) = \min(1.0\ ;\ \frac{800.00MPa}{510.00MPa}\ ;\ \frac{84.70mm}{3\cdot 27.00mm} - 0.25) = 0.80$$

Coefficient determined by bolt spacing

$$k_1 = min(2.5\ ;\ 1.4\cdot\frac{p_2}{d_0} - 1.7) = \min(2.5\ ;\ 1.4\cdot\frac{98.00mm}{27.00mm} - 1.7) = 2.50$$

Bearing resistance of a bolt

$$F_{b,Rdfc} = \frac{k_1\cdot\alpha_b\cdot f_{uc}\cdot d\cdot t_{fc}}{\gamma_{M2}} = \frac{2.50\cdot 0.80\cdot 510.00MPa\cdot 24.00mm\cdot 15.00mm}{1.25} = 292.17kN$$

Bolt bearing on the plate

Coefficient determined by bolt spacing

$$\alpha_{ep} = min(1.0\ ;\ \frac{f_{ub}}{f_{up}}\ ;\ \frac{p_1}{3\cdot d_0} - 0.25) = \min(1.0\ ;\ \frac{800.00MPa}{510.00MPa}\ ;\ \frac{84.70mm}{3\cdot 27.00mm} - 0.25) = 0.80$$

Coefficient determined by bolt spacing

$$k_1 = min(2.5\ ;\ 1.4\cdot\frac{p_2}{d_0} - 1.7) = \min(2.5\ ;\ 1.4\cdot\frac{98.00mm}{27.00mm} - 1.7) = 2.03$$

Bearing resistance of a bolt

$$F_{b,Rdep} = \frac{k_1\cdot\alpha_b\cdot f_{up}\cdot d\cdot t_p}{\gamma_{M2}} = \frac{2.03\cdot 0.80\cdot 510.00MPa\cdot 24.00mm\cdot 20.00mm}{1.25} = 316.85kN$$

Resistance of the bolt row 2

$$V_{Rd(2)} = m_2\cdot min(F_{b,Rdfc}\ ;\ F_{b,Rdep}\ ;\ F_{v,Rd}) = 2 * \min(292.17kN\ ;\ 316.85kN\ ;\ 173.72kN) = 347.44\ \text{kN}$$

BOLTS ROW 3

Bolt bearing on the column flange

Coefficient determined by bolt spacing

$$\alpha_{ep} = min(1.0\ ;\ \frac{f_{ub}}{f_{uc}}\ ;\ \frac{p_1}{3\cdot d_0} - 0.25) = \min(1.0\ ;\ \frac{800.00MPa}{510.00MPa}\ ;\ \frac{84.70mm}{3\cdot 27.00mm} - 0.25) = 0.80$$

Coefficient determined by bolt spacing

$$k_1 = min(2.5\ ;\ 1.4 \cdot \frac{p_2}{d_0} - 1.7) = \min(2.5\ ;\ 1.4 \cdot \frac{98.00mm}{27.00mm} - 1.7) = 2.50$$

Bearing resistance of a bolt

$$F_{b,Rdfc} = \frac{k_1 \cdot \alpha_b \cdot f_{uc} \cdot d \cdot t_{fc}}{\gamma_{M2}} = \frac{2.50 \cdot 0.80 \cdot 510.00MPa \cdot 24.00mm \cdot 15.00mm}{1.25} = 292.17kN$$

Bolt bearing on the plate

Coefficient determined by bolt spacing

$$\alpha_{ep} = min(1.0\ ;\ \frac{f_{ub}}{f_{up}}\ ;\ \frac{p_1}{3 \cdot d_0} - 0.25) = \min(1.0\ ;\ \frac{800.00MPa}{510.00MPa}\ ;\ \frac{84.70mm}{3 \cdot 27.00mm} - 0.25) = 0.80$$

Coefficient determined by bolt spacing

$$k_1 = min(2.5\ ;\ 1.4 \cdot \frac{p_2}{d_0} - 1.7) = \min(2.5\ ;\ 1.4 \cdot \frac{98.00mm}{27.00mm} - 1.7) = 2.03$$

Bearing resistance of a bolt

$$F_{b,Rdep} = \frac{k_1 \cdot \alpha_b \cdot f_{up} \cdot d \cdot t_p}{\gamma_{M2}} = \frac{2.03 \cdot 0.80 \cdot 510.00MPa \cdot 24.00mm \cdot 20.00mm}{1.25} = 316.85kN$$

Resistance of the bolt row 3

$$V_{Rd(3)} = m_3 \cdot min(F_{b,Rdfc}\ ;\ F_{b,Rdep}\ ;\ F_{v,Rd}) = 2 * \min(292.17kN\ ;\ 316.85kN\ ;\ 173.72kN) = 347.44\text{ kN}$$

BOLTS ROW 4

Bolt bearing on the column flange

Coefficient determined by bolt spacing

$$\alpha_{ep} = min(1.0\ ;\ \frac{f_{ub}}{f_{uc}}\ ;\ \frac{e_1}{d_0}) = \min(1.0\ ;\ \frac{800.00MPa}{510.00MPa}\ ;\ \frac{\infty}{27.00mm}) = 1.00$$

Coefficient determined by bolt spacing

$$k_1 = min(2.5\ ;\ 2.8 \cdot \frac{e_2}{d_0}) = \min(2.5\ ;\ 2.8 \cdot \frac{51.00mm}{27.00mm}) = 2.50$$

Bearing resistance of a bolt

$$F_{b,Rdfc} = \frac{k_1 \cdot \alpha_b \cdot f_{uc} \cdot d \cdot t_{fc}}{\gamma_{M2}} = \frac{2.50 \cdot 1.00 \cdot 510.00MPa \cdot 24.00mm \cdot 15.00mm}{1.25} = 367.20kN$$

Bolt bearing on the plate

Coefficient determined by bolt spacing

$$\alpha_{ep} = min(1.0\ ;\ \frac{f_{ub}}{f_{up}}\ ;\ \frac{e_1}{d_0}) = \min(1.0\ ;\ \frac{800.00MPa}{510.00MPa}\ ;\ \frac{36.00mm}{27.00mm}) = 0.44$$

Coefficient determined by bolt spacing

$$k_1 = min(2.5\ ;\ 2.8 \cdot \frac{e_2}{d_0}) = \min(2.5\ ;\ 2.8 \cdot \frac{36.00mm}{27.00mm}) = 2.03$$

Bearing resistance of a bolt

$$F_{b,Rdep} = \frac{k_1 \cdot \alpha_b \cdot f_{up} \cdot d \cdot t_p}{\gamma_{M2}} = \frac{2.03 \cdot 0.44 \cdot 510.00MPa \cdot 24.00mm \cdot 20.00mm}{1.25} = 176.98kN$$

Resistance of the bolt row 4

$V_{Rd(4)} = m_4 \cdot min(F_{b,Rdfc} \; ; \; F_{b,Rdep} \; ; \; F_{v,Rd}) = 2 * \min(367.20kN \; ; \; 176.98kN \; ; \; 173.72kN) = 347.44 \text{ kN}$

$V_{j,Rd} = V_{Rd(1)} + V_{Rd(2)} + V_{Rd(3)} + V_{Rd(4)} = 326.40kN + 347.44kN + 347.44kN + 347.44kN = 1368.71kN$

$\frac{\lvert V_0 \rvert}{V_{j,Rd}} \le 1$		$\lvert 62.88kN \rvert < 1368.71kN$		0.05		✓

Fillet welds connecting beam and front plate

Forces in welds

Axial force

$N_0 = N_{b1,Ed} \cdot cos(\alpha) + V_{b1,Ed} \cdot sin(\alpha) = (-44.28kN) \cdot cos(0.00Deg) + 62.88kN \cdot sin(0.00Deg) = -44.28kN$

Shear force

$V_0 = -N_{b1,Ed} \cdot sin(\alpha) + V_{b1,Ed} \cdot cos(\alpha) = -((-44.28kN)) \cdot sin(0.00Deg) + 62.88kN \cdot cos(0.00Deg) = 62.88kN$

Real bending moment

$M_0 = M_{b1,Ed} = 113.42kNm$

Geometric properties of welds

Beam

Area of horizontal welds on upper flange

$A_{wfu} = [2 \cdot (b_{fb} - r_b) - t_{wb}] \cdot a_f = [2 \cdot (170.00mm - 0.00mm) - 8.00mm] \cdot 7.00mm = 23.24cm^2$

Area of horizontal welds on lower flange

$A_{wfl} = [2 \cdot (b_{fb} - r_b) - t_{wb}] \cdot a_f = [2 \cdot (170.00mm - 0.00mm) - 8.00mm] \cdot 7.00mm = 23.24cm^2$

Area of vertical welds

$$A_{ww} = 2 \cdot \frac{h_b - 2 \cdot (t_{fb} + r_b)}{cos(\alpha)} \cdot a_w = 2 \cdot \frac{360.00mm - 2 \cdot (12.70mm + 0.00mm)}{cos(0.00Deg)} \cdot 4.00mm = 26.77cm^2$$

Area of all welds

$A_w = A_{wfu} + A_{wfl} + A_{ww} = 23.24cm^2 + 23.24cm^2 + 26.77cm^2 = 73.25cm^2$

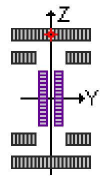
Offset of welds centroid with respect to beam centroid

$e_{0w} = 0.00mm$

Moment of inertia welds

$I_w = 16598.43cm^4$

The point where the stresses are checked	$z_i = 183.50mm$

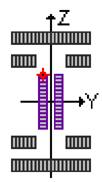
Elastic modulus of welds	
$W_w = 904.55cm^3$	
Stress from axial force	
$\sigma_N = \frac{N_0}{A_w} = \frac{-44.28kN}{73.25cm^2} = -6.05MPa$	
Stress due to bending	
$\sigma_M = \frac{M_0 \cdot z_i}{I_w} = \frac{113.42kNm \cdot 183.50mm}{16598.43cm^4} = 125.39MPa$	
Maximum normal stress	
$\sigma = \sigma_N + \sigma_M = -6.05MPa + 125.39MPa = 119.34MPa$	
Normal perpendicular stress	
$\sigma_\perp = \frac{\sigma}{\sqrt{2}} = \frac{119.34MPa}{\sqrt{2}} = 84.39MPa$	
Perpendicular tangent stress	
$\tau_\perp = \frac{\sigma}{\sqrt{2}} = \frac{119.34MPa}{\sqrt{2}} = 84.39MPa$	

Welds resistance coefficient
$\beta_w = 0.90$

$\left\|\sigma_\perp\right\| \le \frac{0.9 \cdot f_u}{\gamma_{M2}}$	$\|84.39MPa\| < 367.20MPa$	0.17	✓

$\sqrt{\sigma_\perp^2 + 3 \cdot \left(\tau_\perp^2\right)} \le \frac{f_u}{\beta_w \cdot \gamma_{M2}}$	$168.77MPa < 453.33MPa$	0.37	✓

The point where the stresses are checked	$z_i = 167.30mm$

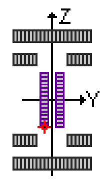
Elastic modulus of welds	
$W_w = 992.14cm^3$	
Stress from axial force	
$\sigma_N = \frac{N_0}{A_w} = \frac{-44.28kN}{73.25cm^2} = -6.05MPa$	
Stress due to bending	
$\sigma_M = \frac{M_0 \cdot z_i}{I_w} = \frac{113.42kNm \cdot 167.30mm}{16598.43cm^4} = 114.32MPa$	
Maximum normal stress	
$\sigma = \sigma_N + \sigma_M = -6.05MPa + 114.32MPa = 108.27MPa$	
Normal perpendicular stress	
$\sigma_\perp = \frac{\sigma}{\sqrt{2}} = \frac{108.27MPa}{\sqrt{2}} = 76.56MPa$	
Perpendicular tangent stress	
$\tau_\perp = \frac{\sigma}{\sqrt{2}} = \frac{108.27MPa}{\sqrt{2}} = 76.56MPa$	
Parallel tangent stress	
$\tau_{II} = \frac{V_0}{A_{ww}} = \frac{62.88kN}{26.77cm^2} = 23.49MPa$	

Welds resistance coefficient
$\beta_w = 0.90$

$\left\|\sigma_\perp\right\| \le \frac{0.9 \cdot f_u}{\gamma_{M2}}$	$\|76.56MPa\| < 367.20MPa$	0.15	✓

$\sqrt{\sigma_\perp^2 + 3 \cdot \left(\tau_\perp^2 + \tau_{II}^2\right)} \le \frac{f_u}{\beta_w \cdot \gamma_{M2}}$	$158.43MPa < 453.33MPa$	0.35	✓

The point where the stresses are checked	$z_i = -167.30mm$

Elastic modulus of welds	
$W_w = 992.14 cm^3$	
Stress from axial force	
$\sigma_N = \frac{N_0}{A_w} = \frac{-44.28kN}{73.25cm^2} = -6.05MPa$	
Stress due to bending	
$\sigma_M = \frac{M_0 \cdot z_i}{I_w} = \frac{113.42kNm \cdot (-167.30mm)}{16598.43cm^4} = -114.32MPa$	
Maximum normal stress	
$\sigma = \sigma_N + \sigma_M = -6.05MPa + (-114.32MPa) = -120.36MPa$	
Normal perpendicular stress	
$\sigma_\perp = \frac{\sigma}{\sqrt{2}} = \frac{-120.36MPa}{\sqrt{2}} = -85.11MPa$	
Perpendicular tangent stress	
$\tau_\perp = \frac{\sigma}{\sqrt{2}} = \frac{-120.36MPa}{\sqrt{2}} = -85.11MPa$	
Parallel tangent stress	
$\tau_{II} = \frac{V_0}{A_{ww}} = \frac{62.88kN}{26.77cm^2} = 23.49MPa$	

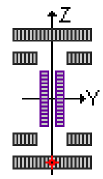
Welds resistance coefficient
$\beta_w = 0.90$

$\left\|\sigma_\perp\right\| \le \frac{0.9 \cdot f_u}{\gamma_{M2}}$	$\|-85.11MPa\| < 367.20MPa$	0.17	✔

$\sqrt{\sigma_\perp^2 + 3 \cdot \left(\tau_\perp^2 + \tau_{II}^2\right)} \le \frac{f_u}{\beta_w \cdot \gamma_{M2}}$	$175.01MPa < 453.33MPa$	0.39	✔

The point where the stresses are checked	$z_i = -183.50mm$

Elastic modulus of welds
$W_w = 904.55cm^3$
Stress from axial force
$\sigma_N = \frac{N_0}{A_w} = \frac{-44.28kN}{73.25cm^2} = -6.05MPa$
Stress due to bending
$\sigma_M = \frac{M_0 \cdot z_i}{I_w} = \frac{113.42kNm \cdot (-183.50mm)}{16598.43cm^4} = -125.39MPa$
Maximum normal stress
$\sigma = \sigma_N + \sigma_M = -6.05MPa + (-125.39MPa) = -131.43MPa$
Normal perpendicular stress
$\sigma_\perp = \frac{\sigma}{\sqrt{2}} = \frac{-131.43MPa}{\sqrt{2}} = -92.94MPa$
Perpendicular tangent stress
$\tau_\perp = \frac{\sigma}{\sqrt{2}} = \frac{-131.43MPa}{\sqrt{2}} = -92.94MPa$



Welds resistance coefficient

$\beta_w = 0.90$

$\lvert\sigma_\perp\rvert \le \frac{0.9 \cdot f_u}{\gamma_{M2}}$	$\lvert -92.94MPa \rvert < 367.20MPa$	0.18	✓

$\sqrt{\sigma_\perp^2 + 3 \cdot (\tau_\perp^2)} \le \frac{f_u}{\beta_w \cdot \gamma_{M2}}$	$185.87MPa < 453.33MPa$	0.41	✓

The rotational stiffness of a joint

Column web panel in shear

$$k_1 = \frac{0.385 \cdot A_{vc}}{\beta \cdot h} = \frac{0.385 \cdot 19.43cm^2}{1.00 \cdot 360.00mm} = 2.13mm$$

Column web in transverse compression

$$k_2 = \infty\, mm$$

The bolt elongation length

$$L_b = t_p + t_{fc} + 0.5 \cdot (m + k) + 2 \cdot t_{wa} = 20.00mm + 15.00mm + 0.5 \cdot (22.30mm + 15.00mm) + 2 \cdot 4.00mm = 61.65mm$$

Bolt tension

$$k_{10} = \frac{3.2 \cdot A_s}{L_b} = \frac{3.2 \cdot 3.53cm^2}{61.65mm} = 9.16mm$$

The depth of the column web

$$d_c = h_c - 2 \cdot (t_{fc} + r_c) = 200.00mm - 2 \cdot (15.00mm + 0.00mm) = 170.00mm$$

Row 1

Column web in transverse tension

$$k_{3(1)} = \frac{0.7 \cdot b_{eff,wc,t} \cdot t_{wc}}{d_c} = \frac{0.7 \cdot 157.21mm \cdot 9.00mm}{170.00mm} = 5.83mm$$

Column flange in bending

$$k_{4(1)} = \frac{0.9 \cdot l_{eff,fc,t} \cdot t_{fc}^3}{m^3} = \frac{0.9 \cdot 157.21mm \cdot (15.00mm)^3}{(44.50mm)^3} = 5.42mm$$

End plate in bending

$$k_{5(1)} = \frac{0.9 \cdot l_{eff} \cdot t_p^3}{m_x^3} = \frac{0.9 \cdot 85.00mm \cdot (20.00mm)^3}{(28.08mm)^3} = 27.64mm$$

$$k_{eff(1)} = \frac{1}{\frac{1}{k_{3(1)}} + \frac{1}{k_{4(1)}} + \frac{1}{k_{5(1)}} + \frac{1}{k_{10}}} = \frac{1}{\frac{1}{5.83mm} + \frac{1}{5.42mm} + \frac{1}{27.64mm} + \frac{1}{9.16mm}} = 1.99mm$$

Row 2

Column web in transverse tension

$$k_{3(2)} = \frac{0.7 \cdot b_{eff,wc,t} \cdot t_{wc}}{d_c} = \frac{0.7 \cdot 241.75mm \cdot 9.00mm}{170.00mm} = 8.96mm$$

Column flange in bending

$$k_{4(2)} = \frac{0.9 \cdot l_{eff,fc,t} \cdot t_{fc}^3}{m^3} = \frac{0.9 \cdot 241.75mm \cdot (15.00mm)^3}{(44.50mm)^3} = 8.33mm$$

End plate in bending

$$k_{5(2)} = \frac{0.9 \cdot l_{eff} \cdot t_p^3}{m^3} = \frac{0.9 \cdot 238.05mm \cdot (20.00mm)^3}{(40.47mm)^3} = 25.85mm$$

$$k_{eff(2)} = \frac{1}{\frac{1}{k_{3(2)}} + \frac{1}{k_{4(2)}} + \frac{1}{k_{5(2)}} + \frac{1}{k_{10}}} = \frac{1}{\frac{1}{8.96mm} + \frac{1}{8.33mm} + \frac{1}{25.85mm} + \frac{1}{9.16mm}} = 2.64mm$$

Row 3

Column web in transverse tension

$$k_{3(3)} = \frac{0.7 \cdot b_{eff,wc,t} \cdot t_{wc}}{d_c} = \frac{0.7 \cdot 241.75mm \cdot 9.00mm}{170.00mm} = 8.96mm$$

Column flange in bending

$$k_{4(3)} = \frac{0.9 \cdot l_{eff,fc,t} \cdot t_{fc}^3}{m^3} = \frac{0.9 \cdot 241.75mm \cdot (15.00mm)^3}{(44.50mm)^3} = 8.33mm$$

End plate in bending

$$k_{5(3)} = \frac{0.9 \cdot l_{eff} \cdot t_p^3}{m^3} = \frac{0.9 \cdot 206.90mm \cdot (20.00mm)^3}{(40.47mm)^3} = 22.47mm$$

$$k_{eff(3)} = \frac{1}{\frac{1}{k_{3(3)}} + \frac{1}{k_{4(3)}} + \frac{1}{k_{5(3)}} + \frac{1}{k_{10}}} = \frac{1}{\frac{1}{8.96mm} + \frac{1}{8.33mm} + \frac{1}{22.47mm} + \frac{1}{9.16mm}} = 2.60mm$$

Lever arm of internal forces

$$z_{eq}=\frac{k_{eff(1)}\cdot h_1^2+k_{eff(2)}\cdot h_2^2+k_{eff(3)}\cdot h_3^2}{k_{eff(1)}\cdot h_1+k_{eff(2)}\cdot h_2+k_{eff(3)}\cdot h_3}=\frac{1.99mm\cdot(389.65mm)^2+2.64mm\cdot(304.95mm)^2+2.60mm\cdot(42.35mm)^2}{1.99mm\cdot 389.65mm+2.64mm\cdot 304.95mm+2.60mm\cdot 42.35mm}=326.80mm$$

Equivalent stiffness coefficient

$$k_{eq}=\frac{k_{eff(1)}\cdot h_1+k_{eff(2)}\cdot h_2+k_{eff(3)}\cdot h_3}{z_{eq}}=\frac{1.99mm\cdot 389.65mm+2.64mm\cdot 304.95mm+2.60mm\cdot 42.35mm}{326.80mm}=5.17mm$$

The initial rotational stiffness of a joint

$$S_{j,ini}=\frac{E\cdot z_{eq}^2}{\frac{1}{k_1}+\frac{1}{k_2}+\frac{1}{k_{eq}}}=\frac{210000.00MPa\cdot(326.80mm)^2}{\frac{1}{2.13mm}+\frac{1}{\infty\, mm}+\frac{1}{5.17mm}}=33792.50\frac{kNm}{rad}$$

The rotational stiffness of a pinned joint

$$S_{j,pin}=\frac{0.5\cdot E\cdot I_{yb}}{L_b}=\frac{0.5\cdot 210000.00MPa\cdot 16270.00cm^4}{3048.01mm}=5604.81\frac{kNm}{rad}$$

The rotational stiffness of a rigid joint

$$S_{j,rig}=\frac{k_b\cdot E\cdot I_{yb}}{L_b}=\frac{8.00\cdot 210000.00MPa\cdot 16270.00cm^4}{3048.01mm}=89676.99\frac{kNm}{rad}$$

Stiffness ratio

$$\mu=\left(\frac{1.5\cdot|M_{b1,Ed}|}{M_{Rd}}\right)^{\psi}=\left(\frac{1.5\cdot|113.42kNm|}{140.81kNm}\right)^{2.7}=1.67$$

The rotational stiffness of a joint

$$S_j=\frac{S_{j,ini}}{\mu}=\frac{33792.50\frac{kNm}{rad}}{1.67}=20278.29\frac{kNm}{rad}$$

Classification of joint

Semi – rigid