CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	1 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Example: Portal frame - eaves moment connection

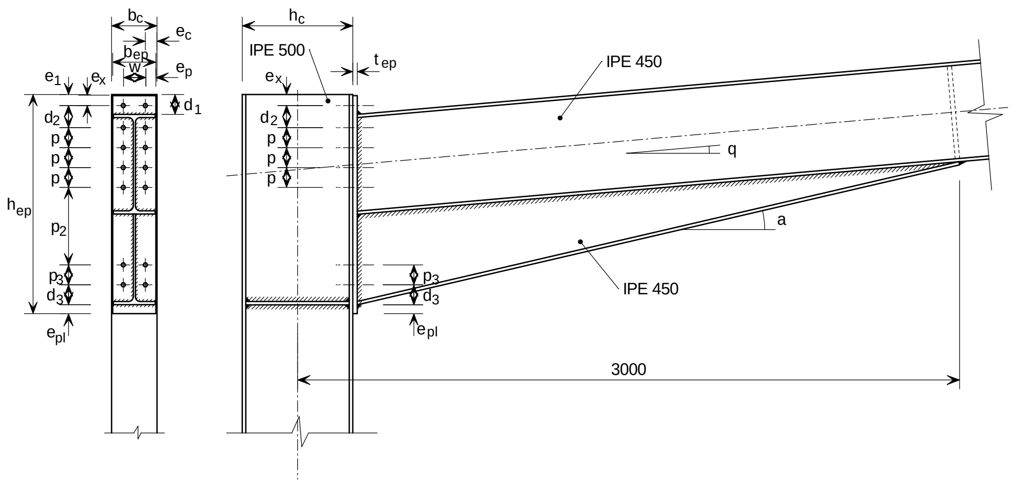
This example presents a method for calculating the moment resistance and the shear resistance of an eaves moment connection, as well as the design of welds. For the calculation of the moment resistance a simplified conservative method is used, which makes possible to avoid the calculation of bolt row groups. The connection is a Category A: Bearing type bolted connection using non-preloaded bolts.

Joint resistance of the eaves moment connection

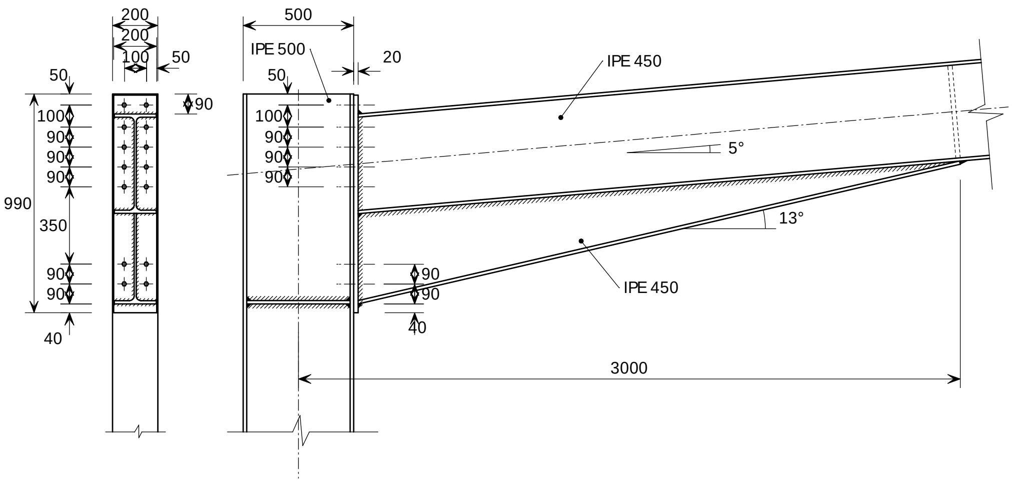
Table 1.1 Joint resistance of eaves moment connection

Resistance	
Potential resistance of bolt rows in the tension zone	$F_{t,Rd}$
Compression resistance	$F_{c,Rd}$
Shear resistance of the column web panel	$V_{wp,Rd}$
Moment resistance	$M_{j,Rd}$
Shear resistance for vertical forces	V_{Rd}

1 Eaves Connection –Details and data



CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	2 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006



Main joint data

Configuration	Rafter to column flange
Column	IPE 500 S355
Beam	IPE 450 S355
Type of connection	End plate connection using non-preloaded bolts
	Category A: Bearing type
End plate	990 × 200 × 20, S355
Bolts	M24, grade 8.8

Column IPE 500, S355

Depth	h_c	= 500 mm
Width	b_c	= 200 mm
Thickness of the web	t_{wc}	= 10,2 mm
Thickness of the flange	t_{fc}	= 16,0 mm
Fillet radius	r_c	= 21 mm
Area	A_c	= 116 cm^2
Second moment of area	$I_{y,c}$	= 48200 cm^4
Depth between fillets	$d_{c,c}$	= 426 mm
Yield strength	$f_{y,c}$	= 355 N/mm^2
Ultimate tensile strength	$f_{u,c}$	= 510 N/mm^2

CALCULATION SHEET	Document Ref:	*SX031a-EN-EU*	Sheet	*3* of *36*
	Title	*Example: Portal frame - eaves moment connection*		
	Eurocode Ref	*EN 1993-1-8*		
	Made by	*Edurne Núñez*	Date	*Nov 2005*
	Checked by	*Abdul Malik*	Date	*Feb 2006*

Supported Beam IPE 450, S355

Depth	h_b	= 450 mm
Width	b_b	= 190 mm
Thickness of the web	t_{wb}	= 9,4 mm
Thickness of the flange	t_{fb}	= 14,6 mm
Fillet radius	r_b	= 21 mm
Area	A_b	= 98,8 cm^2
Second moment of area	$I_{y,b}$	= 33740 cm^4
Depth between fillets	$d_{c,b}$	= 378,8 mm
Depth between flanges	$h_{i,b}$	= 420,8 mm
Yield strength	$f_{y,b}$	= 355 N/mm^2
Ultimate tensile strength	$f_{u,b}$	= 510 N/mm^2

Haunch IPE 450, S355

Depth	h_h	= 450 mm
Width	b_h	= 190 mm
Thickness of the web	t_{wh}	= 9,4 mm
Thickness of the flange	t_{fh}	= 14,6 mm
Fillet radius	r_h	= 21 mm
Yield strength	$f_{y,h}$	= 355 N/mm^2
Ultimate tensile strength	$f_{u,h}$	= 510 N/mm^2

End plate 990 × 200 × 10, S355

Depth	h_p	= 990 mm
Width	b_p	= 200 mm
Thickness	t_p	= 20 mm
Yield strength	$f_{y,p}$	= 355 N/mm^2
Ultimate tensile strength	$f_{u,p}$	= 510 N/mm^2

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	4 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Number of horizontal bolt rows in tension n_t = 5

Number of bolt rows in shear n_s = 2

Plate edge to first bolt row e_x = 50 mm

Column flange edge to first bolt row e_1 = 50 mm

Pitch between bolt rows in the tension zone p = 90 mm

Pitch between last tension bolt and first shear bolt p_2 = 90 mm

Pitch between bolt rows in the shear zone p_3 = 90 mm

Tension flange of the rafter to end plate edge d_1 = 90 mm

Pitch between bolt in the extended zone of the end plate and the first bolt row below the tension flange of the rafter d_2 = 100 mm

Last shear bolt to bottom of compression flange of the haunch d_3 = 90 mm

Distance between the bottom of the compression flange of the rafter and the edge of the end plate e_{pl} = 40 mm

Plate edge to bolt line e_p = 50 mm

Column edge to bolt line e_c = 50 mm

Gauge (i.e. distance between cross centres) w = 100 mm

Bolts M24, 8.8

Tensile stress area A_s = 353 mm^2

Nominal bolt diameter d = 24 mm

Diameter of the holes d_0 = 26 mm

Yield strength f_{yb} = 640 N/mm^2

Ultimate tensile strength f_{ub} = 800 N/mm^2

Partial safety factors

EN 1993-1-1 §6.1, Note 2B

γ_{M0} = 1,0

$\gamma_{M,1}$ = 1,0

$\gamma_{M,2}$ = 1,25 (for shear resistance at ULS)

Steel properties

Elastic modulus E = 210000 N/mm^2

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	5 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Design forces

M_{Ed} = 880 kNm

N_{Ed} = 175 kN

V_{Ed} = 200 kN

Additional geometric data

EN 1993-1-8 Figure 6.2

$$m_{\mathrm{x,p}} = \left(d_1 - e_{\mathrm{x}} - 0{,}8\sqrt{2}a_{\mathrm{tf}}\right) = \left(90 - 50 - 0{,}8 \times \sqrt{2} \times 8\right)$$

$$m_{\mathrm{x,p}} = 30{,}95 \text{ mm}$$

$$m_{\mathrm{p1}} = \frac{\left(w - t_{\mathrm{wb}} - 2 \times 0{,}8\sqrt{2}a_{\mathrm{w}}\right)}{2} = \frac{\left(100 - 9{,}4 - 2 \times 0{,}8 \times \sqrt{2} \times 6\right)}{2}$$

$$m_{\mathrm{p1}} = 38{,}51 \text{ mm}$$

$$m_{\mathrm{p2}} = d_2 - \left(d_1 - e_{\mathrm{x}}\right) - \frac{t_{\mathrm{fb}}}{\cos\left(\theta \frac{2\pi}{360}\right)} - 0{,}8\sqrt{2}a_{\mathrm{tf}}$$

$$m_{\mathrm{p2}} = 100 - (90 - 50) - \frac{14{,}6}{\cos\left(5 \frac{2\pi}{360}\right)} - 0{,}8 \times \sqrt{2} \times 8$$

$$m_{\mathrm{p2}} = 36{,}29 \text{ mm}$$

$$m_{\mathrm{p3}} = \frac{h_{\mathrm{b}}}{\cos\left(\theta \frac{2\pi}{360}\right)} - 0{,}8\sqrt{2}a_{\mathrm{w}} - \left[\left(e_{\mathrm{x}} + d_2\right) - d_1\right] - 3p - \frac{t_{\mathrm{fb}}}{\cos\left(\theta \frac{2\pi}{360}\right)}$$

$$m_{\mathrm{p3}} = \frac{450}{\cos\left(5 \frac{2\pi}{360}\right)} - 0{,}8 \times \sqrt{2} \times 6 - \left[(50 + 100) - 90\right] - 3 \times 90 - \frac{14{,}6}{\cos\left(5 \frac{2\pi}{360}\right)}$$

$$m_{\mathrm{p3}} = 100{,}27 \text{ mm}$$

$$m_{\mathrm{c1}} = \frac{w - 0.8 \times 2r_{\mathrm{c}} - t_{\mathrm{wc}}}{2} = \frac{100 - 0{,}8 \times 2 \times 21 - 10{,}2}{2}$$

$$m_{\mathrm{c1}} = 28{,}1 \text{ mm}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	6 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

End distances

$$e_{\min} = \min(e_{c1};\quad e_p)$$

$$e_{\min} = 50\ \text{mm}$$

$$n_{p,c} = \min(e_{\min};\quad 1{,}25 m_{c1})$$

$$n_{p,c} = 35{,}13\ \text{mm}$$

$$n_{p,ep} = \min(e_{\min};\quad 1{,}25 m_{p1})$$

$$n_{p,ep} = 48{,}14\ \text{mm}$$

Area of the column

EN 1993-1-1 §6.2.6(3)

$$\eta = 1{,}0$$

$$A_{vc} = \max[A_c - 2b_c t_{fc} + t_{fc}(t_{wc} + 2r_c);\quad \eta h_{wc} t_{wc}]$$

$$A_{vc} = \max[11600 - 2\times 200\times 16 + 16\times(10{,}2 + 2\times 21);\quad 1{,}0\times 500\times 10{,}2]$$

$$A_{v,c} = 6035{,}2\ \text{mm}^2$$

Bolt resistance

EN 1993-1-8 Table 3.4.

$$k_2 = 0{,}9$$

$$F_{t,Rd} = \frac{k_2 f_{ub} A_s}{\gamma_{M2}} = \frac{0{,}9\times 800\times 353}{1{,}25} = 203\ \text{kN (for one bolt)}$$

2 Welds

SN041 Section 3

2.1 Tension flange to end-plate weld

According to the first option given in the NCCI on eaves moment connections, the following simple rule can be used to design a full strength weld:

$$a_{tf} \geq 0{,}55 t_{fb} = 0{,}55\times 14{,}6 = 8{,}03$$

Therefore

$$a_{tf} = 8\ \text{mm}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	7 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

2.2 Web to end plate weld

Full strength weld can be designed according to the following expression:

$$a_{\mathrm{w}} \geq 0{,}55 t_{\mathrm{wb}} = 0{,}55 \cdot 9{,}4 = 5{,}17 \text{ mm}$$

Therefore,

$$a_{\mathrm{w}} = 6 \text{ mm}$$

2.3 Compression flange welds

Considering that a good contact can be provided, a nominal weld can be adopted. Haunch flange thickness is 14.6 mm, therefore adopt 6 mm throat thickness.

$$a_{\mathrm{cf}} = 6 \text{ mm}$$

3 Potential bolt row resistances in tension

3.1 Row 1

3.1.1 Column side

Effective length

The effective length of T-stub may be calculated from the minimum of the following expressions:

SN041

$$2\pi m_{\mathrm{c1}} = 2\pi \times 28{,}1 \qquad = 176{,}56 \text{ mm}$$

$$4 m_{\mathrm{c1}} + 1{,}25 e_{\mathrm{x}} = 4 \times 28{,}1 + 1{,}25 \times 50 \qquad = 174{,}9 \text{ mm}$$

$$\pi m_{\mathrm{c1}} + 0{,}5 p = \pi \times 28{,}1 + 0{,}5 \times 90 \qquad = 133{,}28 \text{ mm}$$

$$2 m_{\mathrm{c1}} + 0{,}625 e_{\mathrm{c}} + 0{,}5 p = 2 \times 28{,}1 + 0{,}625 \times 50 + 0{,}5 \times 90 \qquad = 132{,}45 \text{ mm}$$

$$e_{\mathrm{x}} + \frac{d_2}{2} = 50 + \frac{100}{2} \qquad = 100 \text{ mm}$$

$$l_{\mathrm{eff,1,c}} = \min \begin{pmatrix} 2\pi m_{\mathrm{c1}};\ 4 m_{\mathrm{c1}} + 1{,}25 e_{\mathrm{x}};\ \pi m_{\mathrm{c1}} + 0{,}5 p; \\ 2 m_{\mathrm{c1}} + 0{,}625 e_{\mathrm{c}} + 0{,}5 p;\ e_{\mathrm{x}} + \dfrac{d_2}{2} \end{pmatrix} = \min \begin{pmatrix} 176{,}56; 174{,}9; \\ 133{,}28; 132{,}45; 100 \end{pmatrix}$$

$$l_{\mathrm{eff,1,c}} = 100 \text{ mm}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	8 of 36	
	Title	Example: Portal frame - eaves moment connection			
	Eurocode Ref	EN 1993-1-8			
	Made by	Edurne Núñez	Date	Nov 2005	
	Checked by	Abdul Malik	Date	Feb 2006	

Column flange in bending

SN041

Mode 1; Method 1

$$M_{\mathrm{pl,1,Rd,r1,c}} = \frac{0{,}25 l_{\mathrm{eff,1,c}} t_{\mathrm{fc}}^{2} f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25 \times 100 \times 16^{2} \times 355}{1{,}0}$$

$$M_{\mathrm{pl,1,Rd,r1,c}} = 2{,}272 \times 10^{6}\ \mathrm{Nmm}$$

$$F_{\mathrm{T,1,Rd,fc}} = \frac{4 M_{\mathrm{pl,1,Rd,rl,c}}}{m_{\mathrm{c1}}} = \frac{4 \times 2{,}272 \times 10^{6}}{28{,}1}$$

$$\therefore F_{\mathrm{T,1,Rd,fc}} = 393{,}42\ \mathrm{kN}$$

Mode 2

$$M_{\mathrm{pl,2,Rd,r1,c}} = \frac{0{,}25 l_{\mathrm{eff,1,c}} t_{\mathrm{fc}}^{2} f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25 \times 100 \times 16^{2} \times 355}{1{,}0}$$

$$M_{\mathrm{pl,2,Rd,r1,c}} = 2{,}272 \times 10^{6}\ \mathrm{Nmm}$$

$$F_{\mathrm{T,2,Rd,fc}} = \frac{2 M_{\mathrm{pl,2,Rd,r1,c}} + n_{\mathrm{p,c}} \sum F_{\mathrm{t,Rd}}}{m_{\mathrm{c1}} + n_{\mathrm{p,c}}}$$

$$= \frac{2 \times 2{,}272 \times 10^{6} + 35{,}13 \times 406{,}66 \times 10^{3}}{28{,}1 + 35{,}13}$$

$$\therefore F_{\mathrm{T,2,Rd,fc}} = 297{,}8\ \mathrm{kN}$$

Mode 3

$$F_{\mathrm{T,3,Rd,fc}} = \sum F_{\mathrm{t,Rd}}$$

$$F_{\mathrm{T,3,Rd,fc}} = 2 \times 203 = 406\ \mathrm{kN}$$

Therefore the resistance of the column flange in bending is

$$F_{\mathrm{T,Rd,fc}} = \min\left(F_{\mathrm{T,1,Rd,fc}};\ F_{\mathrm{T,2,Rd,fc}};\ F_{\mathrm{T,3,Rd,fc}}\right) = \min(323;\ 298;\ 406)$$

$$F_{\mathrm{T,Rd,fc}} = 298\ \mathrm{kN}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	9 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Column web in transverse tension

$$F_{\mathrm{t,wc,Rd}} = \frac{\omega_{\mathrm{r1,c}} . b_{\mathrm{eff,t,wc}} t_{\mathrm{wc}} f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}}$$

According to the geometry of the connection — EN 1993-1-8 Table 5.4

$$\beta = 1$$

And therefore, — EN 1993-1-8 Table 6.3

$$\omega_{\mathrm{r1,c}} = \omega_{\mathrm{1,r1,c}}$$

$$b_{\mathrm{eff,t,wc}} = l_{\mathrm{eff,1,c}}$$

EN 1993-1-8 §6.2.6.3(3)

$$\omega_{\mathrm{1,r1,c}} = \frac{1}{\sqrt{1+1{,}3\left(\frac{b_{\mathrm{eff,t,wc}} t_{\mathrm{wc}}}{A_{\mathrm{vc}}}\right)^2}} = \frac{1}{\sqrt{1+1{,}3\left(\frac{100 \times 10{,}2}{6035{,}2}\right)^2}}$$

$$\omega_{\mathrm{1,r1,c}} = 0{,}98$$

$$\omega_{\mathrm{r1,c}} = 0{,}98$$

$$F_{\mathrm{t,wc,Rd}} = \frac{0{,}98 \times 100 \times 10{,}2 \times 355}{1{,}0}$$

$$F_{\mathrm{t,wc,Rd}} = 355 \text{ kN}$$

3.1.2 Beam side

Effective length

The effective length may be calculated from the minimum of the following expressions:

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	10 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

$2\pi m_{x,p} = 2\pi \times 30{,}95 \quad = 194{,}46 \text{ mm}$

SN041

$\pi m_{x,p} + w = \pi \times 30{,}95 + 100 \quad = 197{,}23 \text{ mm}$

$\pi m_{x,p} + 2e_p = \pi \times 30{,}95 + 2 \times 50 \quad = 197{,}23 \text{ mm}$

$4m_{x,p} + 1{,}25e_x = 4 \times 30{,}95 + 1{,}25 \times 50 \quad = 186{,}3 \text{ mm}$

$e_p + 2m_{x,p} + 0{,}625e_x = 50 + 2 \times 30{,}95 + 0{,}625 \times 50 \quad = 143{,}15 \text{ mm}$

$0{,}5b_p = 0{,}5 \times 200 \quad = 100 \text{ mm}$

$0{,}5w + 2m_{x,p} + 0{,}625e_x = 0{,}5 \times 100 + 2 \times 30{,}95 + 0{,}625 \times 50 = 143{,}15 \text{ mm}$

SN041

$$l_{eff,1,b} = \min\begin{pmatrix} 2\pi m_{x,p}; & \pi m_{x,p} + w; & \pi m_{x,p} + 2e_p; & 4m_{x,p} + 1{,}25e_x; \\ e_p + 2m_{x,p} + 0{,}625e_x; & 0{,}5b_p; & 0{,}5w + 2m_{x,p} + 0{,}625e_x \end{pmatrix}$$

$$= \min(194{,}46; \quad 197{,}23; \quad 197{,}23; \quad 186{,}3; \quad 143{,}15; \quad 100; \quad 143{,}15)$$

$l_{eff,1,b} = 100 \text{ mm}$

End plate in bending

Mode 1; Method 1

$$M_{pl,1,Rd,r1,b} = \frac{0{,}25 l_{eff,1,b} t_p^{\,2} f_{y,p}}{\gamma_{M0}} = \frac{0{,}25 \times 100 \times 20^2 \times 355}{1{,}0}$$

$M_{pl,1,Rd,r1,b} = 3{,}55 \times 10^6 \text{ Nmm}$

$$F_{T,1,Rd,ep} = \frac{4M_{pl,1,Rd,r1,b}}{m_{p1}} = \frac{4 \times 3{,}55 \times 10^6}{38{,}51}$$

$F_{T,1,Rd,ep} = 368{,}7 \text{ kN}$

Mode 2

$$M_{pl,2,Rd,r1,b} = \frac{0{,}25 l_{eff,1,b} t_p^{\,2} f_{y,p}}{\gamma_{M0}} = \frac{0{,}25 \times 100 \times 20^2 \times 355}{1{,}0}$$

$M_{pl,2,Rd,r1,b} = 3{,}55 \times 10^6 \text{ Nmm}$

CALCULATION SHEET	Document Ref:	*SX031a-EN-EU*	Sheet	*11* of *36*
	Title	*Example: Portal frame - eaves moment connection*		
	Eurocode Ref	*EN 1993-1-8*		
	Made by	*Edurne Núñez*	Date	*Nov 2005*
	Checked by	*Abdul Malik*	Date	*Feb 2006*

$$F_{\mathrm{T,2,Rd,ep}} = \frac{2M_{\mathrm{p1,2,Rd,r1,b}} + n_{\mathrm{p,ep}}\sum F_{\mathrm{t,Rd}}}{m_{\mathrm{p1}} + n_{\mathrm{p,ep}}}$$

$$= \frac{2\times 3{,}55\times 10^{6} + 48{,}14\times 406{,}66\times 10^{3}}{38{,}51 + 48{,}14}$$

$$F_{\mathrm{T,2,Rd,ep}} = 307{,}86 \text{ kN}$$

<u>**Mode 3**</u>

$$F_{\mathrm{T,3,Rd,ep}} = \sum F_{\mathrm{t,Rd}}$$

$$F_{\mathrm{T,3,Rd,ep}} = 2\times 203 = 406 \text{ kN}$$

Therefore the resistance of the end plate in bending is:

$$F_{\mathrm{T,1,Rd,ep}} = \min\left(F_{\mathrm{T,1,Rd,ep}};\quad F_{\mathrm{T,2,Rd,ep}};\quad F_{\mathrm{T,3,Rd,ep}}\right) = \min(369;\ 308;\ 406)$$

$$F_{\mathrm{T,1,Rd,ep}} = 308 \text{ kN}$$

$$\therefore \boxed{F_{\mathrm{t,Rd(row1)}} = \min(298;\quad 355;\quad 308) = 298 \text{ kN}}$$

3.2 Row 2

3.2.1 Column side

<u>**Effective length**</u>

The effective length may be calculated from the minimum of the following expressions:

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	12 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

$$2\pi m_{c1} = 2\pi \times 28{,}1 \quad = 176{,}56 \text{ mm}$$

$$4m_{c1} + 1{,}25e_c = 4 \times 28{,}1 + 1{,}25 \times 50 \quad = 174{,}9 \text{ mm}$$

$$\pi m_{c1} + \frac{p}{2} = \pi \times 28{,}1 + \frac{90}{2} \quad = 133{,}28 \text{ mm}$$

$$2m_{c1} + 0{,}625e_c + \frac{p}{2} = 2 \times 28{,}1 + 0{,}625 \times 50 + \frac{90}{2} \quad = 132{,}45 \text{ mm}$$

$$\pi m_{c1} + \frac{d_2}{2} = \pi \times 28{,}1 + \frac{100}{2} \quad = 138{,}28 \text{ mm}$$

$$2m_{c1} + 0{,}625e_c + \frac{d_2}{2} \quad = 137{,}45 \text{ mm}$$

$$\frac{d_2}{2} + \frac{p}{2} = \frac{100}{2} + \frac{90}{2} \quad = 95 \text{ mm}$$

$$l_{\text{eff,2,c}} = \min\begin{pmatrix} 2\pi m_{c1}; & 4m_{c1} + 1{,}25e_c; & \pi m_{c1} + \frac{p}{2}; & 2m_{c1} + 0{,}625e_c + \frac{p}{2}; \\ \pi m_{c1} + \frac{d_2}{2}; & 2m_{c1} + 0{,}625e_c + \frac{d_2}{2}; & \frac{d_2}{2} + \frac{p}{2} & \end{pmatrix}$$

$$= \min(176{,}56; \quad 174{,}9; \quad 133{,}28; \quad 132{,}45; \quad 138{,}28; \quad 137{,}45; \quad 95)$$

$$l_{\text{eff,2,c}} = 95 \text{ mm}$$

Column flange in bending

Mode 1; Method 1

$$M_{\text{pl,1,Rd,r2,c}} = \frac{0{,}25 l_{\text{eff,2,c}} t_{\text{fc}}^2 f_{\text{y,c}}}{\gamma_{\text{M0}}} = \frac{0{,}25 \times 95 \times 16^2 \times 355}{1{,}0}$$

$$M_{\text{pl,1,Rd,r2,c}} = 2{,}16 \times 10^6 \text{ Nmm}$$

$$F_{\text{T,1,Rd,fc}} = \frac{4M_{\text{pl,1,Rd,r2,c}}}{m_{\text{cl}}} = \frac{4 \times 2{,}16 \times 10^6}{28{,}1}$$

$$F_{\text{T,1,Rd,fc}} = 307{,}5 \text{ kN}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	13 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Mode 2

$$M_{\mathrm{pl,2,Rd,r2,c}} = \frac{0{,}25 l_{\mathrm{eff,2,c}} t_{\mathrm{fc}}^{2} f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25 \times 95 \times 16^{2} \times 355}{1{,}0}$$

$$M_{\mathrm{pl,2,Rd,r2,c}} = 2{,}16 \times 10^{6}\ \mathrm{Nmm}$$

$$F_{\mathrm{T,2,Rd,fc}} = \frac{2M_{\mathrm{p1,2,Rd,r2,c}} + n_{\mathrm{p,c}} \sum F_{\mathrm{t,Rd}}}{m_{\mathrm{c1}} + n_{\mathrm{p,c}}}$$

$$= \frac{2 \times 2{,}16 \times 10^{6} + 35{,}13 \times 406{,}66 \times 10^{3}}{28{,}1 + 35{,}13}$$

$$F_{\mathrm{T,2,Rd,fc}} = 294{,}3\ \mathrm{kN}$$

Mode 3

$$F_{\mathrm{T,3,Rd,fc}} = \sum F_{\mathrm{t,Rd}}$$

$$F_{\mathrm{T,3,Rd,fc}} = 2 \times 203 = 406\ \mathrm{kN}$$

Therefore resistance of the column flange in bending is:

$$F_{\mathrm{T,Rd,fc}} = \min\left(F_{\mathrm{T,1,Rd,fc}};\quad F_{\mathrm{T,2,Rd,fc}};\quad F_{\mathrm{T,3,Rd,fc}}\right)$$

$$= \min\left(308;\quad 294;\quad 406\right)$$

$$F_{\mathrm{T,Rd,fc}} = 294\ \mathrm{kN}$$

Column web in transverse tension

$$F_{\mathrm{t,wc,Rd}} = \frac{\omega_{\mathrm{r2,c}} b_{\mathrm{eff,t,wc}} t_{\mathrm{wc}} f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}}$$

$$b_{\mathrm{eff,t,wc}} = l_{\mathrm{eff,2,c}}$$

$$\omega_{\mathrm{r2,c}} = \omega_{\mathrm{1,r2,c}} = \frac{1}{\sqrt{1 + 1{,}3\left(\frac{b_{\mathrm{eff,t,wc}} t_{\mathrm{wc}}}{A_{\mathrm{vc}}}\right)^{2}}} = \frac{1}{\sqrt{1 + 1{,}3\left(\frac{95 \times 10{,}2}{6035{,}2}\right)^{2}}}$$

$$\omega_{\mathrm{r2,c}} = 0{,}98$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	14 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

$$F_{\mathrm{t,wc,Rd}} = \frac{0,98 \times 95 \times 10,2 \times 355}{1,0}$$

$$\therefore F_{\mathrm{t,wc,Rd}} = 337 \text{ kN}$$

3.2.2 Beam side

Effective length SN041

The effective length may be calculated from the minimum of the following expressions:

$$2\pi m_{\mathrm{p1}} = 2\pi \times 38,51 \quad = 241,98 \text{ mm}$$

$$\alpha_{\mathrm{r2,b}} m_{\mathrm{p1}}$$

α_{r2} depends on $\lambda_{1,\mathrm{r2,b}}$ and $\lambda_{2,\mathrm{r2,b}}$, defined as follows: EN 1993-1-8 Figure 6.11

$$\lambda_{1,\mathrm{r2,b}} = \frac{m_{\mathrm{p1}}}{m_{\mathrm{p1}} + e_{\mathrm{p}}}$$

$$\lambda_{1,\mathrm{r2,b}} = 0,44$$

$$\lambda_{2,\mathrm{r2,b}} = \frac{m_{\mathrm{p2}}}{m_{\mathrm{p1}} + e_{\mathrm{p}}}$$

$$\lambda_{2,\mathrm{r2,b}} = 0,41$$

Therefore:

$$\alpha_{\mathrm{r2,b}} = 6,3$$

$$\alpha_{\mathrm{r2,b}} m_{\mathrm{p1}} = 6,3 \times 38,51 \; = 242,61 \text{ mm}$$

$$l_{\mathrm{eff,2,b}} = \min\left(2\pi m_{\mathrm{p1}}; \quad \alpha_{\mathrm{r2,b}} m_{\mathrm{p1}}\right) = \min\left(241,98; \quad 242,61\right)$$

$$l_{\mathrm{eff,2,b}} = 241,98 \text{ mm}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	15 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

End plate in bending

Mode 1; Method 1

$$M_{\mathrm{pl,1,Rd,r2,b}} = \frac{0{,}25 l_{\mathrm{eff,2,b}} t_{\mathrm{p}}^{2} f_{\mathrm{y,p}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25 \times 241{,}98 \times 20^{2} \times 355}{1{,}0}$$

$$M_{\mathrm{pl,1,Rd,r2,b}} = 8{,}6 \times 10^{6}\ \mathrm{Nmm}$$

$$F_{\mathrm{T,1,Rd,ep}} = \frac{4 M_{\mathrm{pl,1,Rd,r2,b}}}{m_{\mathrm{p1}}} = \frac{4 \times 8{,}6 \times 10^{6}}{38{,}51}$$

$$F_{\mathrm{T,1,Rd,ep}} = 893{,}3\ \mathrm{kN}$$

Mode 2

$$M_{\mathrm{pl,2,Rd,r2,b}} = \frac{0{,}25 l_{\mathrm{eff,2,b}} t_{\mathrm{p}}^{2} f_{\mathrm{y,p}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25 \times 241{,}98 \times 20^{2} \times 355}{1{,}0}$$

$$M_{\mathrm{pl,2,Rd,r2,b}} = 8{,}6 \times 10^{6}\ \mathrm{Nmm}$$

$$F_{\mathrm{T,2,Rd,ep}} = \frac{2 M_{\mathrm{p1,2,Rd,r2,b}} + n_{\mathrm{p,ep}} \Sigma_{\mathrm{Ft,Rd}}}{m_{\mathrm{p1}} + n_{\mathrm{p,ep}}}$$

$$= \frac{2 \times 8{,}6 \times 10^{6} + 48{,}14 \times 406{,}66 \times 10^{3}}{38{,}51 + 48{,}14}$$

$$F_{\mathrm{T,2,Rd,ep}} = 424{,}4\ \mathrm{kN}$$

Mode 3

$$F_{\mathrm{T,3,Rd,ep}} = \sum F_{\mathrm{t,Rd}}$$

$$F_{\mathrm{T,3,Rd,ep}} = 2 \times 203 = 406\ \mathrm{kN}$$

Therefore the resistance of the end plate in bending is:

$$F_{\mathrm{T,Rd,ep}} = \min\left(F_{\mathrm{T,1,Rd,ep}};\quad F_{\mathrm{T,2,Rd,ep}};\quad F_{\mathrm{T,3,Rd,ep}}\right) = \min(893;\ 424;\ 406)$$

$$F_{\mathrm{T,Rd,ep}} = 406\ \mathrm{kN}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	16 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Rafter web in tension

$$F_{\mathrm{t,wb,Rd}} = \frac{b_{\mathrm{eff,t,wb}}\, t_{\mathrm{wb}}\, f_{\mathrm{y,beam}}}{\gamma_{\mathrm{M0}}} = \frac{241{,}98 \times 9{,}4 \times 355}{1{,}0}$$

$b_{\mathrm{eff,t,wb}} = l_{\mathrm{eff,2,b}}$

$F_{\mathrm{t,wb,Rd}} = 807 \text{ kN}$

$$\therefore \boxed{F_{\mathrm{t,Rd(row2)}} = \min(294; \quad 337; \quad 406; \quad 807 = 294 \text{ kN}}$$

3.3 Row 3

3.3.1 Column side

Effective length SN041

The effective length may be calculated from the minimum of the following expressions:

$$2\pi m_{\mathrm{c1}} = 2\pi \times 28{,}1 \quad = 176{,}56 \text{ mm}$$

$$4m_{\mathrm{c1}} + 1{,}25e_{\mathrm{c}} = 4 \times 28{,}1 + 1{,}25 \times 50 \quad = 174{,}9 \text{ mm}$$

$$\pi m_{\mathrm{c1}} + \frac{p}{2} = \pi \times 28{,}1 + \frac{90}{2} \quad = 133{,}28 \text{ mm}$$

$$2m_{\mathrm{c1}} + 0{,}625e_{\mathrm{c}} + \frac{p}{2} = 2 \times 28{,}1 + 0{,}625 \times 50 + \frac{90}{2} \quad = 132{,}45 \text{ mm}$$

$p = 90 \text{ mm}$

$$l_{\mathrm{eff,3,c}} = \min\left(2\pi m_{\mathrm{c1}};\ 4m_{\mathrm{c1}} + 1{,}25e_{\mathrm{c}};\ \pi m_{\mathrm{c1}} + \frac{p}{2};\ 2m_{\mathrm{c1}} + 0{,}625e_{\mathrm{c}} + \frac{p}{2};\ p\right)$$

$$= \min(176{,}56; \quad 174{,}9; \quad 133{,}28; \quad 132{,}45; \quad 90)$$

$l_{\mathrm{eff,3,c}} = 90 \text{ mm}$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	17 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Column flange in bending

Mode 1; Method 1

$$M_{\mathrm{pl,1,Rd,r3,c}} = \frac{0{,}25 l_{\mathrm{eff,3,c}} t_{\mathrm{fc}}^{2} f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25 \times 90 \times 16^{2} \times 355}{1{,}0}$$

$$M_{\mathrm{pl,1,Rd,r3,c}} = 2{,}05 \times 10^{6} \text{ Nmm}$$

$$F_{\mathrm{T,1,Rd,fc}} = \frac{4 \cdot M_{\mathrm{pl,1,Rd,r3,c}}}{m_{\mathrm{c1}}} = \frac{4 \times 2{,}05 \times 10^{6}}{28{,}1}$$

$$F_{\mathrm{T,1,Rd,fc}} = 291{,}8 \text{ kN}$$

Mode 2

$$M_{\mathrm{pl,2,Rd,r3,c}} = \frac{0{,}25 l_{\mathrm{eff,3,c}} t_{\mathrm{fc}}^{2} f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25 \times 90 \times 16^{2} \times 355}{1{,}1}$$

$$M_{\mathrm{pl,2,Rd,r3,c}} = 2{,}05 \times 10^{6} \text{ Nmm}$$

$$F_{\mathrm{T,2,Rd,fc}} = \frac{2 M_{\mathrm{p1,2,Rd,r3,c}} + n_{\mathrm{p,c}} \sum F_{\mathrm{t,Rd}}}{m_{\mathrm{c1}} + n_{\mathrm{p,c}}}$$

$$= \frac{2 \times 2{,}05 \times 10^{6} + 35{,}13 \times 406{,}66 \times 10^{3}}{28{,}1 + 35{,}13}$$

$$F_{\mathrm{T,2,Rd,fc}} = 290{,}8 \text{ kN}$$

Mode 3

$$F_{\mathrm{T,3,Rd,fc}} = \sum F_{\mathrm{t,Rd}}$$

$$F_{\mathrm{T,3,Rd,fc}} = 2 \times 203 = 406 \text{ kN}$$

Therefore the resistance of the column flange in bending is:

$$F_{\mathrm{T,Rd,fc}} = \min\left(F_{\mathrm{T,1,Rd,fc}};\quad F_{\mathrm{T,2,Rd,fc}};\quad F_{\mathrm{T,3,Rd,fc}}\right)$$

$$= \min\left(292;\quad 291;\quad 406\right)$$

$$F_{\mathrm{T,Rd,fc}} = 291 \text{ kN}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	18 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Column web in transverse tension

$$F_{\mathrm{t,wc,Rd}} = \frac{\omega_{\mathrm{r3,c}} b_{\mathrm{eff,t,wc}} t_{\mathrm{wc}} f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}}$$

$$b_{\mathrm{eff,t,wc}} = l_{\mathrm{eff,3,c}}$$

$$\omega_{\mathrm{r3,c}} = \omega_{\mathrm{1,r3,c}} = \frac{1}{\sqrt{1+1,3\left(\frac{b_{\mathrm{eff,t,wc}} t_{\mathrm{wc}}}{A_{\mathrm{vc}}}\right)^2}} = \frac{1}{\sqrt{1+1,3\left(\frac{90\times 10,2}{6035,2}\right)^2}}$$

$$\omega_{\mathrm{r3,c}} = 0,99$$

$$F_{\mathrm{t,wc,Rd}} = \frac{0,99\times 90\times 10,2\times 355}{1,0}$$

$$F_{\mathrm{t,wc,Rd}} = 323\ \mathrm{kN}$$

3.3.2 Beam side

Effective length

The effective length may be calculated from the minimum of the following expressions:

$$2\pi m_{\mathrm{p1}} = 2\pi\times 38,51 \quad = 241,98\ \mathrm{kN}$$

$$4m_{\mathrm{p1}} + 1,25e_{\mathrm{p}} = 4\times 38,51 + 1,25\times 50 \quad = 216,55\ \mathrm{kN}$$

$$l_{\mathrm{eff,3,b}} = \min\left(2\pi m_{\mathrm{p1}};\quad 4m_{\mathrm{p1}} + 1,25e_{\mathrm{p}}\right) = \min\left(241,98;\quad 216,55\right)$$

$$l_{\mathrm{eff,3,b}} = 216,55\ \mathrm{mm}$$

End plate in bending

Mode 1; Method 1

$$M_{\mathrm{pl,1,Rd,r3,b}} = \frac{0,25 l_{\mathrm{eff,3,b}} t_{\mathrm{p}}^2 f_{\mathrm{y,p}}}{\gamma_{\mathrm{M0}}} = \frac{0,25\times 216,55\times 20^2\times 355}{1,0}$$

$$M_{\mathrm{pl,1,Rd,r3,b}} = 7,68\times 10^6\ \mathrm{Nmm}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	19 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

$$F_{\mathrm{T,1,Rd,ep}} = \frac{4M_{\mathrm{pl,1,Rd,r3,b}}}{m_{\mathrm{p1}}} = \frac{4\times 7{,}68\times 10^6}{38{,}51}$$

$$F_{\mathrm{T,1,Rd,ep}} = 797{,}7\ \mathrm{kN}$$

Mode 2

$$M_{\mathrm{pl,2,Rd,r3,b}} = \frac{0{,}25 l_{\mathrm{eff,3,b}} t_{\mathrm{p}}^{2} f_{\mathrm{y,p}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25\times 216{,}55\times 20^2\times 355}{1{,}0}$$

$$M_{\mathrm{pl,2,Rd,r3,b}} = 7{,}68\times 10^6\ \mathrm{Nmm}$$

$$F_{\mathrm{T,2,Rd,ep}} = \frac{2M_{\mathrm{p1,2,Rd,r3,b}} + n_{\mathrm{p,ep}}\sum F_{\mathrm{t,Rd}}}{m_{\mathrm{p1}} + n_{\mathrm{p,ep}}}$$

$$= \frac{2\times 7{,}68\times 10^6 + 48{,}14\times 406{,}66\times 10^3}{38{,}51 + 48{,}14}$$

$$F_{\mathrm{T,2,Rd,ep}} = 403{,}2\ \mathrm{kN}$$

Mode 3

$$F_{\mathrm{T,3,Rd,ep}} = \sum F_{\mathrm{t,Rd}}$$

$$F_{\mathrm{T,3,Rd,ep}} = 2\times 203 = 406\ \mathrm{kN}$$

The resistance of the end plate in bending is:

$$F_{\mathrm{T,Rd,ep}} = \min\left(F_{\mathrm{T,1,Rd,ep}};\quad F_{\mathrm{T,2,Rd,ep}};\quad F_{\mathrm{T,3,Rd,ep}}\right)$$

$$= \min(798;\quad 403;\quad 406)$$

$$F_{\mathrm{T,Rd,ep}} = 403\ \mathrm{kN}$$

Rafter web in tension

$$F_{\mathrm{t,wb,Rd}} = \frac{b_{\mathrm{eff,t,wb}} t_{\mathrm{bw}} f_{\mathrm{y,beam}}}{\gamma_{\mathrm{M0}}} = \frac{216{,}55\times 9{,}4\times 355}{1{,}0}$$

$$b_{\mathrm{eff,t,wb}} = l_{\mathrm{eff,3,b}}$$

$$F_{\mathrm{t,wb,Rd}} = 723\ \mathrm{kN}$$

$$\therefore\ \boxed{F_{\mathrm{t,Rd(row3)}} = \min(291;\quad 323;\quad 403;\quad 723) = 291\ \mathrm{kN}}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	20 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

3.4 Row 4

3.4.1 Column side

Effective length

SN041

The effective length may be calculated from the minimum of the following expressions:

$$2\pi m_{c1} = 2\pi \times 28{,}1 \qquad = 176{,}56 \text{ mm}$$

$$4m_{c1} + 1{,}25e_c = 4 \times 28{,}1 + 1{,}25 \times 50 \qquad = 174{,}9 \text{ mm}$$

$$\pi m_{c1} + \frac{p}{2} = \pi \times 28{,}1 + \frac{90}{2} \qquad = 133{,}28 \text{ mm}$$

$$2m_{c1} + 0{,}625e_c + \frac{p}{2} = 2 \times 28{,}1 + 0{,}625 \times 50 + \frac{90}{2} \qquad = 132{,}45 \text{ mm}$$

$$p \qquad = 90 \text{ mm}$$

$$l_{eff,4,c} = \min\left(2\pi m_{c1};\ 4m_{c1} + 1{,}25e_c;\ \pi m_{c1} + \frac{p}{2};\ 2m_{c1} + 0{,}625e_c + \frac{p}{2};\ p\right)$$

$$= \min(176{,}56;\quad 174{,}9;\quad 133{,}28;\quad 132{,}45;\quad 90)$$

$$l_{eff,4,c} = 90 \text{ mm}$$

Column flange in bending

Mode 1; Method 1

$$M_{pl,1,Rd,r4,c} = \frac{0{,}25 l_{eff,4,c} t_{fc}^{2} f_{y,c}}{\gamma_{M0}} = \frac{0{,}25 \times 90 \times 16^2 \times 355}{1{,}0}$$

$$M_{pl,1,Rd,r4,c} = 2{,}05 \times 10^6 \text{ Nmm}$$

$$F_{T,1,Rd,fc} = \frac{4 \cdot M_{pl,1,Rd,r4,c}}{m_{c1}} = \frac{4 \times 2{,}05 \times 10^6}{28{,}1}$$

$$F_{T,1,Rd,fc} = 291{,}8 \text{ kN}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	21 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Mode 2

$$M_{\rm pl,2,Rd,r4,c} = \frac{0{,}25 l_{\rm eff,4,c} t_{\rm fc}{}^{2} f_{\rm yc}}{\gamma_{\rm M0}} = \frac{0{,}25 \times 90 \times 16^{2} \times 355}{1{,}0}$$

$$M_{\rm pl,2,Rd,r4,c} = 2{,}05 \times 10^{6}\ \text{Nmm}$$

$$F_{\rm T,2,Rd,fc} = \frac{2M_{\rm p1,2,Rd,r4,c} + n_{\rm p,c} \sum F_{\rm t,Rd}}{m_{\rm c1} + n_{\rm p,c}}$$

$$= \frac{2 \times 2{,}05 \times 10^{6} + 35{,}13 \times 406{,}66 \times 10^{3}}{28{,}1 + 35{,}13}$$

$$F_{\rm T,2,Rd,fc} = 290{,}8\ \text{kN}$$

Mode 3

$$F_{\rm T,3,Rd,fc} = \sum F_{\rm t,Rd}$$

$$F_{\rm T,3,Rd,fc} = 2 \times 203 = 406\ \text{kN}$$

Therefore the resistance of the column flange in bending is:

$$F_{\rm T,Rd,fc} = \min\left(F_{\rm T,1,Rd,fc};\quad F_{\rm T,2,Rd,fc};\quad F_{\rm T,3,Rd,fc}\right)$$

$$= \min\left(292;\quad 291;\quad 406\right)$$

$$F_{\rm T,Rd,fc} = 291\ \text{kN}$$

Column web in transverse tension

$$F_{\rm t,wc,Rd} = \frac{\omega_{\rm r4,c} b_{\rm eff,t,wc} t_{\rm wc} f_{\rm y,c}}{\gamma_{\rm M0}}$$

$$b_{\rm eff,t,wc} = l_{\rm eff,4,c}$$

$$\omega_{\rm r4,c} = \omega_{\rm 1,r4,c} = \frac{1}{\sqrt{1 + 1{,}3\left(\frac{b_{\rm eff,t,wc} t_{\rm wc}}{A_{\rm vc}}\right)^{2}}} = \frac{1}{\sqrt{1 + 1{,}3\left(\frac{90 \times 10{,}2}{6035{,}2}\right)^{2}}}$$

$$\omega_{\rm r4,c} = 0{,}99$$

$$F_{\rm t,wc,Rd} = \frac{0{,}99 \times 90 \times 10{,}2 \times 355}{1{,}0}$$

$$F_{\rm t,wc,Rd} = 323\ \text{kN}$$

3.4.2 Beam side

Effective length

SN041

The effective length may be calculated from the minimum of the following expressions:

$$2\pi m_{\text{p1}} = 2\pi \times 38{,}51 \quad = 241{,}98 \text{ kN}$$

$$4m_{\text{p1}} + 1{,}25e_{\text{p}} = 4 \times 38{,}51 + 1{,}25 \times 50 \quad = 216{,}55 \text{ kN}$$

$$l_{\text{eff,4,b}} = \min\left(2\pi m_{\text{p1}}; \quad 4m_{\text{p1}} + 1{,}25e_{\text{p}}\right) = \min\left(241{,}98; \quad 216{,}55\right)$$

$$l_{\text{eff,4,b}} = 216{,}55 \text{ mm}$$

End plate in bending

Mode 1; Method 1

$$M_{\text{pl,1,Rd,r4,b}} = \frac{0{,}25 l_{\text{eff,4,b}} t_{\text{p}}^{2} f_{\text{y,p}}}{\gamma_{\text{M0}}} = \frac{0{,}25 \times 216{,}55 \times 20^2 \times 355}{1{,}0}$$

$$M_{\text{pl,1,Rd,r4,b}} = 7{,}68 \times 10^6 \text{ Nmm}$$

$$F_{\text{T,1,Rd,ep}} = \frac{4M_{\text{pl,1,Rd,r4,b}}}{m_{\text{p1}}} = \frac{4 \times 7{,}68 \times 10^6}{38{,}51}$$

$$F_{\text{T,1,Rd,ep}} = 797{,}7 \text{ kN}$$

Mode 2

$$M_{\text{pl,2,Rd,r4,b}} = \frac{0{,}25 l_{\text{eff,4,b}} t_{\text{p}}^{2} f_{\text{y,p}}}{\gamma_{\text{M0}}} = \frac{0{,}25 \times 216{,}55 \times 20^2 \times 355}{1{,}0}$$

$$M_{\text{pl,2,Rd,r4,b}} = 7{,}68 \times 10^6 \text{ Nmm}$$

$$F_{\text{T,2,Rd,ep}} = \frac{2M_{\text{p1,2,Rd,r4,b}} + n_{\text{p,ep}} \sum F_{\text{t,Rd}}}{m_{\text{p1}} + n_{\text{p,ep}}}$$

$$= \frac{2 \times 7{,}68 \times 10^6 + 48{,}14 \times 406{,}66 \times 10^3}{38{,}51 + 48{,}14}$$

$$F_{\text{T,2,Rd,ep}} = 403{,}2 \text{ kN}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	23 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Mode 3

$F_{\mathrm{T,3,Rd,ep}} = \sum F_{\mathrm{t,Rd}}$

$F_{\mathrm{T,3,Rd,ep}} = 2 \times 203 = 406 \text{ kN}$

The resistance of the end plate in bending is:

$F_{\mathrm{T,Rd,ep}} = \min\left(F_{\mathrm{T,1,Rd,ep}};\quad F_{\mathrm{T,2,Rd,ep}};\quad F_{\mathrm{T,3,Rd,ep}}\right)$

$= \min(798;\quad 403;\quad 406)$

$F_{\mathrm{T,Rd,ep}} = 403 \text{ kN}$

Rafter web in tension

$$F_{\mathrm{t,wb,Rd}} = \frac{b_{\mathrm{eff,t,wb}} t_{\mathrm{wb}} f_{\mathrm{y,beam}}}{\gamma_{\mathrm{M0}}} = \frac{216{,}55 \times 9{,}4 \times 355}{1{,}0}$$

$b_{\mathrm{eff,t,wb}} = l_{\mathrm{eff,4,b}}$

$F_{\mathrm{t,wb,Rd}} = 723 \text{ kN}$

$\therefore$ $F_{\mathrm{t,Rd(row4)}} = \min(291;\quad 323;\quad 403;\quad 723) = 291 \text{ kN}$

3.5 Row 5

3.5.1 Column side

$2\pi m_{\mathrm{c1}} = 2\pi \times 28{,}1 = 176{,}56 \text{ mm}$ SN041

$4m_{\mathrm{c1}} + 1{,}25 e_{\mathrm{c}} = 4 \times 28{,}10 + 1{,}25 \times 50 = 174{,}9 \text{ mm}$

$$\pi m_{\mathrm{c1}} + \frac{p}{2} = \pi \times 28{,}1 + \frac{90}{2} = 133{,}28 \text{ mm}$$

$$2m_{\mathrm{c1}} + 0{,}625 e_{\mathrm{c}} + \frac{p}{2} = 2 \times 28{,}1 + 0{,}625 \times 50 + \frac{90}{2} = 132{,}45 \text{ mm}$$

$$\frac{p_2}{2} + \frac{p}{2} = \frac{350}{2} + \frac{90}{2} = 220 \text{ mm}$$

$$l_{\mathrm{eff,5,c}} = \min\left(2\pi m_{\mathrm{c1}};\ 4m_{\mathrm{c1}} + 1{,}25e_{\mathrm{c}};\ \pi m_{\mathrm{c1}} + \frac{p}{2};\ 2m_{\mathrm{c1}} + 0{,}625e_{\mathrm{c}} + \frac{p}{2};\ \frac{p_2}{2} + \frac{p}{2}\right)$$

$= \min(176{,}56;\quad 174{,}9;\quad 133{,}28;\quad 132{,}45;\quad 220)$

$l_{\mathrm{eff,5,c}} = 132{,}45 \text{ mm}$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	24 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Column flange in bending

Mode 1; Method 1

$$M_{\mathrm{pl,1,Rd,r5,c}} = \frac{0{,}25 l_{\mathrm{eff,5,c}} {t_{\mathrm{fc}}}^2 f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25 \times 132{,}45 \times 16^2 \times 355}{1{,}0}$$

$$M_{\mathrm{pl,1,Rd,r5,c}} = 3 \times 10^6 \text{ kN}$$

$$F_{\mathrm{T,1,Rd,fc}} = \frac{4M_{\mathrm{pl,1,Rd,r5,c}}}{m_{\mathrm{c1}}} = \frac{4 \times 3 \times 10^6}{28{,}1}$$

$$F_{\mathrm{T,1,Rd,fc}} = 427 \text{ kN}$$

Mode 2

$$M_{\mathrm{pl,2,Rd,r5,c}} = \frac{0{,}25 l_{\mathrm{eff,5,c}} {t_{\mathrm{fc}}}^2 f_{\mathrm{y,c}}}{\gamma_{\mathrm{M0}}} = \frac{0{,}25 \times 132{,}45 \times 16^2 \times 355}{1{,}0}$$

$$M_{\mathrm{pl,2,Rd,r5,c}} = 3 \times 10^6 \text{ Nmm}$$

$$F_{\mathrm{T,2,Rd,fc}} = \frac{2M_{\mathrm{p1,2,Rd,r5,b}} + n_{\mathrm{p,c}} \sum F_{\mathrm{t,Rd}}}{m_{\mathrm{c1}} + n_{\mathrm{p,c}}}$$

$$= \frac{2 \times 3 \times 10^6 + 35{,}13 \times 406{,}66 \times 10^3}{28{,}1 + 35{,}13}$$

$$F_{\mathrm{T,2,Rd,fc}} = 320{,}8 \text{ kN}$$

Mode 3

$$F_{\mathrm{T,3,Rd,fc}} = \sum F_{\mathrm{t,Rd}}$$

$$F_{\mathrm{T,3,Rd,fc}} = 2 \times 203 = 406 \text{ kN}$$

Therefore the resistance of the column flange in bending is:

$$F_{\mathrm{T,Rd,fc}} = \min\left(F_{\mathrm{T,1,Rd,fc}};\quad F_{\mathrm{T,2,Rd,fc}};\quad F_{\mathrm{T,3,Rd,fc}}\right)$$

$$= \min(427;\quad 321;\quad 406)$$

$$F_{\mathrm{T,Rd,fc}} = 321 \text{ kN}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	25 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

In the last bolt row a greater resistance than in any of the previous rows is not allowed, so $F_{t,Rd,fc}$ is limited to the resistance in bolt row 4. Therefore:

$F_{t,Rd,fc} = 291\ \text{kN}$

Column web in transverse tension

$$F_{T,wc,Rd} = \frac{\omega_{r5,c} b_{eff,t,wc} t_{wc} f_{y,c}}{\gamma_{M0}}$$

$b_{eff,t,wc} = l_{eff,5,c}$

According to the geometry of the connection

$\beta = 1$

And therefore,

$$\omega_{r5,c} = \omega_{1,r5,c} = \frac{1}{\sqrt{1 + 1{,}3\left(\frac{b_{eff,t,wc} \cdot t_{wc}}{A_{vc}}\right)^2}}$$

$$= \frac{1}{\sqrt{1 + 1{,}3\left(\frac{132{,}45 \times 10{,}2}{6035{,}2}\right)^2}}$$

$\omega_{r5,c} = 0{,}97$

$$F_{T,wc,Rd} = \frac{0{,}97 \times 132{,}45 \times 10{,}2 \times 355}{1{,}0}$$

$F_{T,wc,Rd} = 465\ \text{kN}$

3.5.2 Beam side

Effective length — SN041

The effective length may be calculated from the minimum of the following expressions:

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	26 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

$2\pi m_{p1} = 2\pi \times 38{,}51 \quad = 241{,}98 \text{ mm}$

$4m_{p1} + 1{,}25e_p = 4 \times 38{,}51 + 1{,}25 \times 50 \quad = 216{,}55 \text{ mm}$

$l_{eff,5,b} = \min(2\pi m_{p1}; \quad 4m_{p1} + 1{,}25e_p) = \min(241{,}98; \quad 216{,}55)$

$l_{eff,5,b} = 216{,}55 \text{ mm}$

End plate in bending

Mode 1; Method 1

$$M_{pl,1,Rd,r5,b} = \frac{0{,}25 l_{eff,5,b} t_p^2 f_{y,p}}{\gamma_{M0}} = \frac{0{,}25 \times 216{,}55 \times 20^2 \times 355}{1{,}0}$$

$$M_{pl,1,Rd,r5,b} = 7{,}68 \times 10^6 \text{ Nmm}$$

$$F_{T,1,Rd,ep} = \frac{4M_{pl,1,Rd,r5,b}}{m_{p1}} = \frac{4 \times 7{,}68 \times 10^6}{38{,}51}$$

$$F_{T,1,Rd,ep} = 797{,}7 \text{ kN}$$

Mode 2

$$M_{pl,2,Rd,r5,b} = \frac{0{,}25 l_{eff,5,b} t_p^2 f_{y,p}}{\gamma_{M0}} = \frac{0{,}25 \times 216{,}55 \times 20^2 \times 355}{1{,}0}$$

$$M_{pl,2,Rd,r5,b} = 7{,}68 \times 10^6 \text{ Nmm}$$

$$F_{T,2,Rd,ep} = \frac{2M_{p1,2,Rd,r5,b} + n_{p,ep} \sum F_{t,Rd}}{m_{p1} + n_{p,ep}}$$

$$= \frac{2 \times 7{,}68 \times 10^6 + 48{,}14 \times 406{,}66 \times 10^3}{38{,}51 + 48{,}14}$$

$$F_{T,2,Rd,ep} = 403{,}2 \text{ kN}$$

Mode 3

$$F_{T,3,Rd,ep} = \sum F_{t,Rd}$$

$$F_{T,3,Rd,ep} = 2 \times 203 = 406 \text{ kN}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	27 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Therefore the resistance of the end plate in bending is:

$$F_{\mathrm{T,Rd,ep}} = \min\left(F_{\mathrm{T,1,Rd,ep}}; F_{\mathrm{t,2,Rd,ep}}; F_{\mathrm{t,3,Rd,ep}}\right) = \min\left(798;\quad 403;\quad 406\right)$$

$$F_{\mathrm{t,Rd,ep}} = 403\ \mathrm{kN}$$

Rafter web in tension

$$F_{\mathrm{t,wb,Rd}} = \frac{b_{\mathrm{eff,t,wb}} t_{\mathrm{wb}} f_{\mathrm{y,beam}}}{\gamma_{\mathrm{M0}}}$$

$$b_{\mathrm{eff,t,wb}} = l_{\mathrm{eff,5,b}}$$

$$F_{\mathrm{t,wb,Rd}} = \frac{216{,}55 \times 9{,}4 \times 355}{1{,}0} = 723\ \mathrm{kN}$$

In the last bolt row the potential tension resistance will be limited by the value of the previous row. Therefore:

$$F_{\mathrm{t,wb,Rd}} = 291\ \mathrm{kN}$$

$$\therefore \boxed{F_{\mathrm{t,Rd(row5)}} = \min(291;\quad 465;\quad 403;\quad 723) = 291\ \mathrm{kN}}$$

Summary:

$$F_{\mathrm{t,Rd(row1)}} = 298\ \mathrm{kN}$$

$$F_{\mathrm{t,Rd(row2)}} = 294\ \mathrm{kN}$$

$$F_{\mathrm{t,Rd(row3)}} = 291\ \mathrm{kN}$$

$$F_{\mathrm{t,Rd(row4)}} = 291\ \mathrm{kN}$$

$$F_{\mathrm{t,Rd(row5)}} = 291\ \mathrm{kN}$$

$$\sum F_{\mathrm{t,Rd(row)}} = 1465\ \mathrm{kN}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	28 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

4 Assessment of the Compression Zone

The following condition has to be satisfied:

$$F_{\mathrm{c,Ed}} \leq F_{\mathrm{c,Rd}}$$

The acting force is the sum of the design tension resistances of the bolt rows:

$$F_{\mathrm{c,Ed}} = \sum F_{\mathrm{t,Rd(row)}} = 1465 \text{ kN}$$

The design compression resistance of the compression zone is the minimum of the design compression resistance of the column web and the design compression resistance of the haunch flange and web:

$$F_{\mathrm{c,Rd}} = \min(F_{\mathrm{c,wc,Rd}}; \quad F_{\mathrm{c,fg,Rd}})$$

4.1 Column web in transverse compression

$$F_{\mathrm{c,wc,Rd}} = \min\left(\frac{\omega_{\mathrm{c}}\, k_{\mathrm{wc}}\, b_{\mathrm{eff,c,wc}}\, t_{\mathrm{wc}}\, f_{\mathrm{y,wc}}}{\gamma_{\mathrm{M0}}}; \quad \frac{\omega_{\mathrm{c}}\, k_{\mathrm{wc}}\, \rho_c\, b_{\mathrm{eff,c,wc}}\, t_{\mathrm{wc}}\, f_{\mathrm{y,wc}}}{\gamma_{\mathrm{M1}}}\right)$$ SN041

According to the geometry

$$\beta = 1$$

and therefore:

$$\omega_{\mathrm{c}} = \omega_{1,\mathrm{c}} = \frac{1}{\sqrt{1 + 1{,}3\left(\frac{b_{\mathrm{eff,c,wc}}\, t_{\mathrm{wc}}}{A_{\mathrm{vc}}}\right)^2}}$$

Where:

$$b_{\mathrm{eff,c,wc}} = t_{\mathrm{fb}} + 2\sqrt{2}a_{\mathrm{cf}} + 5(t_{\mathrm{fc}} + r_{\mathrm{c}}) + s_{\mathrm{p,c}}$$

Where:

$$s_{\mathrm{p,c}} = \sqrt{2}t_{\mathrm{p}} = \sqrt{2} \times 20 = 28{,}28 \text{ mm}$$

$$\therefore b_{\mathrm{eff,c,wc}} = 14{,}6 + 2\sqrt{2} \times 6 + 5(16 + 21) + 28{,}28 = 244{,}85 \text{ mm}$$

$$\therefore \omega_{\mathrm{c}} = \frac{1}{\sqrt{1 + 1{,}3\left(\frac{244{,}85 \times 10{,}2}{6035{,}2}\right)^2}} = 0{,}9$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	29 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

Conservatively:

$k_{wc} = 0,7$

$$\therefore \frac{\omega_c\, k_{wc}\, b_{eff,c,wc}\, t_{wc}\, f_{y,wc}}{\gamma_{M0}} = \frac{0,9 \times 0,7 \times 244,85 \times 10,2 \times 355}{1,0} = 558,6\ \text{kN}$$

$$\rho_c = \frac{(\lambda_{p,c} - 0,2)}{\lambda_{p,c}^{\ 2}}$$

Where:

$$\lambda_{p,c} = 0,932\sqrt{\frac{b_{eff,c,wc}\, d_c\, f_{y,c}}{E t_{wc}^{\ 2}}} = 0,932\sqrt{\frac{244,85 \times 426 \times 355}{210000 \times 10,2^2}}$$

$$\lambda_{p,c} = 1,21$$

$$\rho_c = \frac{(1,21 - 0,2)}{1,21^2}$$

$$\rho_c = 0,69$$

$$\frac{\omega\, k_{wc}\, \rho_c\, b_{eff,c,wc}\, t_{wc}\, f_{y,wc}}{\gamma_{M1}} = \frac{0,9 \times 0,7 \times 0,69 \times 244,85 \times 10,2 \times 355}{1,0} = 385,4\ \text{kN}$$

$$\therefore F_{c,wc,Rd} = \min(559;\quad 385) = 385\ \text{kN}$$

$$F_{c,wc,Rd} = 385\ \text{kN} \leq 1465\ \text{kN} = F_{c,Ed}$$

The resistance of the column web in compression is very small comparing to the acting force and therefore a stiffener is needed.

The design resistance of the compression stiffener is calculated in accordance with §9.1(3) of EN 1993-1-5. EN 1993-1-5 §9.1(3)

$$\therefore\ F_{c,wcs,Rd} = 1966\ \text{kN} \geq 1465\ \text{kN} = F_{c,Ed}$$

Therefore with the stiffener, the compression check in the column web is ok.

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	30 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

4.2 Haunch flange and web in compression

$$F_{\mathrm{c,fh,Rd}} = \frac{M_{\mathrm{c,Rd}}}{(h - t_{\mathrm{fh}})}$$ SN041

Where:

$$M_{\mathrm{c,Rd}} = W_{\mathrm{el,y}} \frac{f_{\mathrm{y,h}}}{\gamma_{\mathrm{M0}}}$$

The elastic modulus works out:

$$W_{\mathrm{el,y}} = 3373{,}68\ \mathrm{cm}^3$$

$$\therefore M_{\mathrm{c,Rd}} = 3373{,}68 \times 10^3 \frac{355}{1{,}0} = 1198\ \mathrm{kNm}$$

The lever arm h is:

$$h = 845{,}4\ \mathrm{mm}$$

$$\therefore F_{\mathrm{c,fh,Rd}} = \frac{1198}{(845{,}4 - 14{,}6)} = 1442\ \mathrm{kN}$$

The maximum resistance that can be allocated to the flange is: SN041

$$F_{\mathrm{c,fh,max}} \le \frac{1}{0{,}8} b_{\mathrm{h}} t_{\mathrm{fh}} \frac{f_{\mathrm{y,h}}}{\gamma_{\mathrm{M0}}} = \frac{1}{0{,}8} 190 \times 14{,}6 \frac{355}{1{,}0} = 1230{,}9\ \mathrm{kN}$$ EN 1993-1-8 §6.2.6.7(1)

Therefore the compression resistance of the haunch is the minimum of the above two:

$$\therefore F_{\mathrm{c,fh,Rd}} = 1231\ \mathrm{kN}$$

$$\therefore F_{\mathrm{c,Rd}} = \min(1966;\ \ 1231) = 1231\ \mathrm{kN} < 1465\ \mathrm{kN} = \mathrm{F}_{\mathrm{c,Ed}}$$

Since the requirement of $F_{\mathrm{c,Ed}} \le F_{\mathrm{c,Rd}}$ is not satisfied, a force redistribution is needed. See section 7 of this document for details on the redistribution

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	31 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

5 Column web panel in shear

$$\varepsilon_{c} = \sqrt{\frac{235}{f_{y,c}}} = \sqrt{\frac{235}{355}} = 0{,}81$$

$$\frac{d_{c}}{t_{wc}} = \frac{426}{10{,}2} = 41{,}76$$

$$69\varepsilon_{c} = 69 \times 0{,}81 = 56{,}14$$

$$\frac{d_{c}}{t_{wc}} = 41{,}76 \leq 56{,}14 = 69\varepsilon_{c}$$

Therefore the column web panel resistance in shear is:

$$V_{wp,Rd} = \frac{0{,}9 f_{y,wc} A_{vc}}{\sqrt{3}\gamma_{M0}} = \frac{0{,}9 \times 355 \times 6035{,}2}{\sqrt{3} \times 1{,}0} = 1113{,}3\,\text{kN}$$

To avoid the column web panel in shear being the critical check and limiting the tension resistance the bolts can develop, supplementary web plates are added in the column flange. The new resistance of the web panel in shear is:

EN 1993-1-8 §6.2.6.1

SN041 Section 9.

$$V_{wp,Rd,mod} = \frac{0{,}9 f_{y,wc} A_{vc,mod}}{\sqrt{3}\gamma_{M0}}$$

The new shear area:

$$A_{vc,mod} = A_{vc} + b_{s} t_{wc}$$

Where

$$b_{s} = \min\left(40\varepsilon t_{s};\quad h_{c} - 2r_{c} - 2t_{s} - 2t_{fc}\right)$$

For a 10 mm thick web plate:

$$40\varepsilon t_{s} = 40 \times \sqrt{\frac{235}{355}} \times 10 = 325{,}45\,\text{mm}$$

$$h_{c} - 2r_{c} - 2t_{s} - 2t_{fc} = 500 - 2 \times 21 - 2 \times 10 - 2 \times 16 = 406\,\text{mm}$$

$$b_{s} = \min(325{,}45;\quad 406) = 325{,}45\,\text{mm}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	32 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

$$A_{\text{vc,mod}} = 6035{,}2 + 325{,}45 \times 10{,}2 = 9354{,}75\ \text{mm}^2$$

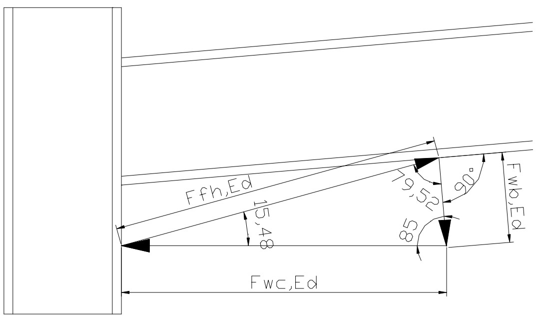
$$\therefore\ V_{\text{wp,Rd,mod}} = \frac{0{,}9 f_{\text{y,wc}} A_{\text{vc,mod}}}{\sqrt{3}\gamma_{\text{M0}}} = \frac{0{,}9 \times 355 \times 9354{,}75}{\sqrt{3} \times 1{,}0} = 1726\ \text{kN}$$

6 Rafter web in compression

$$F_{\text{c,wb,Rd}} = \min\left(\frac{\omega_{\text{b}} k_{\text{w,b}} b_{\text{eff,cw,b}} t_{\text{wb}} f_{\text{y,beam}}}{\gamma_{\text{M0}}};\ \frac{\omega_{\text{b}} \rho_c k_{\text{w,b}} b_{\text{eff,cw,b}} t_{\text{wb}} f_{\text{y,beam}}}{\gamma_{\text{M1}}}\right)$$

The procedure to calculate the compression resistance of the rafter web is the same as for the column web without a compression stiffener. Detail calculations are not shown here.

The acting force in the rafter web can be calculated according to the following acting forces triangle:



$$F_{\text{wb,Ed}} = 283\ \text{kN}$$

$$F_{\text{c,wb,Rd}} = 323\ \text{kN} > 283\ \text{kN} = F_{\text{wb,Ed}}$$

The resistance of the rafter web is greater than the acting force in the rafter web, therefore OK. If the compression resistance of the rafter web was not greater than the compression acting force, then a compression stiffener should be provided as for the column web.

7 Force distribution in bolt rows

The first condition the effective design tension resistance has to satisfy is: SN041

$$F_{\text{c,Ed}} \leq F_{\text{c,Rd}}$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	33 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

$$F_{c,Ed} = \sum F_{t,Rd(row)} = F_{t,Rd,1} + F_{t,Rd,2} + F_{t,Rd,3} + F_{t,Rd,4} + F_{t,Rd,5}$$
$$= 298 + 294 + 291 + 291 + 291 = 1465 \text{ kN}$$

$$F_{c,Rd} = \min\left(F_{c,wc,Rd};\quad F_{c,fh,Rd}\right) = 1231 \text{ kN}$$

$\therefore$ Since $F_{c,Ed} > F_{c,Rd}$

Therefore the following distribution will be adopted:

$$F_{t1,Rd} = 298 \text{ kN}$$

$$F_{t2,Rd} = 294 \text{ kN}$$

$$F_{t3,Rd} = 291 \text{ kN}$$

$$F_{t4,Rd} = 291 \text{ kN}$$

$$F_{t5,Rd} = 57 \text{ kN}$$

$$\sum F_{tr,Rd} = 1231 \text{ kN}$$

The column web panel in shear check is as follows:

$$\sum F_{t,Rd(row)} \leq \frac{V_{wp,Rd,mod}}{\beta}$$

In this case $\beta = 1$

$$\sum F_{t,Rd(row)} = 1231 < 1726 = \frac{V_{wp,Rd,mod}}{\beta}$$

Therefore this condition is satisfied and no more redistribution is needed.

The effective design tension resistance also has to satisfy the following:

$$F_{tx,Rd} \leq 1{,}9 F_{t,Rd}$$

$$1{,}9 F_{t,Rd} = 1{,}9 \times 203 = 386 \text{ kN}$$

Considering the worst of the possible cases:

$$F_{t1,Rd} = 298 < 386 \text{ kN}$$

Therefore the condition is satisfied and the above mentioned resistances will be taken as the effective tension resistances of the bolt rows.

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	34 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

8 Moment resistance of the joint

$$M_{\mathrm{j,Rd}} = F_{\mathrm{t1,Rd}} h_1 + F_{\mathrm{t2,Rd}} h_2 + F_{\mathrm{t3,Rd}} h_3 + F_{\mathrm{t4,Rd}} h_4 + F_{\mathrm{t5,Rd}} h_5$$
$$= 298 \times 892{,}7 + 294 \times 792{,}7 + 291 \times 702{,}7 + 291 \times 612{,}7 + 57 \times 522{,}7$$
$$= 912 \text{ kNm}$$

$$M_{\mathrm{j,Rd}} = 912 \text{ kNm} > 880 \text{ kNm} = M_{\mathrm{Ed}}$$

The resistance is greater than the acting moment, therefore OK.

9 Assessment of the shear resistance

9.1 Bolts in shear

The shear resistance of one bolt is:

$$F_{\mathrm{v,Rd}} = \frac{\alpha_{\mathrm{v}} f_{\mathrm{ub}} A_{\mathrm{s}}}{\gamma_{\mathrm{M2}}}$$

Where for 8.8 bolts:

$$\alpha_{\mathrm{v}} = 0{,}6$$

EN 1993-1-8 Table 3.4.

$$\therefore \boxed{F_{\mathrm{v,Rd}} = \frac{0{,}6 \times 800 \times 353}{1{,}25} = 136 \text{ kN}}$$

9.2 Bolts in bearing on column flange

The bearing resistance of one bolt on the column flange is:

$$F_{\mathrm{b,i,Rd}} = \frac{k_{1,\mathrm{c}} \alpha_{\mathrm{b,c}} f_{\mathrm{u,c}} d t_{\mathrm{fc}}}{\gamma_{\mathrm{M2}}}$$

Where:

$$k_{1,\mathrm{c}} = \min\left(2{,}8\frac{e_1}{d_0} - 1{,}7; \quad 1{,}4\frac{w}{d_0} - 1{,}7; \quad 2{,}5\right)$$

$$2{,}8\frac{e_1}{d_0} - 1{,}7 = 2{,}8 \times \frac{50}{26} - 1{,}7 = 3{,}68$$

$$1{,}4\frac{w}{d_0} - 1{,}7 = 1{,}4 \times \frac{100}{26} - 1{,}7 = 3{,}68$$

CALCULATION SHEET	Document Ref:	SX031a-EN-EU	Sheet	35 of 36
	Title	Example: Portal frame - eaves moment connection		
	Eurocode Ref	EN 1993-1-8		
	Made by	Edurne Núñez	Date	Nov 2005
	Checked by	Abdul Malik	Date	Feb 2006

$$\therefore\ k_1 = \min(3{,}68;\quad 3{,}68;\quad 2{,}5) = 2{,}5$$

$$\alpha_{b,c} = \min\left(\alpha_{d,c};\quad \frac{f_{ub}}{f_{u,c}};\quad 1{,}0\right)$$

$$\alpha_{d,c} = \min\left(\frac{e_{1,bc}}{3d_0};\quad \frac{p}{3d_0} - \frac{1}{4}\right)$$

$$\frac{e_{1,bc}}{3d_0} = \frac{130}{3 \times 26} = 1{,}66$$

$$\frac{p}{3d_0} - \frac{1}{4} = \frac{90}{3 \times 26} - \frac{1}{4} = 0{,}9$$

$$\alpha_{d,c} = \min(1{,}66;\quad 0{,}9) = 0{,}9$$

$$\frac{f_{ub}}{f_{u,c}} = \frac{800}{510} = 1{,}57$$

$$\alpha_{b,c} = \min(0{,}9;\quad 1{,}57;\quad 1{,}0) = 0{,}9$$

$$F_{b,i,Rd} = \frac{2{,}5 \times 0{,}9 \times 510 \times 24 \times 16}{1{,}25}$$

$$\therefore\ \boxed{F_{b,i,Rd} = 353\text{ kN}}$$

9.3 Bolts in bearing on end plate

The bearing resistance of one bolt on the end plate:

$$F_{b,i,p,Rd} = \frac{k_{1,p}\alpha_{b,p} f_{u,p} d t_p}{\gamma_{M2}}$$

Where:

$$k_{1,p} = \min\left(2{,}8\frac{e_1}{d_0} - 1{,}7;\quad 1{,}4\frac{w}{d_0} - 1{,}7;\quad 2{,}5\right)$$

$$2{,}8\frac{e_1}{d_0} - 1{,}7 = 2{,}8 \times \frac{50}{26} - 1{,}7 = 3{,}68$$

CALCULATION SHEET	Document Ref:	**SX031a-EN-EU**	Sheet	**36** of **36**
	Title	***Example: Portal frame - eaves moment connection***		
	Eurocode Ref	**EN 1993-1-8**		
	Made by	**Edurne Núñez**	Date	**Nov 2005**
	Checked by	**Abdul Malik**	Date	**Feb 2006**

$$1{,}4\frac{w}{d_0} - 1{,}7 = 1{,}4 \times \frac{100}{26} - 1{,}7 = 3{,}68$$

$$\therefore\ k_{1,\mathrm{p}} = \min(3{,}68;\quad 3{,}68;\quad 2{,}5) = 2{,}5$$

$$\alpha_{\mathrm{b,p}} = \min\left(\alpha_{\mathrm{d,p}};\quad \frac{f_{\mathrm{ub}}}{f_{\mathrm{u,p}}};\quad 1{,}0\right)$$

$$\alpha_{\mathrm{d,p}} = \min\left(\frac{e_{1,\mathrm{bp}}}{3d_0};\quad \frac{p}{3d_0} - \frac{1}{4}\right)$$

$$\frac{e_{1,\mathrm{bp}}}{3d_0} = \frac{130}{3 \times 26} = 1{,}66$$

$$\frac{p}{3d_0} - \frac{1}{4} = \frac{90}{3 \times 26} - \frac{1}{4} = 0{,}9$$

$$\alpha_{\mathrm{d,p}} = \min(1{,}66;\quad 0{,}9) = 0{,}9$$

$$\frac{f_{\mathrm{ub}}}{f_{\mathrm{u,p}}} = \frac{800}{510} = 1{,}57$$

$$\alpha_{\mathrm{b,p}} = \min(0{,}9;\quad 1{,}57;\quad 1{,}0) = 0{,}9$$

$$F_{\mathrm{b,i,p,Rd}} = \frac{2{,}5 \times 0{,}9 \times 510 \times 24 \times 20}{1{,}25}$$

$$\therefore\ F_{\mathrm{b,i,p,Rd}} = 441\mathrm{kN}$$

The design shear resistance of one bolt is the minimum of the above three resistances, i.e. $\min(136;\quad 353;\quad 441) = 136\ \mathrm{kN}$.

Number of bolts required to resist the vertical shear is:

$\frac{V_{\mathrm{Ed}}}{136} = \frac{200}{136} = 1{,}47$, i.e. two bolts

Therefore, number of bolt rows required for shear is one. Design shear resistance of the joint

$$2 \times 136 = 272\ \mathrm{kN}$$

Example: Portal frame - eaves moment connection

SX031a-EN-EU

Quality Record

RESOURCE TITLE	Example: Portal frame - eaves moment connection		
Reference(s)			
ORIGINAL DOCUMENT			
	Name	**Company**	**Date**
Created by	Edurne Núñez	SCI	
Technical content checked by	Abdul Malik	SCI	
Editorial content checked by			
Technical content endorsed by the following STEEL Partners:			
1. UK	G W Owens	SCI	23/5/06
2. France	A Bureau	CTICM	23/5/06
3. Sweden	B Uppfeldt	SBI	23/5/06
4. Germany	C Müller	RWTH	23/5/06
5. Spain	J Chica	Labein	23/5/06
Resource approved by Technical Coordinator	G W Owens	SCI	11/9/06
TRANSLATED DOCUMENT			
This Translation made and checked by:			
Translated resource approved by:			