Build Book Annex 1: Detail Calculations

Heavy-duty Arched roof Container Shelter 10 m: CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD

Content	: Build Book Annex 1
Structure	: CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD
Manufacturer	: Kroftman
Document owner	: Kroftman
Reference number	: 251114
Author	: Aromal. S
Checked by	: I. J. Bakker
Date	: 04-12-2025

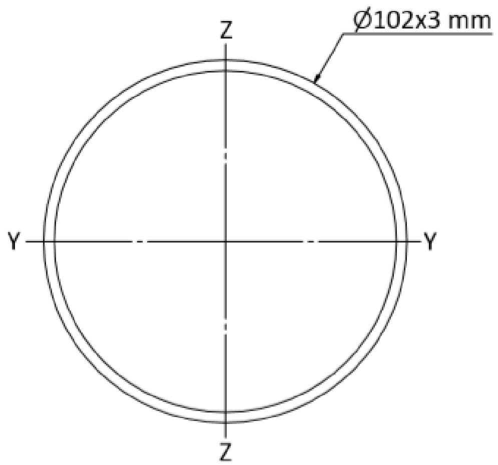
9. Annex 1

The annexes below will provide a check on the members and detailed connections. Slight variation will be found in the input cross-section properties because RFEM uses simplified cross-section geometry. In order to stay conservative, the lowest cross-section properties have been chosen to check components and connections.

Contents

9.1. Main profile Ø102 x 3 mm - S355 (Roof frame & gable column)

9.1.1. Description



Cross-Section Property	Symbol	Value	Unit
Outer diameter	D	102.0	mm
Wall thickness	s	3.0	mm
Cross-sectional area	A	9.33	cm^2
Shear area	A_y	4.65	cm^2
Core area	A_c	76.98	cm^2
Moment of inertia	I_y	114.42	cm^4
Polar moment of inertia	I_p	228.83	cm^4
Governing radius of gyration	r_y	35.0	mm
Polar radius of gyration	r_o	49.5	mm
Weight	wt	7.3	kg/m
Surface	A_{surf}	0.320	m^2/m
Torsional constant	J	228.83	cm^4
Section modulus for torsion	S_t	44.87	cm^3
Elastic section modulus	S_y	22.43	cm^3
Statical moment of area	$Q_{y,max}$	7.35	cm^3
Plastic section modulus	$Z_{y,max}$	29.41	cm^3
Plastic shape factor	$Z_{y,max}/S_y$	1.311	

Cross-section Ø102 x 3 mm

Cross-sectional properties

A = 933 mm^2

$W_{pl,\,y} = W_{pl,\,z} = 29410\ mm^3$

Material – S355

$f_o = 355\ N/mm^2$

$f_u = 510\ N/mm^2$

$\gamma_{M0} = 1.0$

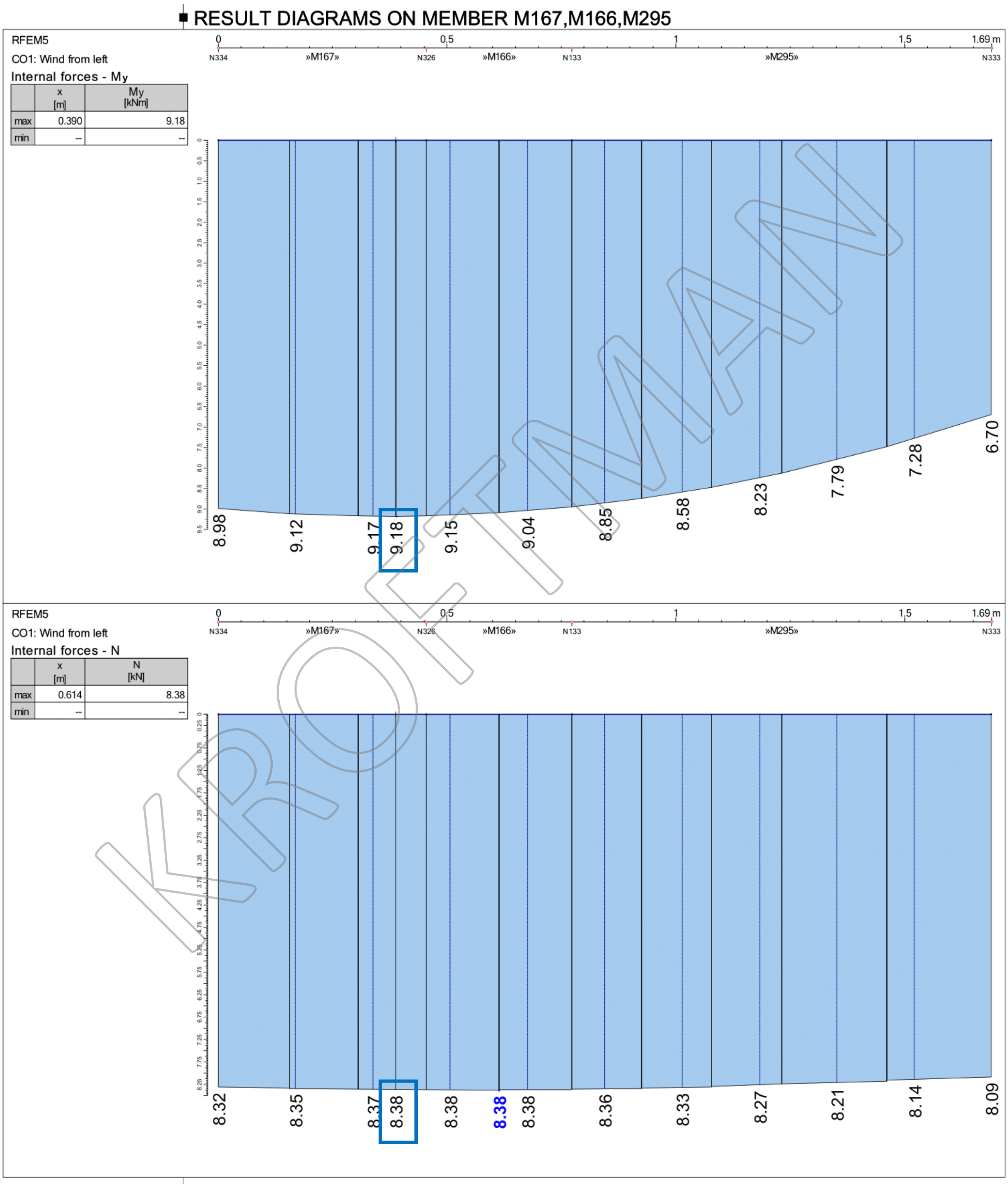
9.1.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1024-HD),

$M_{Y,Ed}$ = 9.18 kNm (CO1, member no: 167)

$M_{z,Ed}$ = 0 kNm (CO1, member no: 167)

N_{Ed} = 8.38 kN (CO1, member no: 167)

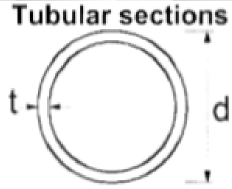


9.1.3. Capacity of cross-section

Cross-section classification;

(EN 1993-1-1, table 5.2)

Tubular sections



Class	Section in bending and/or compression
1	$d/t \leq 50\varepsilon^2$
2	$d/t \leq 70\varepsilon^2$
3	$d/t \leq 90\varepsilon^2$ NOTE For $d/t > 90\varepsilon^2$ see EN 1993-1-6.

$\varepsilon = \sqrt{235/f_y}$	f_y	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71
	ε^2	1,00	0,85	0,66	0,56	0,51

d / t = 102 / 3 = 34

70 x ε^2 = 70 x 0.66 = 46.2

34 < 46.2, Cross-section class 2

(EN 1993-1-1, equation 6.13)

$M_{y,Rd} = M_{Pl,Rd} = W_{pl,y} f_y / \gamma_{M0}$

$M_{y,Rd} = M_{z,Rd}$ = (29410 x 355) / 1.0 = 10440550 Nmm = **10.44 kNm**

(EN 1993-1-1, equation 6.6)

$N_{Rd} = A f_y / \gamma_{M0}$

N_{Rd} = (933 x 355) / 1.0 = 331215 N = **331.22 kN**

9.1.4. Check on cross-section

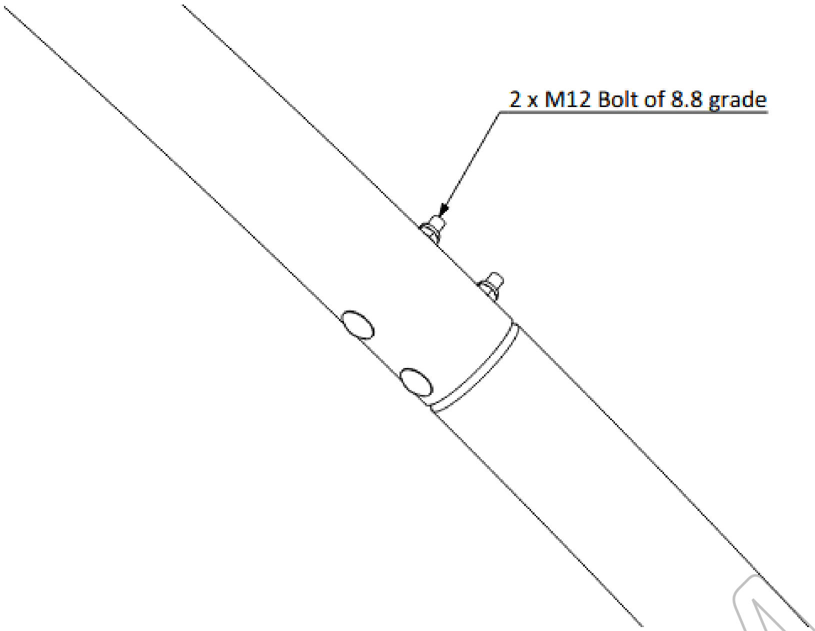
(EN 1993-1-1, equation 6.2)

$(N_{Ed} / N_{Rd}) + (M_{y,Ed} / M_{y,Rd}) + (M_{z,Ed} / M_{z,Rd}) \leq 1.0$

(8.38 /331.22) + (9.18 / 10.44) + (0 / 10.44) = **0.90** $\leq$ 1.0, OK.

9.2. Frame to frame connection

9.2.1. Description



Cross-sectional properties

Material – S355 (Main profile)

f_y = 355 N/mm^2

f_U = 510 N/mm^2

Bolt M12 of Grade 8.8

f_y = 640 N/mm^2

f_{up} = 800 N/mm^2

A_s = 84.3 mm^2

α_v = 0.6

γ_{M2} = 1.25

γ_{M0} = 1.0

9.2.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1006-HD),

N_{Ed} = 25.11 kN (CO2, Node No: 249)

9.2.3. Capacity of component

Shear capacity of the bolt M12 (8.8 grade)

(EN 1993-1-8+ C2:2011 Table 3.4)

$F_{v,Rd} = \alpha_v A f_{ub} / \gamma_{m2}$ = 0.6 x 84.3 x 800 / 1.25 = 32371.2 N = **32.37 kN**

Capacity of the main profile Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\, t\, d\, f_y / \gamma_{m0}$ = 1.5 x 6 x (2 x 12) x 355 / 1.0 = 76680 N = **76.68 kN**

9.2.4. Check on component

Check on the bolt M12 (8.8 grade)

(EN 1993 -1-8 Table 3.10)

$F_{v,Ed} / F_{v,Rd} \leq 1.0$

For one bolt, $F_{v,Ed}$ = 25.11 / 2 = 12.56 kN

12.56 / 32.37 = **0.39** ≤ 1.0, OK.

Check on the main profile Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

25.11 / 76.68 = **0.33** ≤ 1.0, OK.

9.2.5. Pin and plate calculation – check on bolt

The sheet below provides a check on the bolt connection of the frame-to-frame connection.

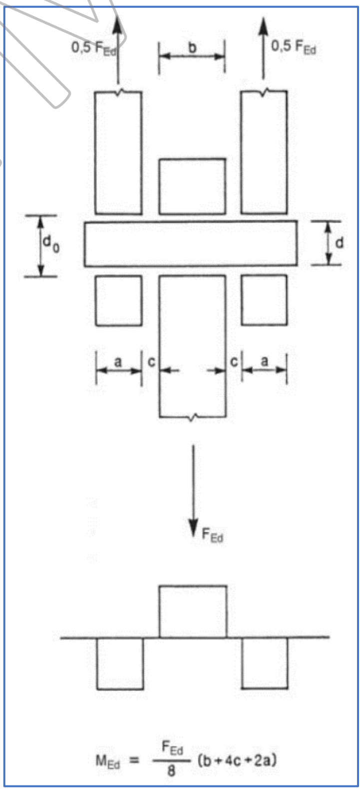
project:	Kroftman CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD
component:	Frame to frame connection, bolt connection
date:	14-11-2025

STEEL BOLT

d	12	mm	
a	3	mm	
b	6	mm	
c	1.5	mm	
f_{yp}	640	N/mm²	8.8
f_{up}	800	N/mm²	
f_{ymin}	640	N/mm²	
γ_{M0}	1.00	1/1	
γ_{M2}	1.25	1/1	
A_s	84.3		
F_{Ed}	25.11	kN	Node no: 581
n_{pins}	2	1/1	
$F_{ed / pin}$	12.56	kN	
M_{Ed}	28.25	kNmm	
$F_{v,Rd}$	32.37	kN	$= 0{,}6\, A\, f_{up} / \gamma_{M2}$
U.C.	0.39	1/1	
$M_{E,Rd}$	162.86	kNmm	
U.C.	0.17	1/1	
U.C.$_{combined}$	0.18	1/1	$\left[\frac{M_{Ed}}{M_{Rd}}\right]^2 + \left[\frac{F_{v,Ed}}{F_{v,Rd}}\right]^2 \leq 1$

STEEL PLATE INNER FLANGES

S355			
f_y	355	N/mm²	
$t_{b\ or\ 2\ x\ a}$	6	mm	
$F_{b,Rd}$	38.34	kN	$= 1{,}5\, t\, d\, f_y / \gamma_{M0}$
U.C.	0.33	1/1	



STEEL PLATE OUTER FLANGES

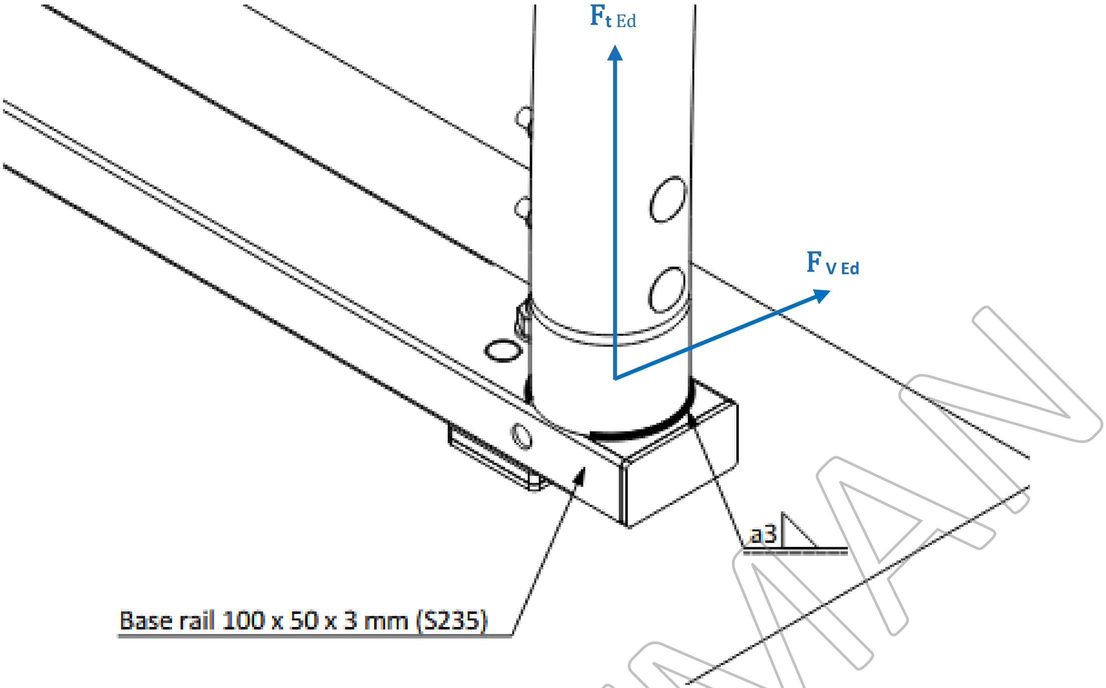
f_y	355	N/mm²	S355
$t_{b\ or\ 2\ x\ a}$	6	mm	
$F_{b,Rd}$	38.34	kN	$= 1{,}5\, t\, d\, f_y / \gamma_{M0}$
U.C.	0.33	1/1	

Unity Check:

Bolt	0.18	< 1 OK
Steel plate inner flanges	0.33	< 1 OK
Steel plate outer flanges	0.33	< 1 OK

9.3. Base rail to roof frame connection (weld check)

9.3.1. Description



Weld material – S235

f_y = 235 N/mm^2

f_u = 360 N/mm^2

β_w = 0.8 (EN 1993 -1-8 Table 4.1)

Minimum weld size, a = 3 mm

Radius, r (at the center of the weld) = (103 / 2) + (3 / 2) = 52.5 mm

Weld length = 2πr = 2 x π x 52.5 = 329.87 mm

Effective weld length, l_{eff} = 329.87 / 3 = 110 mm (Conservatively chosen)

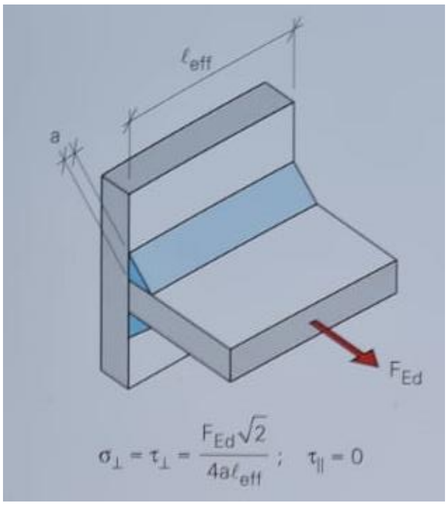
9.3.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1006-HD),

$F_{t\,Ed}$ = 18.67 kN (CO2, Node No: 94)

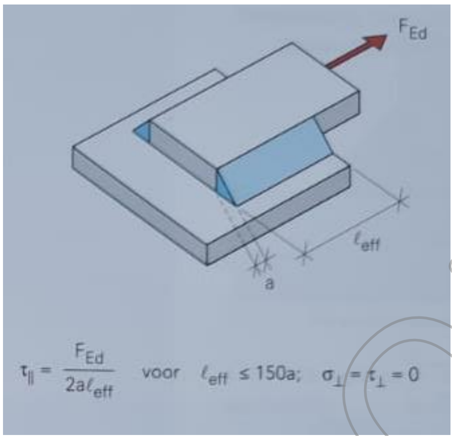
$F_{V\,Ed}$ = 3.43 kN (CO2, Node No: 94)

9.3.3. Stress in weld (Equivalent method)



$\sigma_\perp = \tau_\perp = (F_{Ed}\sqrt{2}) / (4a\ l_{eff})$

$\sigma_{\perp 1} = (18.67 \times 10^3 \times \sqrt{2}) / (4 \times 3 \times 110) = 20\ N/mm^2$



$\tau_\parallel = F_{Ed} / (2a\ l_{eff})$

$\tau_\parallel = (3.43 \times 10^3) / (2 \times 3 \times 110) = 5.20\ N/mm^2$

$\Sigma\tau$ = **5.20 N/mm²**

$\Sigma\sigma$ = **20 N/mm²**

9.3.3.1. Conclusion

$\sqrt{(\sigma_\perp{}^2 + 3\,(\tau_\perp{}^2 + \tau_\parallel{}^2)} \leq f_u / \beta_w \gamma_{m2}$

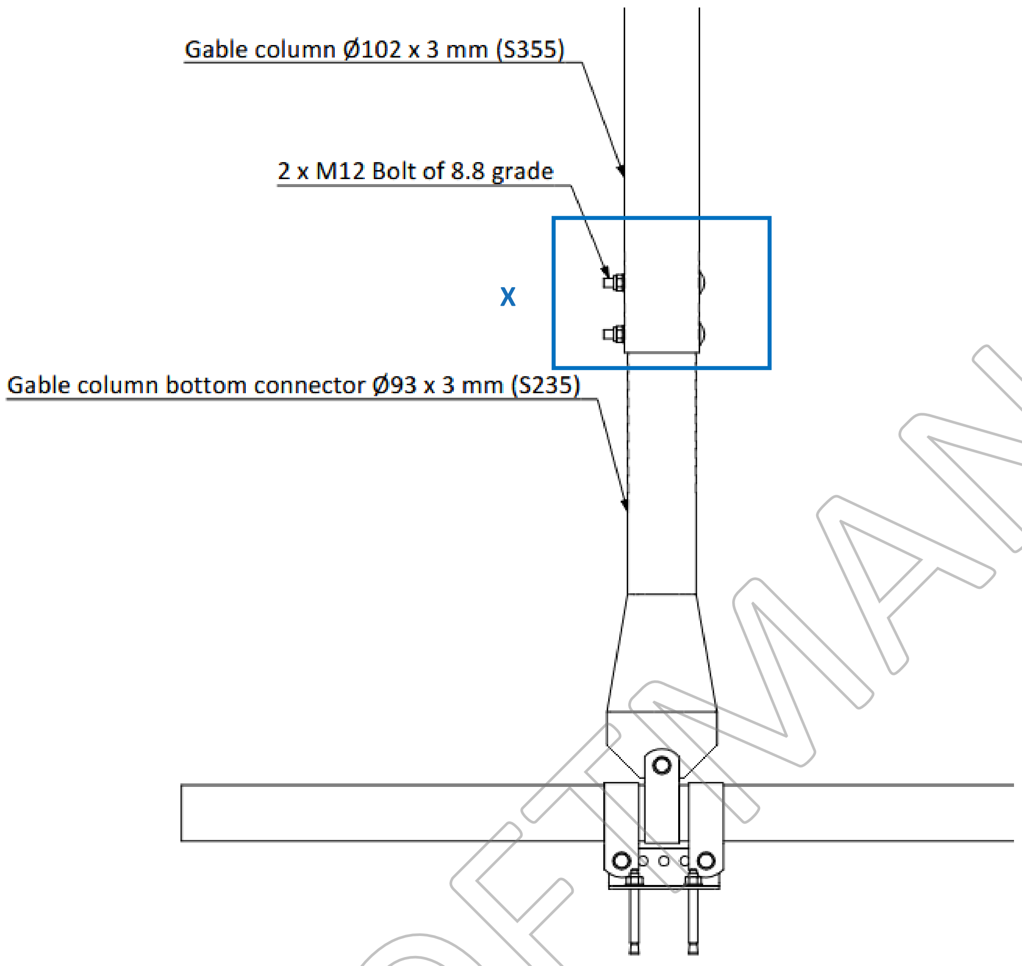
$\sqrt{(\sigma_\perp{}^2 + 3\,(\tau_\perp{}^2 + \tau_\parallel{}^2)} = (20^2 + (3 \times (0 + 5.20^2)))^{0.5} = \mathbf{21.93\ N/mm^2}$

$f_u / \beta_w \gamma_{m2} = 360 / (0.8 \times 1.25) = 360\ N/mm^2$

21.93 / 360 = **0.06** ≤ 1.0, OK.

9.4. Gable column bottom connector (Detail X)

9.4.1. Description



Cross-sectional properties

Material – S235 (Gable column bottom connector)

$f_y = 235\ N/mm^2$

$f_U = 360\ N/mm^2$

Material – S355 (Gable column)

$f_y = 355\ N/mm^2$

$f_U = 510\ N/mm^2$

Bolt M12 of Grade 8.8

$f_y = 640\ N/mm^2$

$f_{up} = 800\ N/mm^2$

$A_s = 84.3\ mm^2$

$\alpha_v = 0.6$

$\gamma_{M2} = 1.25$

$\gamma_{M0} = 1.0$

9.4.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1024-HD),

N_{Ed} = 13.78 kN (CO2, Node No: 7)

9.4.3. Capacity of component

Shear capacity of the bolt M12 (8.8 grade)

(EN 1993-1-8+ C2:2011 Table 3.4)

$F_{v,Rd} = \alpha_v A f_{ub} / \gamma_{m2}$ = 0.6 x 84.3 x 800 / 1.25 = 32371.2N = **32.37 kN**

Capacity of the circular hollow tube Ø93 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\, t\, d\, f_y / \gamma_{m0}$ = 1.5 x 6 x (2 x 12) x 235 / 1.0 = 50760 N = **50.76 kN**

Capacity of the gable column Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\, t\, d\, f_y / \gamma_{m0}$ = 1.5 x 6 x (2 x 12) x 355 / 1.0 = 76680 N = **76.68 kN**

9.4.4. Check on component

Check on the bolt M12 (8.8 grade)

(EN 1993 -1-8 Table 3.10)

$F_{v,Ed} / F_{v,Rd} \leq 1.0$

For one bolt, = 13.78 / 2 = 6.89 kN

6.89 / 32.37 = **0.21** ≤ 1.0, OK.

Check on the circular hollow tube Ø93 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

13.78 / 50.76 = **0.27** ≤ 1.0, OK.

Check on the gable column Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

13.78 / 76.68 = **0.18** ≤ 1.0, OK.

9.4.5. Pin and plate calculation – check on bolt

The below sheet provides a check on the bolt connection of the gable column bottom connector to gable column.

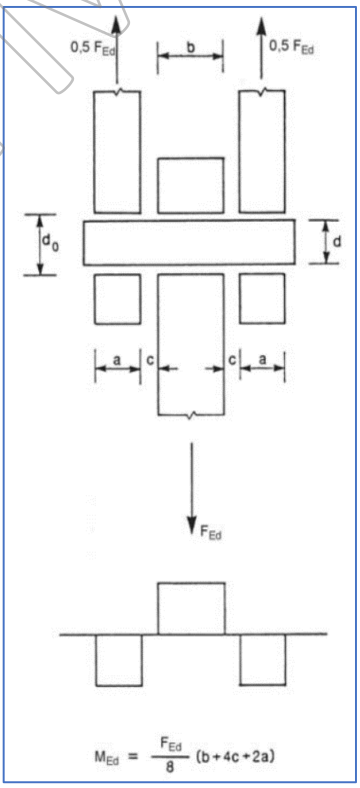
project:	Kroftman CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD
component:	Gable column bottom connector, bolt connection
date:	14-11-2025

STEEL BOLT

d	12	mm	
a	3	mm	
b	6	mm	
c	1.5	mm	
f_{yp}	640	N/mm²	8.8
f_{up}	800	N/mm²	
f_{ymin}	640	N/mm²	
γ_{M0}	1.00	1/1	
γ_{M2}	1.25	1/1	
A_s	84.3		
F_{Ed}	13.78	kN	Node no: 7
n_{pins}	2	1/1	
$F_{ed / pin}$	6.89	kN	
M_{Ed}	15.50	kNmm	
$F_{v,Rd}$	32.37	kN	$= 0{,}6\, A\, f_{up} / \gamma_{M2}$
U.C.	0.21	1/1	
$M_{E,Rd}$	162.86	kNmm	
U.C.	0.10	1/1	
U.C.$_{combined}$	0.05	1/1	$\left[\frac{M_{Ed}}{M_{Rd}}\right]^2 + \left[\frac{F_{v,Ed}}{F_{v,Rd}}\right]^2 \leq 1$

STEEL PLATE INNER FLANGES

S235			
f_y	235	N/mm²	
$t_{b\ or\ 2\ x\ a}$	6	mm	
$F_{b,Rd}$	25.38	kN	$= 1{,}5\, t\, d\, f_y / \gamma_{M0}$
U.C.	0.27	1/1	



STEEL PLATE OUTER FLANGES

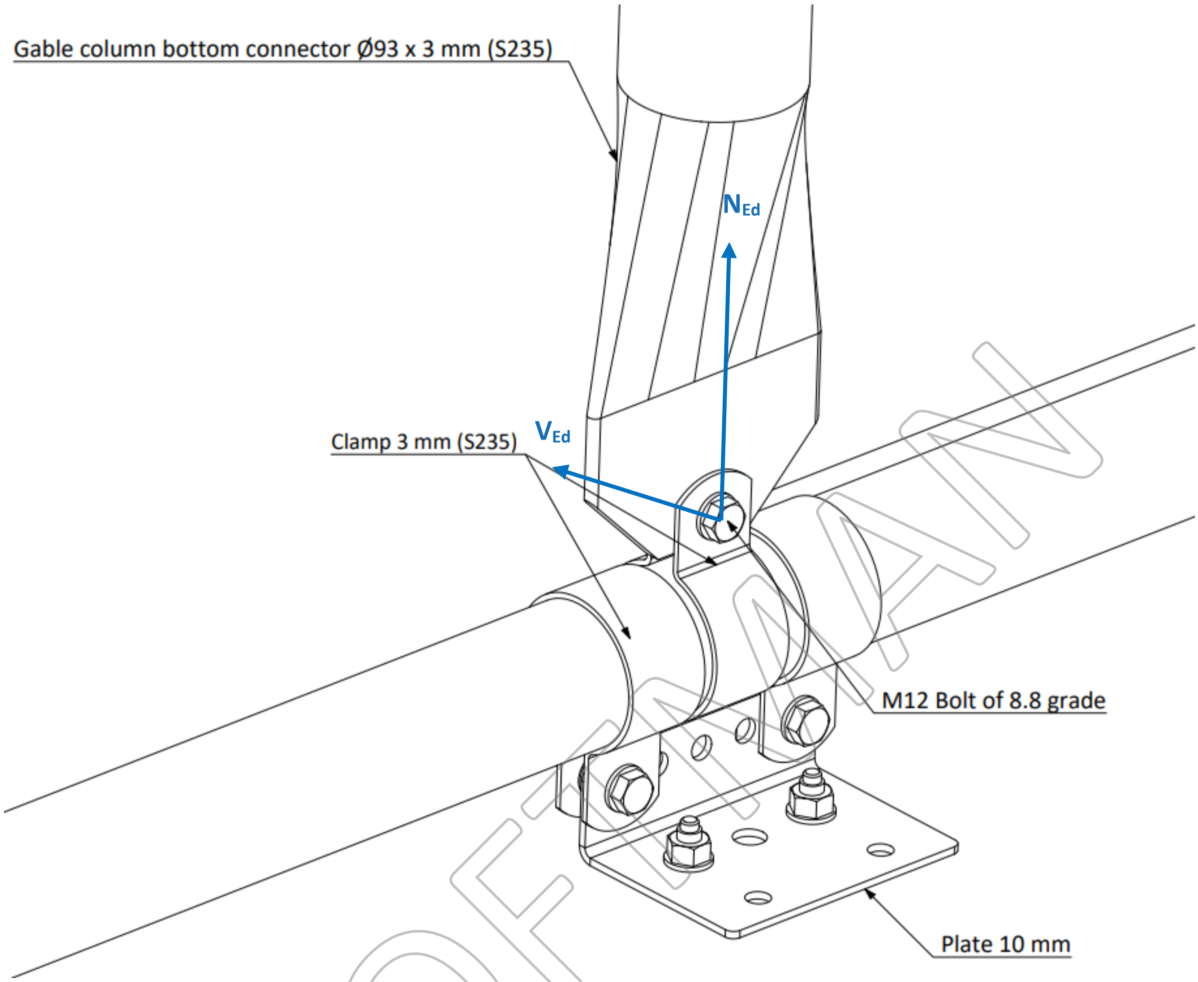
f_y	355	N/mm²	S355
$t_{b\ or\ 2\ x\ a}$	6	mm	
$F_{b,Rd}$	38.34	kN	$= 1{,}5\, t\, d\, f_y / \gamma_{M0}$
U.C.	0.18	1/1	

Unity Check:

Bolt	0.05	< 1 OK
Steel plate inner flanges	0.27	< 1 OK
Steel plate outer flanges	0.18	< 1 OK

9.5. Gable column bottom connection

9.5.1. Description



Cross-sectional properties

Material – S235 (Gable column bottom connector & clamp)

$f_y = 235\ N/mm^2$

$f_U = 360\ N/mm^2$

Material – S355 (Bended plate 10 mm)

$f_y = 355\ N/mm^2$

$f_U = 510\ N/mm^2$

Bolt M12 of Grade 8.8

$f_y = 640\ N/mm^2$

$f_{up} = 800\ N/mm^2$

$A_s = 84.3\ mm^2$

$\alpha_v = 0.6$

$\gamma_{M2} = 1.25$

$\gamma_{M0} = 1.0$

9.5.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1024-HD),

N_{Ed} = 13.78 kN (CO2, Node No: 7)

V_{Ed} = 7.28 kN (CO2, Node No: 7)

$F_{N\,Ed} = (13.78^2 + 7.28^2)^{0.5}$ = **15.60 kN**

9.5.3. Capacity of component

Capacity of the bolt M12 (8.8 grade)

(EN 1993-1-8+ C2:2011 Table 3.4)

$F_{v,Rd} = \alpha_v\, A\, f_{ub} / \gamma_{m2}$ = 0.6 x 84.3 x 800 / 1.25 = 32371.2N = **32.37 kN**

(EN 1993-1-8+ C2:2011 Table 3.4)

$F_{t\,Rd} = K_2\, f_{Ub}\, A_s / \gamma_{M2}$ = 0.9 x 800 x 84.3 / 1.25 = 48556.8 N = **48.55 kN**

Capacity of the clamp 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\, t\, d\, f_y / \gamma_{m0}$ = 1.5 x 6 x 12 x 235 / 1.0 = 25380 N = **25.38 kN**

Capacity of the gable column bottom connector (S235) Ø93 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\, t\, d\, f_y / \gamma_{m0}$ = 1.5 x 6 x 12 x 235 / 1.0 = 25380 N = **25.38 kN**

9.5.4. Check on component

Check on the bolt M12 (8.8 grade)

(EN 1993-1-8+ C2: 2011 Table 3.4)

$(F_{v\,Ed} / F_{v\,Rd}) + (F_{t\,Ed} / (1.4\, F_{t\,Rd})) \leq 1.0$

(13.78 / 32.37) + (7.28 / (1.4 x 48.55)) = **0.53** ≤ 1.0, OK.

Check on the clamp 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

15.60 / 25.38 = **0.61** ≤ 1.0, OK.

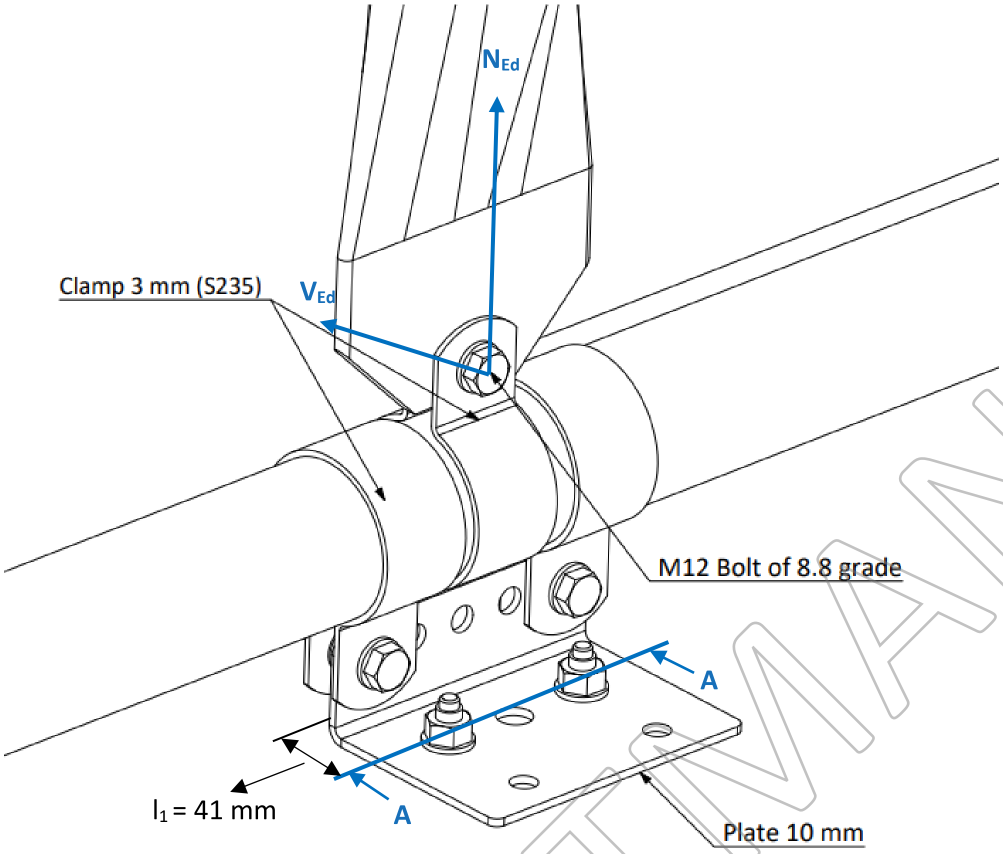
Check on the gable column bottom connector (S235) Ø93 x 3 mm (t = 2 x 3 = 6 mm)

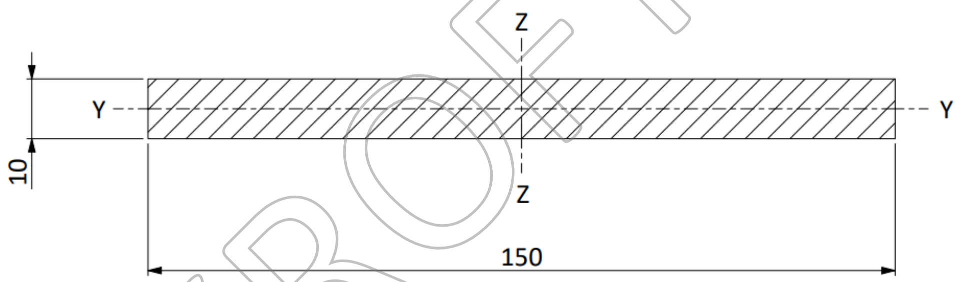
(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

15.60 / 25.38 = **0.61** ≤ 1.0, OK.

9.5.5. Check on the cross-section (A - A) of the bottom plate





Cross-section A-A
Scale 3:1

Cross-sectional properties

Area of cross-section A – A, A = 150 x 10 = 1500 mm^2

Material – S355

f_y = 355 N/mm^2

f_u = 510 N/mm^2

l_1 = 41 mm = 0.041 m

9.5.6. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1024-HD),

N_{Ed} = 13.78 kN (CO2, Node No: 7)

V_{Ed} = 7.28 kN (CO2, Node No: 7)

9.5.7. Check on the cross-section A – A (Equivalent method)

Section modulus of cross-section A – A

Section modulus $W_Y = bh^2 / 6$

$W_Y = (150 \times 10^2) / 6 = 2500 \text{ mm}^3$

Section modulus $W_Z = bh^2 / 6$

$W_z = (10 \times 150^2) / 6 = 37500 \text{ mm}^3$

Bending moment at section A – A due to N_{Ed},

l_1 = 41 mm = 0.041 m

$M_{Ed} = N_{Ed} \times l_1 = 13.78 \times 0.041 = 0.565$ kNm

Bending stress at section A – A due to the M_{Ed},

$\sigma_{M1} = M_{Ed} / W_Y = 0.565 \times 10^6 / 2500 = 226 \text{ N/mm}^2$

Tensile stress at section A – A due to $V_{Ed,}$

$\sigma_2 = V_{Ed} / A = 7.28 \times 10^3 / 1500 = 4.85 \text{ N/mm}^2$

Shear stress at section A – A due to N_{Ed},

$\tau = N_{Ed} / A = 13.78 \times 10^3 / 1500 = 9.19 \text{ N/mm}^2$

$\Sigma\sigma$ = 226 + 4.85 = **230.85 N/mm²**

$\Sigma\tau$ = **9.19 N/mm²**

9.5.7.1. Conclusion

$\sigma_{Vonmises} / (f_y / \gamma_{m1}) \leq 1.0$

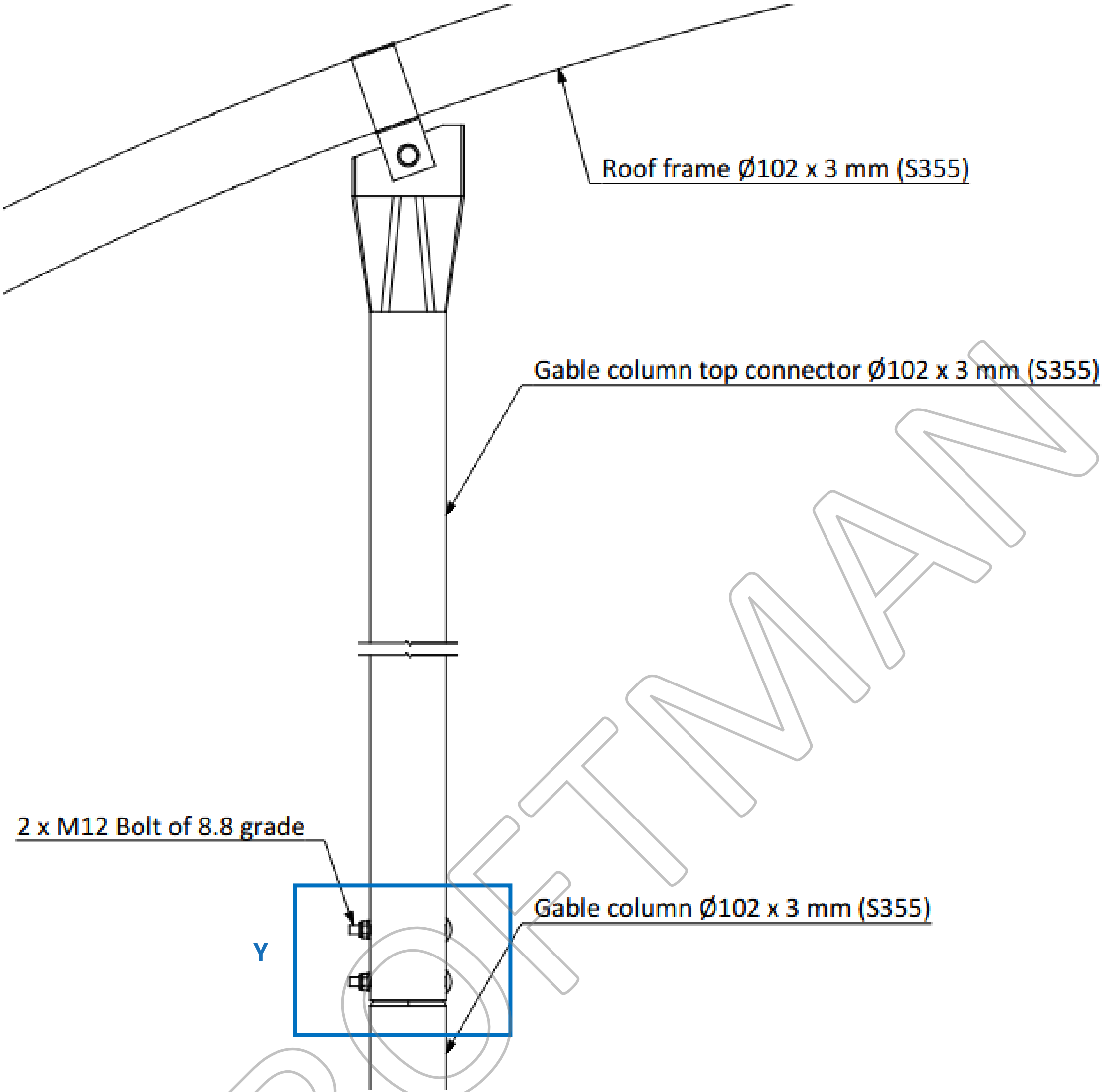
(f_y / γ_{m1}) = 355 / 1.1 = **322.73 N/mm²**

$\sigma_{Vonmises} = \sqrt{(\Sigma\sigma^2 + 3\,\Sigma\tau^2)}$ = $(230.85^2 + (3 \times 9.19^2))^{0.5}$ = **231.40 N/mm²**

231.40 / 322.73 = **0.72** ≤ 1.0, OK.

9.6. Gable column top connector (Detail Y)

9.6.1. Description



Material – S355 (Gable column & Gable column top connector)

$f_y = 355\ N/mm^2$

$f_U = 510\ N/mm^2$

Bolt M12 of Grade 8.8

$f_y = 640\ N/mm^2$

$f_{up} = 800\ N/mm^2$

$A_s = 84.3\ mm^2$

$\alpha_v = 0.6$

$\gamma_{M2} = 1.25$

$\gamma_{M0} = 1.0$

9.6.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1024-HD),

N_{Ed} = 13.78 kN (CO2, Node No: 7)

9.6.3. Capacity of component

Shear capacity of the bolt M12 (8.8 grade)

(EN 1993-1-8+ C2:2011 Table 3.4)

$F_{v,Rd} = \alpha_v A f_{ub} / \gamma_{m2}$ = 0.6 x 84.3 x 800 / 1.25 = 32371.2N = **32.37 kN**

Capacity of the gable column top connector (S355) Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\, t\, d\, f_y / \gamma_{m0}$ = 1.5 x 6 x (2 x 12) x 355 / 1.0 = 76680 N = **76.68 kN**

Capacity of the gable column (S355) Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\, t\, d\, f_y / \gamma_{m0}$ = 1.5 x 6 x (2 x 12) x 355 / 1.0 = 76680 N = **76.68 kN**

9.6.4. Check on component

Check on the bolt M12 (8.8 grade)

(EN 1993 -1-8 Table 3.10)

$F_{v,Ed} / F_{v,Rd} \leq 1.0$

For one bolt, = 13.78 / 2 = 6.90kN

6.90 / 32.37 = **0.21** ≤ 1.0, OK.

Check on the gable column top connector (S355) Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

13.78 / 76.68 = **0.18** ≤ 1.0, OK.

Check on the gable column (S355) Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

13.78 / 76.68 = **0.18** ≤ 1.0, OK.

9.6.5. Pin and plate calculation – check on bolt

The below sheet provides a check on the bolt connection of the gable column top connector to gable column.

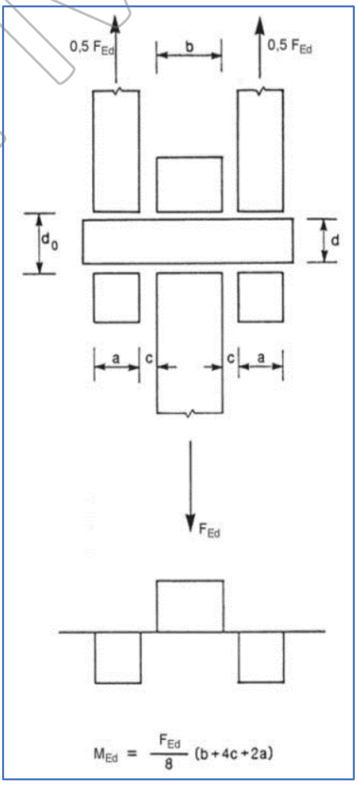
project:	Kroftman CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD
component:	Gable upright top connector, bolt connection
date:	14-11-2025

STEEL BOLT

d	12	mm	
a	3	mm	
b	6	mm	
c	0.5	mm	
f_{yp}	640	N/mm²	8.8
f_{up}	800	N/mm²	
f_{ymin}	640	N/mm²	
γ_{M0}	1.00	1/1	
γ_{M2}	1.25	1/1	
A_s	84.3		
F_{Ed}	8.11	kN	Node no: 259
n_{pins}	2	1/1	
$F_{ed / pin}$	4.06	kN	
M_{Ed}	7.10	kNmm	
$F_{v,Rd}$	32.37	kN	$= 0,6\, A\, f_{up} / \gamma_{M2}$
U.C.	0.13	1/1	
$M_{E,Rd}$	162.86	kNmm	
U.C.	0.04	1/1	
U.C.$_{combined}$	0.02	1/1	$\left[\frac{M_{Ed}}{M_{Rd}}\right]^2 + \left[\frac{F_{v,Ed}}{F_{v,Rd}}\right]^2 \leq 1$

STEEL PLATE INNER FLANGES

S355			
f_y	355	N/mm²	
$t_{b\ or\ 2\ x\ a}$	6	mm	
$F_{b,Rd}$	38.34	kN	$= 1,5\, t\, d\, f_y / \gamma_{M0}$
U.C.	0.11	1/1	



STEEL PLATE OUTER FLANGES

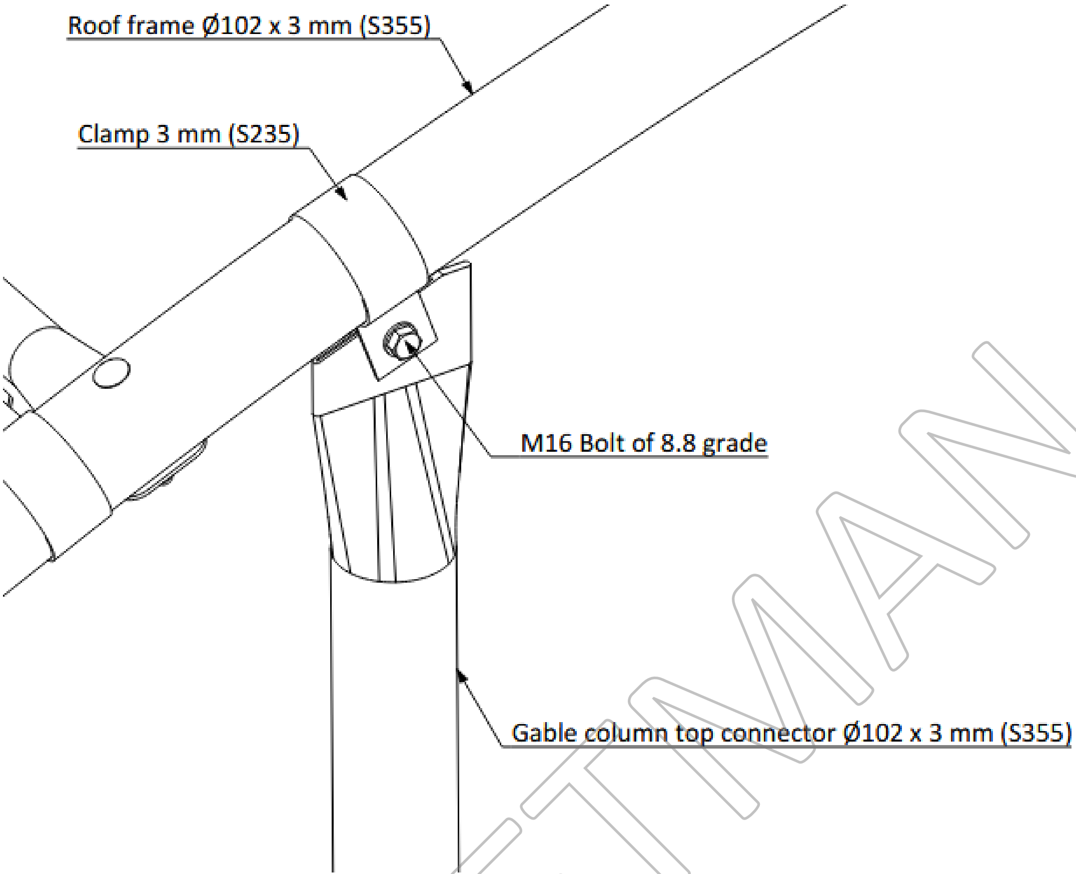
f_y	355	N/mm²	S235
$t_{b\ or\ 2\ x\ a}$	6	mm	
$F_{b,Rd}$	38.34	kN	$= 1,5\, t\, d\, f_y / \gamma_{M0}$
U.C.	0.11	1/1	

Unity Check:

Bolt	0.02	< 1 OK
Steel plate inner flanges	0.11	< 1 OK
Steel plate outer flanges	0.11	< 1 OK

9.7. Gable column to roof frame connection (Clamp connection)

9.7.1. Description



Material – S235 (Clamp)

$f_y = 235\ N/mm^2$

$f_U = 360\ N/mm^2$

Material – S355 (Gable column top connector)

$f_y = 355\ N/mm^2$

$f_U = 510\ N/mm^2$

Bolt M16 of Grade 8.8

$f_y = 640\ N/mm^2$

$f_{up} = 800\ N/mm^2$

$A_s = 157\ mm^2$

$\alpha_v = 0.6$

$\gamma_{M2} = 1.25$

$\gamma_{M0} = 1.0$

9.7.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1024-HD),

N_{Ed} = 6.92 kN (CO2 Node No: 11)

$V_{,Ed}$ = 5.05 kN (CO2 Node No: 11)

$F_{Ed} = (6.92^2 + 5.05^2)^{0.5}$ = 8.57 kN

9.7.3. Capacity of component

Shear capacity of the bolt M16 (8.8 grade)

(EN 1993-1-8+ C2:2011 Table 3.4)

$F_{v,Rd} = \alpha_v A f_{ub} / \gamma_{m2}$ = 0.6 x 157 x 800 / 1.25 = 60288 N = **60.29 kN**

Capacity of the clamp 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\, t\, d\, f_y / \gamma_{m0}$ = 1.5 x 6 x 16 x 235 / 1.0 = 33840 N = **33.84 kN**

Capacity of the gable column top connector (S355) Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\, t\, d\, f_y / \gamma_{m0}$ = 1.5 x 6 x 16 x 355 / 1.0 = 51120 N = **51.12 kN**

9.7.4. Check on component

Check on the bolt M16 (8.8 grade)

(EN 1993 -1-8 Table 3.10)

$F_{v,Ed} / F_{v,Rd} \leq 1.0$

8.57 / 60.29 = **0.14** ≤ 1.0, OK.

Check on the clamp 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

8.57 / 33.84 = **0.25** ≤ 1.0, OK.

Check on the gable column top connector (S355) Ø102 x 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{,Ed} / F_{b,Rd} \leq 1.0$

8.57 / 51.12 = **0.17** ≤ 1.0, OK.

9.7.5. Pin and plate calculation – check on bolt

The below sheet provides a check on the bolt connection of the gable column top connector to the clamp.

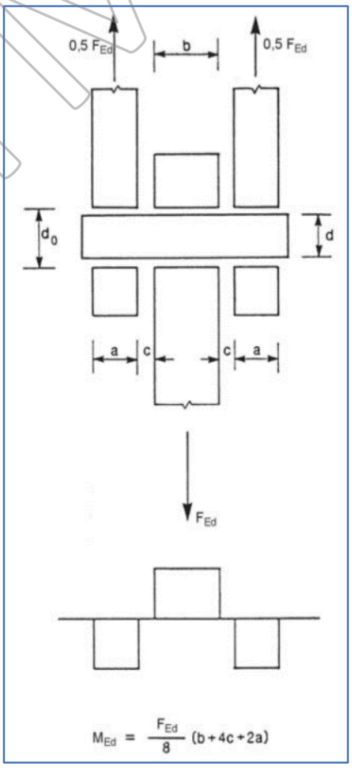
project:	Kroftman CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD
component:	Gable column top connector to clamp connection, bolt connection
date:	14-11-2025

STEEL BOLT

d	16	mm	
a	3	mm	
b	6	mm	
c	4.5	mm	
f_{yp}	640	N/mm²	
f_{up}	800	N/mm²	8.8
f_{ymin}	640	N/mm²	
γ_{M0}	1.00	1/1	
γ_{M2}	1.25	1/1	
A_s	157		
F_{Ed}	8.57	kN	Node no: 11
n_{pins}	1	1/1	
$F_{ed / pin}$	8.57	kN	
M_{Ed}	32.14	kNmm	
$F_{v,Rd}$	60.29	kN	$= 0{,}6\, A\, f_{up} / \gamma_{M2}$
U.C.	0.14	1/1	
$M_{E,Rd}$	386.03	kNmm	
U.C.	0.08	1/1	
U.C.$_{combined}$	0.03	1/1	$\left[\frac{M_{Ed}}{M_{Rd}}\right]^2 + \left[\frac{F_{v,Ed}}{F_{v,Rd}}\right]^2 \leq 1$

STEEL PLATE INNER FLANGES

S355			
f_y	355	N/mm²	
$t_{b\ or\ 2\ x\ a}$	6	mm	
$F_{b,Rd}$	51.12	kN	$= 1{,}5\, t\, d\, f_y / \gamma_{M0}$
U.C.	0.17	1/1	



STEEL PLATE OUTER FLANGES

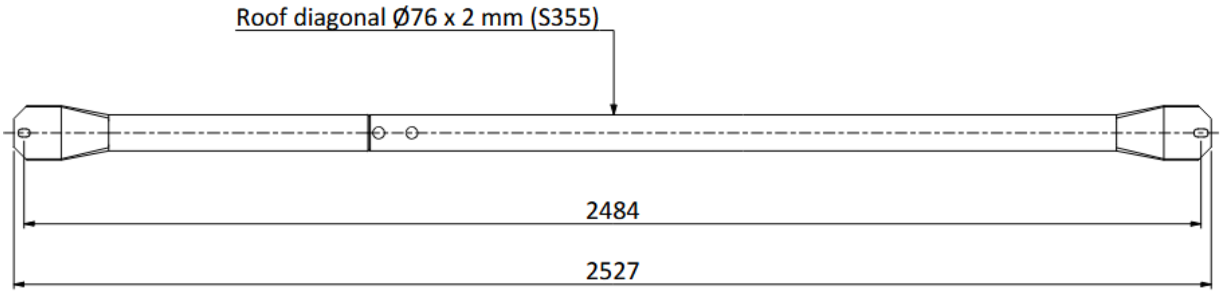
f_y	235	N/mm²	S235
$t_{b\ or\ 2\ x\ a}$	6	mm	
$F_{b,Rd}$	33.84	kN	$= 1{,}5\, t\, d\, f_y / \gamma_{M0}$
U.C.	0.25	1/1	

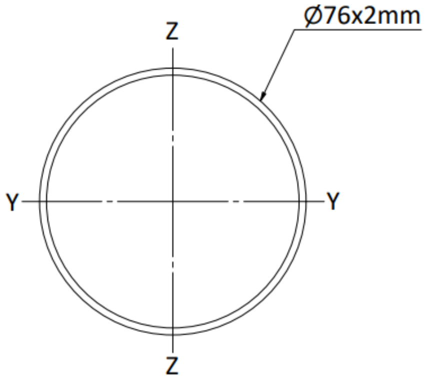
Unity Check:

Bolt	0.03	< 1 OK
Steel plate inner flanges	0.17	< 1 OK
Steel plate outer flanges	0.25	< 1 OK

9.8. Roof diagonal – Ø76 x 2 mm (S355)

9.8.1. Description





Cross-section Ø76 x 2 mm

Cross-sectional properties

A = 465 mm^2

L = 2484 mm

I_y = 318500 mm^4

Material – S355

f_o = 355 N/mm^2

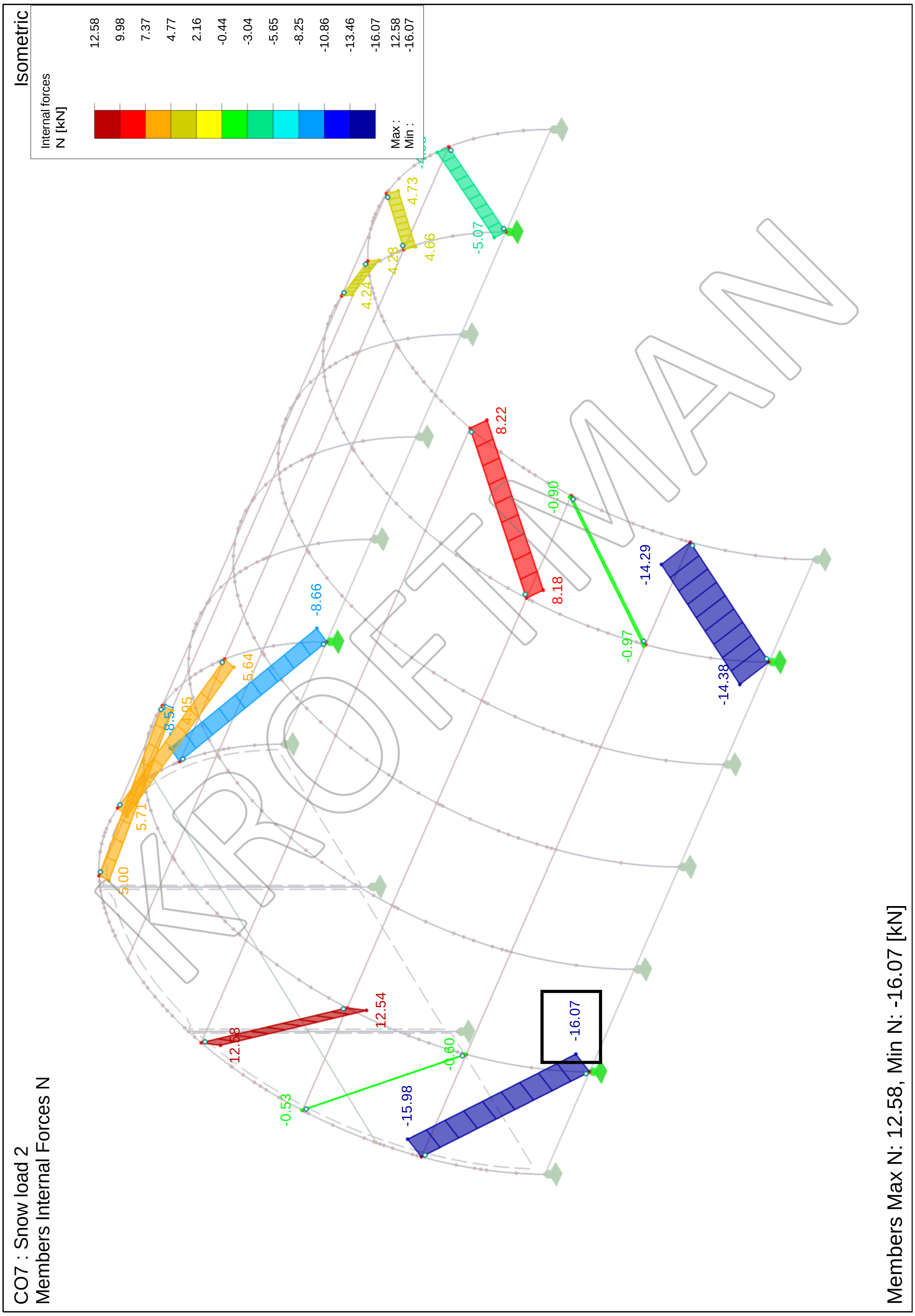
f_u = 510 N/mm^2

Outer diameter	D	76.0	mm
Wall thickness	s	2.0	mm
Cross-sectional area	A	4.65	cm^2
Shear area	A_y	2.32	cm^2
Core area	A_c	43.01	cm^2
Moment of inertia	I_y	31.85	cm^4
Polar moment of inertia	I_p	63.70	cm^4
Governing radius of gyration	r_y	26.2	mm
Polar radius of gyration	r_o	37.0	mm
Weight	wt	3.6	kg/m
Surface	A_{surf}	0.239	m^2/m
Torsional constant	J	63.70	cm^4
Section modulus for torsion	S_t	16.76	cm^3
Elastic section modulus	S_y	8.38	cm^3
Statical moment of area	$Q_{y,max}$	2.74	cm^3
Plastic section modulus	$Z_{y,max}$	10.95	cm^3
Plastic shape factor	$Z_{y,max}/S_y$	1.307	
Buckling curve (DIN 18800-2:2008-11)	$BC_{y,DIN}$	a	
Buckling curve acc. to EN	$BC_{y,EN}$	a	
Buckling curve acc. to EN for steel S 460	[illegible]	a0	

9.8.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1012-HD),

N_{Ed} = 16.07 kN (CO7, Member No: 424)



9.8.3. Check on component – Buckling check

Project:	Kroftman CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD
Cross section:	Roof diagonal Ø76x2 mm - S355
Date:	14-11-2025

L	2484	
k	1	tabel 6.8
L_{cr}	2484	mm
A_{eff}	465	mm²
$I_{xy\,/\,zwak}$	318500	mm⁴
E	210000	N/mm²
γ_{M1}	1.1	
f_0	355	N/mm²
f_y	510	N/mm²

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} = \frac{L_{cr}}{i}\frac{1}{\lambda_1} \quad \text{voor doorsneden van klasse 1, 2 en 3} \quad (6.50)$$

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}} = \frac{L_{cr}}{i}\frac{\sqrt{\frac{A_{eff}}{A}}}{\lambda_1} \quad \text{voor doorsneden van klasse 4} \quad (6.51)$$

waarin L_{cr} is de kniklengte in het beschouwde knikvlak;

i is de traagheidsstraal om de beschouwde as, bepaald uitgaande van de kenmerken van de brutodoorsnede;

$$\lambda_1 = \pi\sqrt{\frac{E}{f_y}} = 93{,}9\varepsilon$$

$$\varepsilon = \sqrt{\frac{235}{f_y}} \quad (f_y \text{ in N/mm}^2)$$

Tabel 6.1 — Imperfectiefactoren voor de knikkrommen

Knikkromme	a_0	a	b	c	d
Imperfectiefactor α	0,13	0,21	0,34	0,49	0,76

i	26.2	mm
λ_{rel}	1.24	
ε	0.81	
λ_1	76.4	
α	0.49	tabel 6.1, knikkromme "c"
Ø	1.53	
X	0.41	

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \quad \text{maar } \chi \le 1{,}0$$

waarin:

$$\Phi = 0{,}5\left[1 + \alpha\left(\bar{\lambda} - 0{,}2\right) + \bar{\lambda}^2\right]$$

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} \quad \text{voor doorsneden van klasse 1, 2 en 3}$$

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}} \quad \text{voor doorsneden van klasse 4}$$

α is een imperfectiefactor;

N_{Ed}	16.07	kN
$N_{b,Rd}$	62.15	kN
U.C.	0.26	

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \quad \text{voor doorsneden van klasse 4} \quad (6.48)$$

waarin χ de reductiefactor voor de van toepassing zijnde knikvorm.

y-as

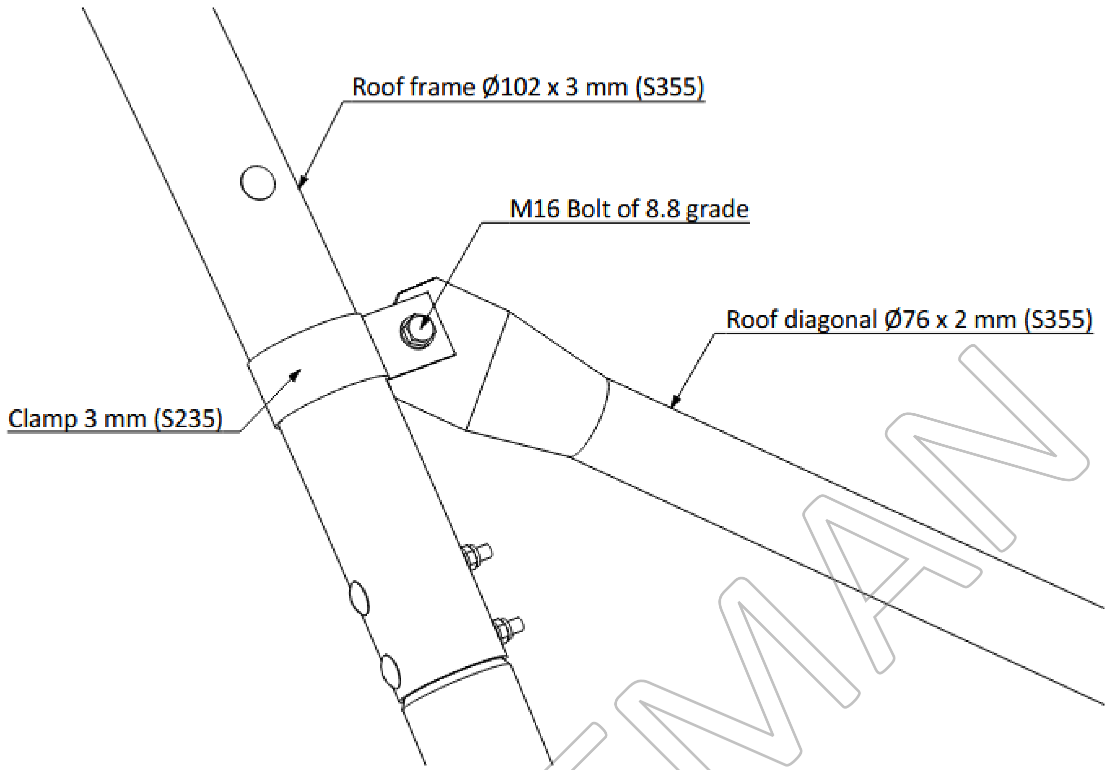
$W_{el\,y}$	8380	mm³
$W_{net\,y}$	8380	mm³

z-as

$W_{el\,z}$	8380	mm³
$W_{net\,y}$	8380	mm³

9.9. Roof diagonal to roof frame connection

9.9.1. Description



Material – S355 (Diagonal)

$f_o = 355$ N/mm^2

$f_u = 510$ N/mm^2

Material – S235 (Clamp)

$f_y = 235$ N/mm^2

$f_U = 360$ N/mm^2

Bolt M16 of Grade 8.8

$f_y = 640$ N/mm^2

$f_{up} = 800$ N/mm^2

$A_s = 157$ mm^2

$\alpha_v = 0.6$

$\gamma_{M2} = 1.25$

$\gamma_{M0} = 1.0$

9.9.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1012-HD),

$N_{Ed} = 16.07$ kN (CO7, Member No: 424)

9.9.3. Capacity of component

Shear capacity of the bolt M16 (8.8 grade)

(EN 1993-1-8+ C2:2011 Table 3.4)

$F_{v,Rd} = \alpha_v A f_{ub} / \gamma_{m2}$ = 0.6 x 157 x 800 / 1.25 = 60288 N = **60.29 kN**

Capacity of the clamp 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\ t\ d\ f_y / \gamma_{m0}$ = 1.5 x 6 x 16 x 235 / 1.0 = 33840 N = **33.84 kN**

Capacity of the roof diagonal Ø76 x 2 mm (t = 2 x 2 = 4 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\ t\ d\ f_y / \gamma_{m0}$ = 1.5 x 4 x 16 x 355 / 1.0 = 34080 N = **34.08 kN**

9.9.4. Check on component

Check on the bolt M16 (8.8 grade)

(EN 1993 -1-8 Table 3.10)

$F_{v,Ed} / F_{v,Rd} \leq 1.0$

16.07 / 60.29 = **0.27** ≤ 1.0, OK.

Check on the clamp 3 mm (t = 2 x 3 = 6 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

16.07 / 33.84 = **0.47** ≤ 1.0, OK.

Capacity of the roof diagonal Ø76 x 2 mm (t = 2 x 2 = 4 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

16.07 / 34.08 = **0.47** ≤ 1.0, OK.

9.9.5. Pin and plate calculation – check on bolt

The below sheet provides an additional check on the bolt connection of the roof diagonal to the clamp.

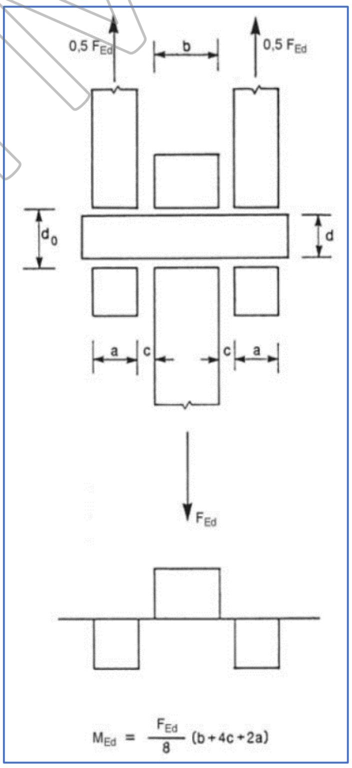
project:	Kroftman CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD
component:	Roof diagonals to clamp connection, bolt connection
date:	14-11-2025

STEEL BOLT (8.8)

d	16	mm	
a	3	mm	
b	4	mm	
c	6.25	mm	
f_{yp}	640	N/mm²	
f_{up}	800	N/mm²	
f_{ymin}	640	N/mm²	
γ_{M0}	1.00	1/1	
γ_{M2}	1.25	1/1	
A_s	157		
F_{Ed}	16.07	kN	Member no: 424
n_{pins}	1	1/1	
$F_{ed/pin}$	16.07	kN	
M_{Ed}	70.31	kNmm	
$F_{v,Rd}$	60.29	kN	$= 0{,}6\,A\,f_{up}/\gamma_{M2}$
U.C.	0.27	1/1	
$M_{E,Rd}$	386.03	kNmm	
U.C.	0.18	1/1	
U.C.$_{combined}$	0.10	1/1	$\left[\frac{M_{Ed}}{M_{Rd}}\right]^2 + \left[\frac{F_{v,Ed}}{F_{v,Rd}}\right]^2 \leq 1$

STEEL PLATE INNER FLANGES

S355			
f_y	355	N/mm²	
$t_{b\ or\ 2\times a}$	4	mm	
$F_{b,Rd}$	34.08	kN	$= 1{,}5\,t\,d\,f_y/\gamma_{M0}$
U.C.	0.47	1/1	



STEEL PLATE OUTER FLANGES

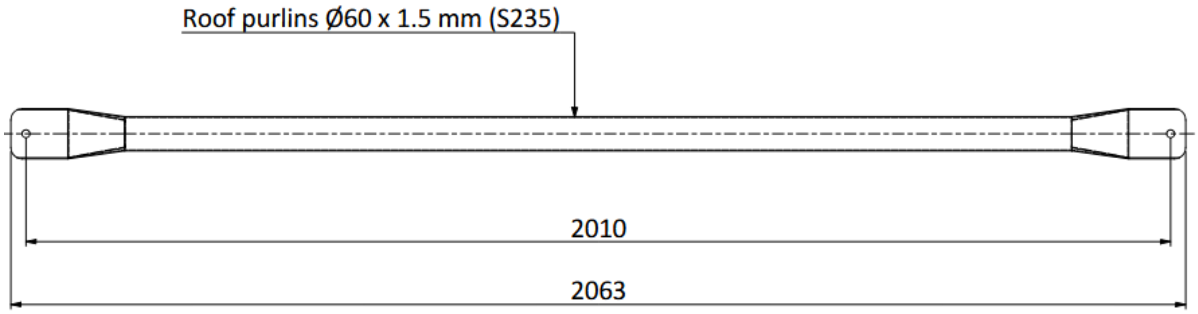
f_y	235	N/mm²	S235
$t_{b\ or\ 2\times a}$	6	mm	
$F_{b,Rd}$	33.84	kN	$= 1{,}5\,t\,d\,f_y/\gamma_{M0}$
U.C.	0.47	1/1	

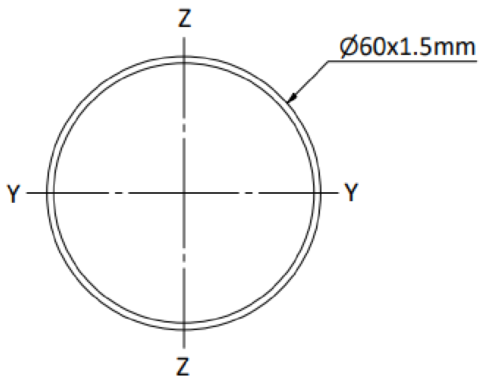
Unity Check:

Bolt	0.10	< 1 OK
Steel plate inner flanges	0.47	< 1 OK
Steel plate outer flanges	0.47	< 1 OK

9.10. Roof Purlins – Ø60 x 1.5 mm (S235)

9.10.1. Description





Cross-section Ø60 x 1.5 mm

Cross-sectional properties

A = 276 mm²

L = 2010 mm

I_y = 118000 mm⁴

Material – S235

f_o = 235 N/mm²

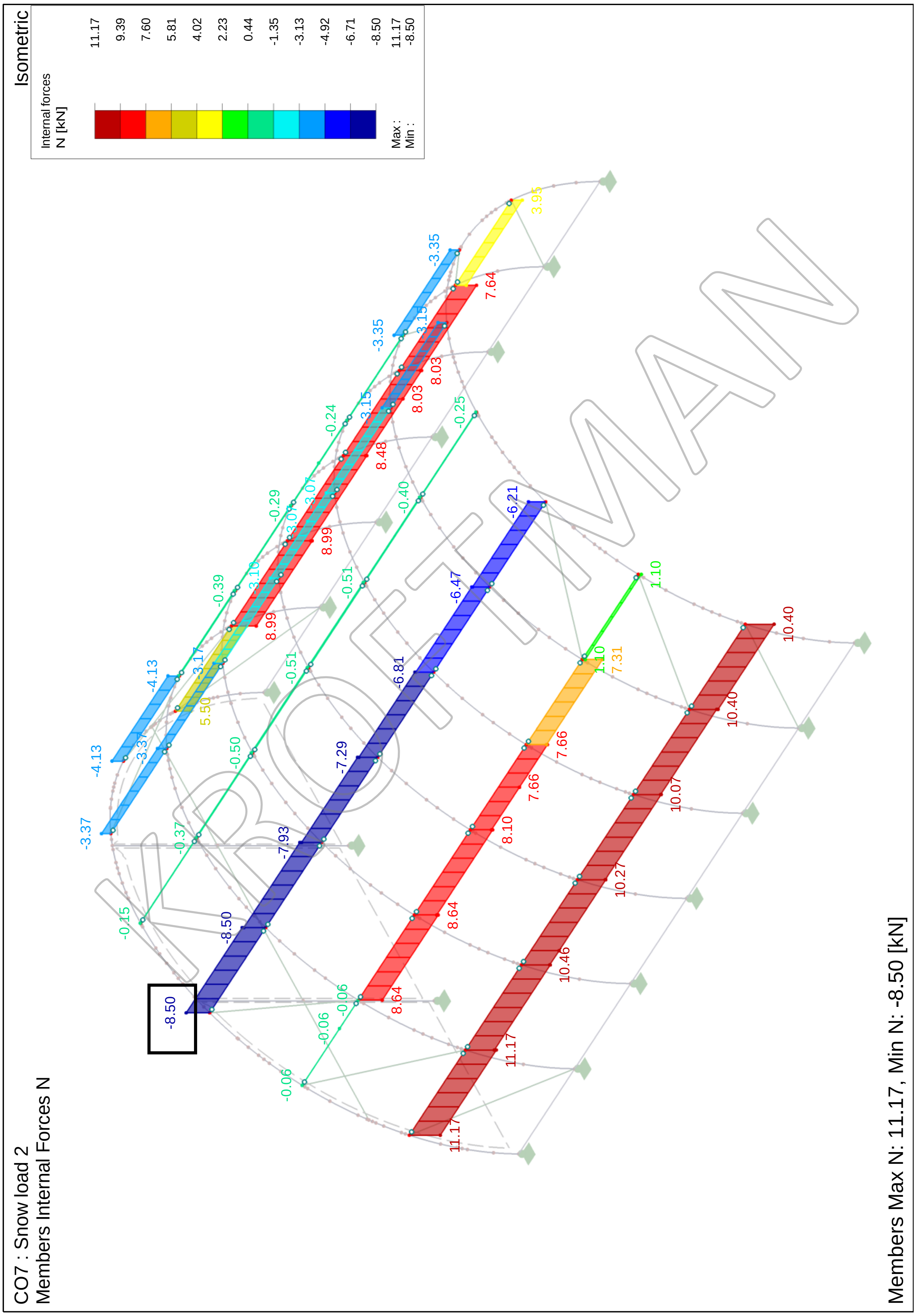
f_u = 360 N/mm²

Cross-Section Property	Symbol	Value	Unit
Outer diameter	D	60.0	mm
Wall thickness	s	1.5	mm
Cross-sectional area	A	2.76	cm^2
Shear area	A_y	1.37	cm^2
Core area	A_c	26.88	cm^2
Moment of inertia	I_y	11.80	cm^4
Polar moment of inertia	I_p	23.60	cm^4
Governing radius of gyration	r_y	20.7	mm
Polar radius of gyration	r_o	29.3	mm
Weight	wt	2.2	kg/m
Surface	A_{surf}	0.188	m^2/m
Torsional constant	J	23.60	cm^4
Section modulus for torsion	S_t	7.87	cm^3
Elastic section modulus	S_y	3.93	cm^3
Statical moment of area	$Q_{y,max}$	1.28	cm^3
Plastic section modulus	$Z_{y,max}$	5.13	cm^3

9.10.2.Loadings

Decisive loadings as per the RFEM analysis (CT-A-1012-HD),

N_{Ed} = 8.50 kN (CO7, member No: 399)



9.10.3.Check on component – Buckling check

Project:	Kroftman CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD
Cross section:	Roof purlins Ø60 x 1.5 mm - S235
Date:	14-11-2025

L	2010	
k	1	tabel 6.8
L_{cr}	2010	mm
A_{eff}	276	mm²
$I_{xy\,/\,zwak}$	118000	mm⁴
E	210000	N/mm²
γ_{M1}	1.1	
f_0	235	N/mm²
f_y	360	N/mm²

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} = \frac{L_{cr}}{i}\frac{1}{\lambda_1} \quad \text{voor doorsneden van klasse 1, 2 en 3} \qquad (6.50)$$

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}} = \frac{L_{cr}}{i}\frac{\sqrt{\frac{A_{eff}}{A}}}{\lambda_1} \quad \text{voor doorsneden van klasse 4} \qquad (6.51)$$

waarin L_{cr} is de kniklengte in het beschouwde knikvlak;

i is de traagheidsstraal om de beschouwde as, bepaald uitgaande van de kenmerken van de brutodoorsnede;

$$\lambda_1 = \pi\sqrt{\frac{E}{f_y}} = 93{,}9\varepsilon$$

$$\varepsilon = \sqrt{\frac{235}{f_y}} \quad (f_y \text{ in N/mm}^2)$$

Tabel 6.1 —Imperfectiefactoren voor de knikkrommen

Knikkromme	a_0	a	b	c	d
Imperfectiefactor α	0,13	0,21	0,34	0,49	0,76

i	20.7	mm
λ_{rel}	1.04	
ε	1.00	
λ1	93.9	
α	0.49	tabel 6.1, knikkromme "c"
Ø	1.24	
X	0.52	

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \quad \text{maar } \chi \leq 1{,}0$$

waarin:

$$\Phi = 0{,}5\left[1 + \alpha(\bar{\lambda} - 0{,}2) + \bar{\lambda}^2\right]$$

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} \quad \text{voor doorsneden van klasse 1, 2 en 3}$$

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}} \quad \text{voor doorsneden van klasse 4}$$

α is een imperfectiefactor;

N_{Ed}	8.5	kN
$N_{b,Rd}$	30.65	kN
U.C.	0.28	

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \quad \text{voor doorsneden van klasse 4} \qquad (6.48)$$

waarin χ de reductiefactor voor de van toepassing zijnde knikvorm.

y-as

$W_{el\,y}$	3930	mm³
$W_{net\,y}$	3930	mm³

z-as

$W_{el\,z}$	3930	mm³
$W_{net\,y}$	3930	mm³

9.10.4.Compression combined with bending

Project :	Kroftman CT-A-1006-HD/CT-A-1012-HD/CT-A-1024-HD
Cross section:	Roof purlins Ø60 x 1.5 mm - S235
Date :	14-11-2025

Bending Due to own weight

Own weight of purlin	2.2	kg/m
Own weight of purlin, W_p	0.02	kN/m
Weight of the fabric, W_f	0.01187	kN/m
W_y	0.03	kN/m
Bending due to own weight Myo	0.02	kNm
Bending due to snow roof My_T	0.40	kNm

$W_y = W_p + W_f$

$Myo = \frac{Wy \times L^2}{8}$

L	2.01	m
Length between purlins	1.978	m

Total Bending

Total bending My_{ED}	0.42	kNm
Total bending MZED	0.00	kNm

1.35 x Myo + MyL

A_{eff}	276	mm²
I_{xy} / zwak	118000	mm⁴
E	210000	N/mm²
γ_{M1}	1.1	
f_0	235	N/mm²
f_y	360	N/mm²

$W_{el\,y}$	3930	mm³
$W_{net\,y}$	3930	mm³
$W_{el\,z}$	3930	mm³
$W_{net\,z}$	3930	mm³

Bending unity check

MyRd	0.92	kNm
MZRD	0.92	kNm

Unity check on My	0.46
Unity cbheck on Mz	0.00

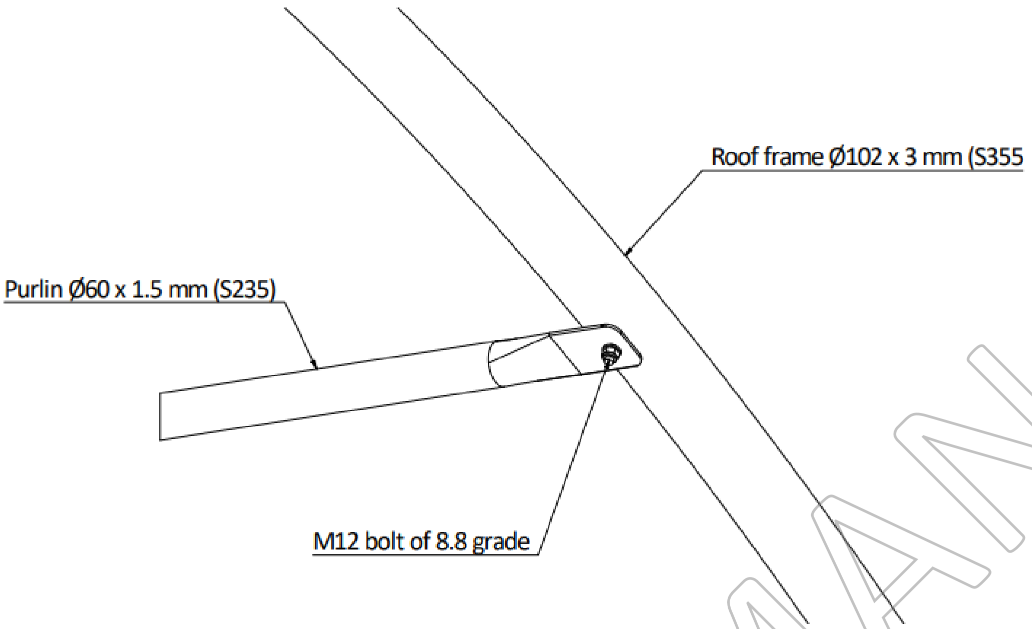
Bending and Compression

Nb,Rd	30.7	kN	
N_{Ed}	8.5	kN	
Ψ_c	0.8		
ω_0	1		
U.C.	0.74	≤	1.0

$$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$$

9.11. Roof purlins to roof frame connection

9.11.1. Description



Material – S235 (Purlin)

$f_y = 235$ N/mm²

$f_U = 360$ N/mm²

Bolt M12 of Grade 8.8

$f_y = 640$ N/mm²

$f_{up} = 800$ N/mm²

$A_s = 84.3$ mm²

$\alpha_v = 0.6$

$\gamma_{M2} = 1.25$

$\gamma_{M0} = 1.0$

9.11.2. Loadings

Decisive loadings as per the RFEM analysis (CT-A-1006-HD),

$N_{Ed} = 11.70$ kN (CO7, member No: 231)

9.11.3.Capacity of component

Shear capacity of the bolt M12 (8.8 grade)

(EN 1993-1-8+ C2:2011 Table 3.4)

$F_{v,Rd} = \alpha_v A f_{ub} / \gamma_{m2}$ = 0.6 x 84.3 x 800 / 1.25 = 32371.2 N = **32.37 kN**

Capacity of the purlin Ø60 x 1.5 mm (t = 1.5 x 2 = 3 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\ t\ d\ f_y / \gamma_{m0}$ = 1.5 x 3 x 12 x 235 / 1.0 = 12690 N = **12.69 kN**

Capacity of the main profile Ø102 x 3 mm (t = 3 mm)

(EN 1993 -1-8 Table 3.10)

$F_{b,Rd} = 1.5\ t\ d\ f_y / \gamma_{m0}$ = 1.5 x 3 x 12 x 355 / 1.0 = 19170 N = **19.17 kN**

9.11.4.Check on component

Check on the bolt M12 (8.8 grade)

(EN 1993 -1-8 Table 3.10)

$F_{v,Ed} / F_{v,Rd} \leq 1.0$

11.70 / 32.37 = **0.36** ≤ 1.0, OK.

Check on the purlin Ø60 x 1.5 mm (t = 1.5 x 2 = 3 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

11.70 / 12.69 = **0.92** ≤ 1.0, OK.

Check on the main profile Ø102 x 3 mm (t = 3 mm)

(EN 1993 -1-8 Table 3.10)

$F_{N,Ed} / F_{b,Rd} \leq 1.0$

11.70 / 19.17 = **0.61** ≤ 1.0, OK