BAYLISS CONSULTING
CIVIL AND STRUCTURAL ENGINEERING CONSULTANTS
t: 01332 292 192
e: info@baylissconsulting.co.uk
w: www.baylissconsulting.co.uk

STRUCTURAL CALCULATIONS

FOR THE PROPOSED CANOPIED EXTENSION

AT

WILLINGTON SPORTS PAVILLION

TWYFORD ROAD

WILLINGTON

DERBYSHIRE

THESE CALCULATIONS HAVE BEEN PREPARED IN ACCORDANCE WITH THE RELEVANT PARTS OF THE FOLLOWING BRITISH STANDARD CODES OF PRACTICE:-

1. BS 6399 "LOADINGS FOR BUILDINGS"
2. BS 5950 "STRUCTURAL USE OF STEELWORK"
3. BS 5628 "UNREINFORCED MASONRY"

JOB REF: 6000

DATE: JUNE 2023

INTRODUCTION

We have been instructed by Willington Parish Council to prepare the structural calculations for the proposed canopied extension at Willington Sports Pavillion, Twyford Road, Willington.

In order to carry out the above we have been provided with architectural drawings prepared by Making Plans Architecture, no pre-alteration survey has been conducted by this office.

The design covers the steelwork support to the canopied roof. The roof is trussed rafters, designed and manufactured by a truss manufacturer. Our calculations assume that the trusses are positively fixed to the steelwork, that the roof is braced in accordance with BS5268 and that the ceiling acts as a rigid diaphragm.

Beam spans shown in these calculations are for design purposes only and so all dimensions should be checked on site by the builder prior to the fabrication of steelwork.

The heaviest beam specified in these calculations will weigh approximately 250 kg, the building contractor should ensure they have appropriate lifting gear for the safe installation of the steelwork.

All structural steelwork to be grade S355 and hot rolled. Plates are grade 275.

Due to its external location we also recommend the steelwork is hot dip galvanised.

These calculations have been prepared for Building Regulation purposes, and should be read in conjunction with the Architects drawings, and our mark up plan, any discrepancies should be reported immediately to this office.

Bayliss Consulting have not been asked to design the temporary works for the project. The builder is to provide adequate temporary propping to ensure the stability of the structure during the work.

Minor post – construction cracking of brittle finishes may occur.

STRUCTURE LOADS

Roof

S = 0.75 kN/m²

D =	Tiles	= 0.65 kN/m²	
	Battens	= 0.03 kN/m²	
	Felt	= 0.02 kN/m²	
	Rafters	= 0.10 kN/m²	= 0.80 kN/m²

Ceiling

S = 0.25 kN/m²

D =	Joists	= 0.10 kN/m²	
	Insulation	= 0.05 kN/m²	
	Ceiling Board	= 0.15 kN/m²	
	Services	= 0.05 kN/m²	= 0.35 kN/m²

Stud Wall

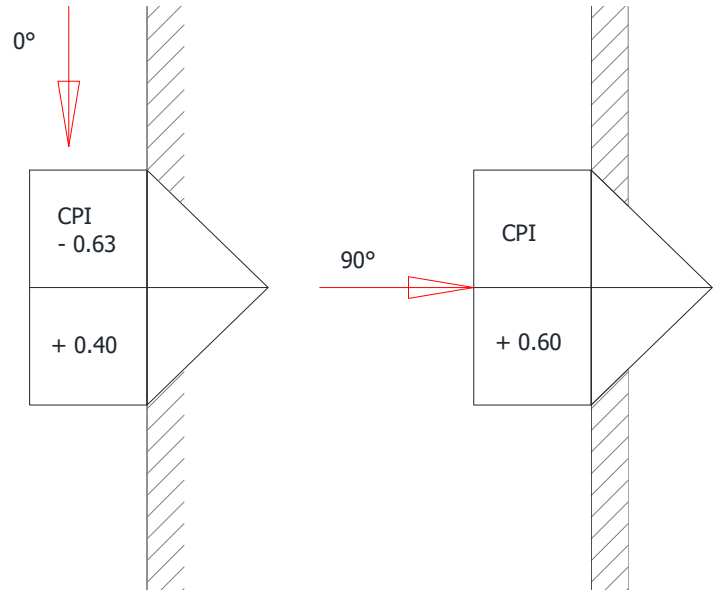
D =	Studs	= 0.15 kN/m²	
	Insulation	= 0.05 kN/m²	
	Ply Sheathing and Membrane	= 0.30 kN/m²	
	Timber Cladding	= 0.25 kN/m²	= 0.75 kN/m²

WIND LOAD DATA

Site Post Code	DE65 6BN
Site Coordinates	SK298285
Site Altitude	45 Metres
Location	Countryside
Distance to Sea	125m
Basic Wind Speed	21.40 m/sec

CALCULATE WIND ON CANOPY

Treat as an open sided building with 3 open sides.

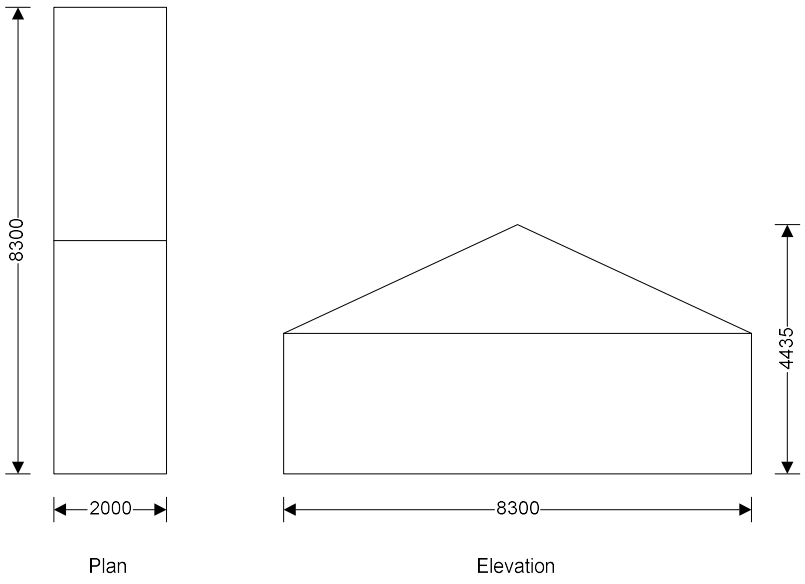


WIND LOADING (BS6399)

WIND LOADING (BS6399)

In accordance with BS6399

Tedds calculation version 3.0.18



Building data

Type of roof	Duopitch		
Length of building	L = **2000** mm	Width of building	W = **8300** mm
Pitch of roof	α_0 = **25.0** deg		
Reference height	H_r = **4435** mm		

Dynamic classification

Building type factor (table 1)	K_b = **4.0**	Dynamic augmentation factor (1.6.1)	C_r = **0.05**

Site wind speed

Location	Willington	Basic wind speed	V_b = **21.4** m/s
Site altitude	Δ_S = **45** m	Upwind dist from sea to site	d_{sea} = **125** km
Direction factor	S_d =**1.00**	Seasonal factor	S_s = **1.00**
Probability factor	S_p = **1.00**	Critical gap between buidlings	g = **5000** mm
Topography not significant			
Altitude factor	S_a = **1.05**	Site wind speed	V_s = **22.4** m/s
Terrain category	Country		
Displacement height	H_d = 0mm		

The velocity pressure for the windward face of the building with a 0 degree wind is to be considered as 2 parts as the height h is greater than b but less than 2b (cl.2.2.3.2)

The velocity pressure for the windward face of the building with a 90 degree wind is to be considered as 1 part as the height h is less than b (cl.2.2.3.2)

Dynamic pressure - windward wall (lower part) - Wind 0 deg

Reference height	H_e = **2000** mm		
Fetch factor (Table 22)	S_c = **0.723**	Turbulence factor (Table 22)	S_t = **0.215**
Gust peak factor	g_t = **3.44**	Terrain and building factor	S_b = **1.26**
Effective wind speed	V_e = **28.1** m/s	Dynamic pressure	q_s = **0.485** kN/m^2

Dynamic pressure - windward wall (upper part) - Wind 0 deg and roof

Reference height	H_e = **2500** mm		
Fetch factor (Table 22)	S_c = **0.750**	Turbulence factor (Table 22)	S_t = **0.211**
Gust peak factor	g_t = **3.44**	Terrain and building factor	S_b = **1.29**
Effective wind speed	V_e = **28.9** m/s	Dynamic pressure	q_s = **0.513** kN/m^2

Dynamic pressure - windward wall - Wind 90 deg and roof

Reference height	H_e = **4435** mm		
Fetch factor (Table 22)	S_c = **0.852**	Turbulence factor (Table 22)	S_t = **0.196**
Gust peak factor	g_t = **3.44**	Terrain and building factor	S_b = **1.43**
Effective wind speed	V_e = **31.9** m/s	Dynamic pressure	q_s = **0.625** kN/m^2

Size effect factors

Diag dim for gablewall	a_{eg} = **8.7** m	Exte size effect factor	C_{aeg} = **0.958**
Diag dim for side wall	a_{es} = **3.2** m	Exte size effect factor	C_{aes} = **1.000**
Diag dim for roof	a_{er} = **5.0** m	Exte size effect factor	C_{aer} = **1.000**
Diag dim for top windward side	a_{eus} = **2.1** m	Exte size effect factor	C_{aeus} = **1.000**
Diag dim for bottom windward side	C_{aebs} = **1.000**	a_{ebs} = **2.8** m	Exte size effect factor
Volume for int size effect	V_i = **40.0** m^3	Diag dim for int size effect	a_i = **34.2** m
Internal size effect factor	C_{ai} = **0.855**		

Pressures and forces

Net pressure $p = q_s \times c_{pe} \times C_{ae} - q_s \times c_{pi} \times C_{ai}$

Net force $F_w = p \times A_{ref}$

Roof load case 1 - Wind 0, c_{pi} -0.63, + c_{pe}

Zone	Ext pressure coefficient, c_{pe}	Dynamic pressure, q_s (kN/m^2)	External size factor, C_{ae}	Net Pressure, p (kN/m^2)	Area, A_{ref} (m^2)	Net force, F_w (kN)
A (+ve)	0.60	0.62	1.000	0.71	0.44	0.31
C (+ve)	0.33	0.62	1.000	0.54	8.72	4.75
E (+ve)	-1.03	0.62	1.000	-0.31	0.44	-0.14
G (+ve)	-0.50	0.62	1.000	0.02	8.72	0.21

Total vertical net force $F_{w,v}$ = **4.65** kN Total horizontal net force $F_{w,h}$ = **2.11** kN

Roof load case 2 - Wind 0, c_{pi} 0.40, - c_{pe}

Zone	Ext pressure coefficient, c_{pe}	Dynamic pressure, q_s (kN/m^2)	External size factor, C_{ae}	Net Pressure, p (kN/m^2)	Area, A_{ref} (m^2)	Net force, F_w (kN)
A (-ve)	-0.70	0.62	1.000	-0.65	0.44	-0.29
C (-ve)	-0.27	0.62	1.000	-0.38	8.72	-3.31
E (-ve)	-1.03	0.62	1.000	-0.86	0.44	-0.38
G (-ve)	-0.50	0.62	1.000	-0.53	8.72	-4.58

Total vertical net force $F_{w,v}$ = **-7.76** kN Total horizontal net force $F_{w,h}$ = **0.57** kN

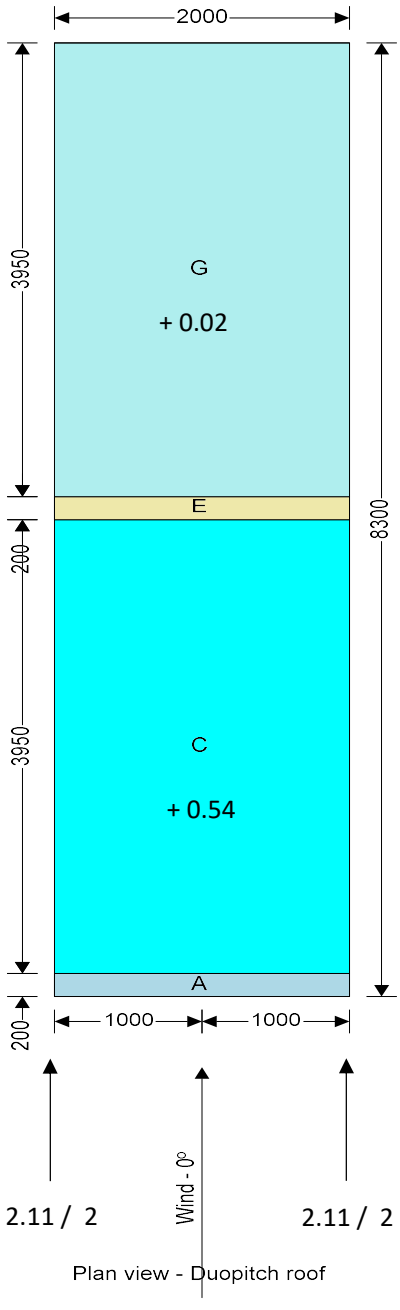
Roof load case 3 - Wind 90, c_{pi} 0.60, - c_{pe}

Zone	Ext pressure coefficient, c_{pe}	Dynamic pressure, q_s (kN/m^2)	External size factor, C_{ae}	Net Pressure, p (kN/m^2)	Area, A_{ref} (m^2)	Net force, F_w (kN)
A (-ve)	-1.33	0.62	1.000	-1.15	3.80	-4.38
B (-ve)	-1.23	0.62	1.000	-1.09	3.80	-4.15
C (-ve)	-0.60	0.62	1.000	-0.70	10.71	-7.45

Total vertical net force $F_{w,v}$ = **-14.48** kN Total horizontal net force $F_{w,h}$ = **0.00** kN

CPI = - 0.63

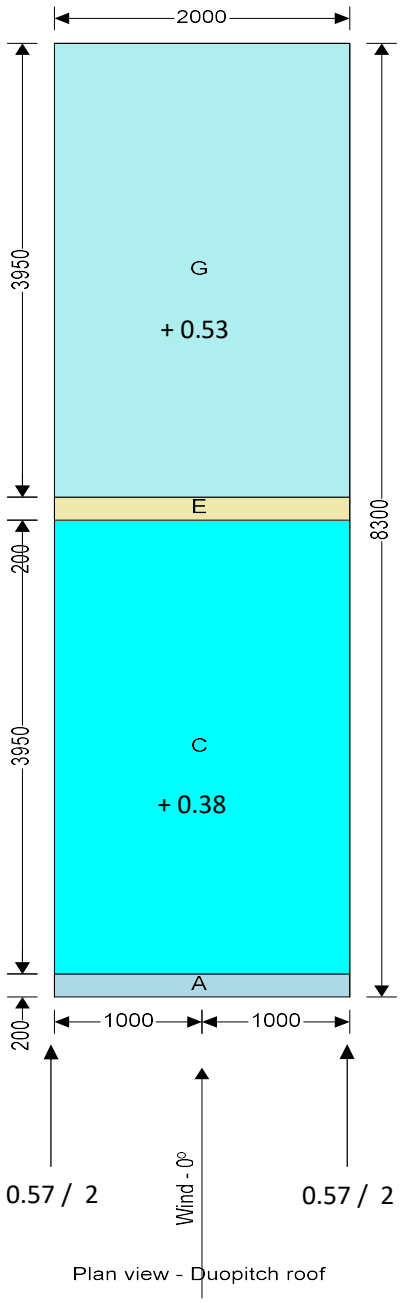
Vertical Force = + 4.65 kN



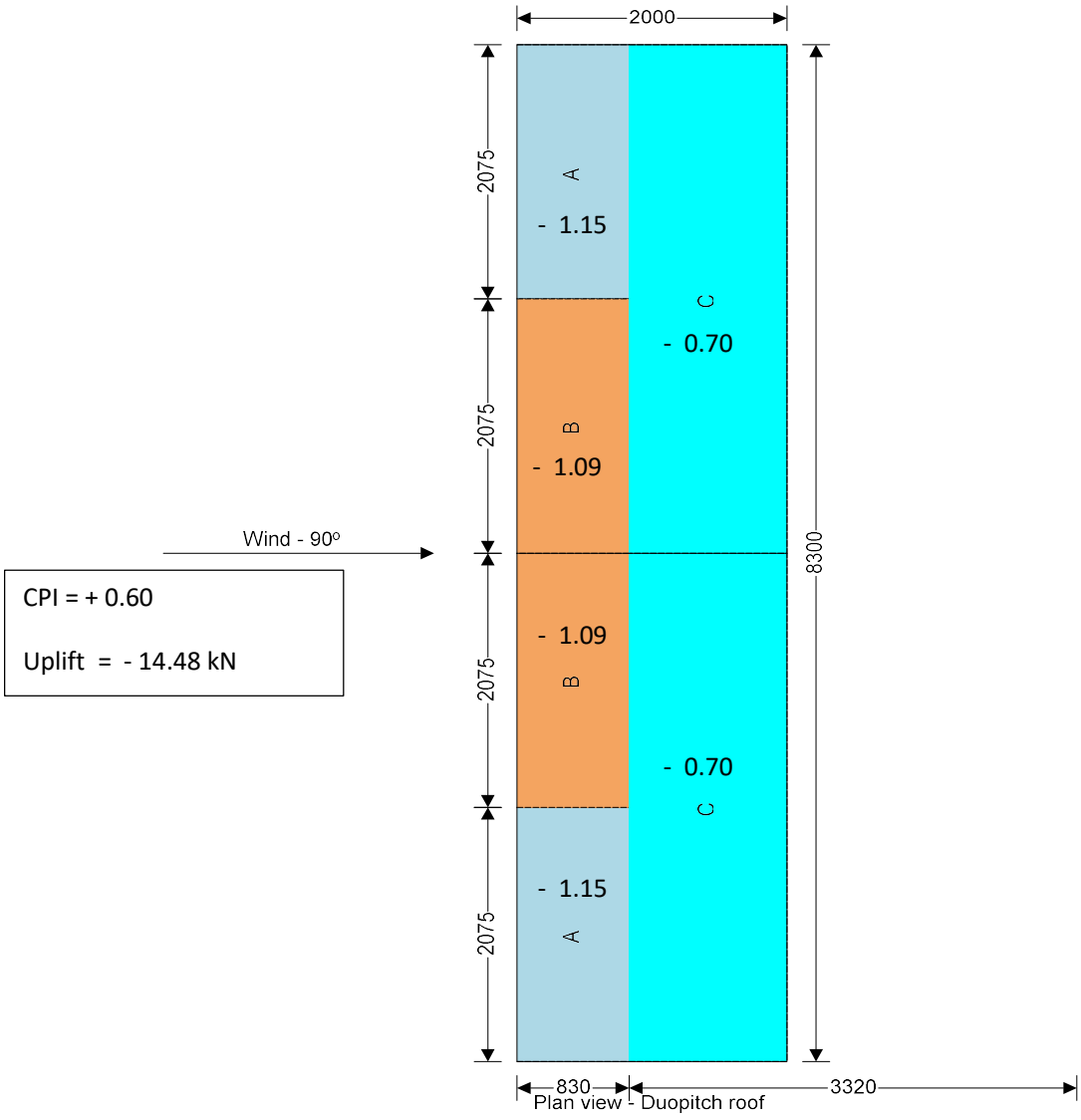
Plan view - Duopitch roof

CPI = + 0.40

Uplift = - 7.76 kN



Plan view - Duopitch roof


2000
2075
2075
2075
2075
8300
A
- 1.15
C
- 0.70
B
- 1.09
Wind - 90°
CPI = + 0.60
Uplift = - 14.48 kN
- 1.09
B
- 0.70
C
- 1.15
A
830
3320
Plan view - Duopitch roof

CONSIDER BEAM B01 **SPAN = 2.0 m (effective)**

Loads

Roof	S =	0.75	x	2.0	x	4.3	x	1.6	= 10.32 kN
	D =	0.80	x	2.0	x	4.8	x	1.4	= 10.75 kN
Ceiling	S =	0.25	x	2.0	x	4.3	x	1.6	= 3.44 kN
	D =	0.35	x	2.0	x	4.3	x	1.4	= 4.21 kN
Swt	D =	0.30	x	2.0	x	1.4			= 0.84 kN
									= 29.56 kN

$e\ell$ 1.2L + 2D = 2.70 m

V = 29.56 / 2 = 14.78 kN

M = 29.56 x 2.0 / 8 = 7.39 kNm

δim = 2000 / 360 = 5.5 mm

$$I_{req'd} = \frac{5 \times 20.30 \times 2.0^3 \times 10^3}{384 \times 2.1 \times 5.5} = 183 \text{ cm}^4$$

PROVIDE 150 x 90 x 24 kg PFC S355

Mb @ 2.70 m = 46.9 kNm > 7.39 kNm

$I_{prov'd}$ = 1160 cm^4 > 183 cm^4

CONSIDER BEAM B02 **SPAN = 8.3 m (effective)**

Loads

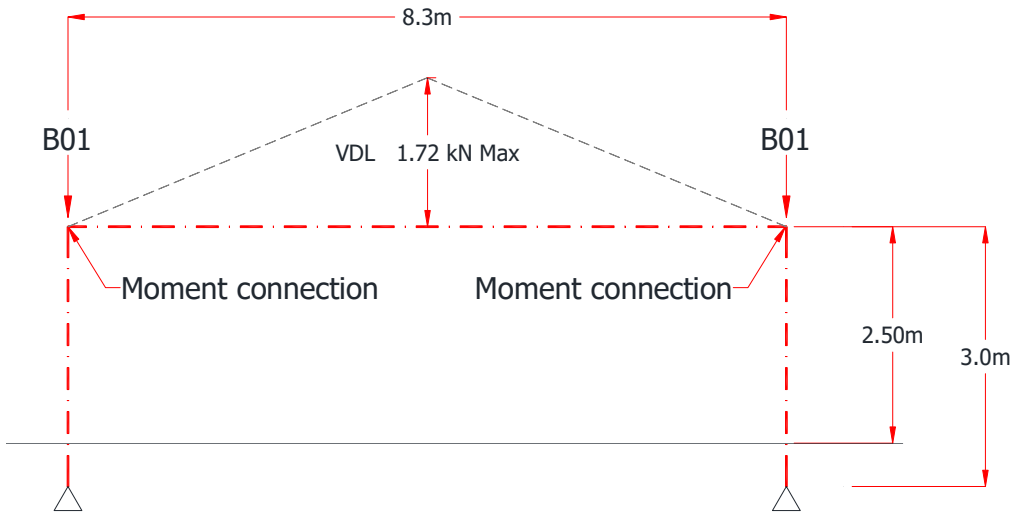
Timber Stud Frame and Cladding D = 0.75 x 2.30 = 1.72 kN Max 0 kN Min

GOAL POST FRAME

B02 AND CORNER POSTS AS GOAL POST FRAME FOR STABILITY

Load Case 1

Dead + Live



B01 Reaction S = 4.3 kN

D = 5.6 kN

Loadcase 1 - Dead + Live

STEEL 2D ANALYSIS & DESIGN (EN1993)

GOAL POST - DEAD + LIVE

In accordance with EN1993-1-1:2005 incorporating Corrigenda February 2006 and April 2009 and the UK national annex

Tedds calculation version 4.4.10

ANALYSIS

Tedds calculation version 1.0.37

Geometry

Materials

Name	Density (kg/m^3)	Youngs Modulus kN/mm^2	Shear Modulus kN/mm^2	Thermal Coefficient $°C^{-1}$
Steel (EC3)	7850	210	80.8	0.000012

Sections

Name	Area (cm^2)	Moment of inertia Major (cm^4)	Moment of inertia Minor (cm^4)	Shear area parallel to Minor (cm^2)	Shear area parallel to Major (cm^2)
Column - UC 152x152x23	29.2	1249.8	399.9	8.8	18.6
Beam - UB 254x146x31	39.7	4413.4	447.5	15.1	22.6

Nodes

Node	Co-ordinates X (m)	Co-ordinates Z (m)	Freedom X	Freedom Z	Freedom Rot.	Coordinate system Name	Coordinate system Angle (°)	Spring X (kN/m)	Spring Z (kN/m)	Spring Rot. kNm/°
1	0	0	Fixed	Fixed	Free		0	0	0	0
2	0	3	Free	Free	Free		0	0	0	0
3	8.3	0	Fixed	Fixed	Free		0	0	0	0
4	8.3	3	Free	Free	Free		0	0	0	0

Elements

Element	Length (m)	Nodes Start	Nodes End	Section	Material	Releases Start moment	Releases End moment	Rotated Axial
1	3	1	2	Column - UC 152x152x23	Steel (EC3)	Fixed	Fixed	Fixed

Element	Length (m)	Nodes Start	Nodes End	Section	Material	Releases Start moment	Releases End moment	Releases Axial	Rotated
2	3	3	4	Column - UC 152x152x23	Steel (EC3)	Fixed	Fixed	Fixed	
3	8.3	2	4	Beam - UB 254x146x31	Steel (EC3)	Fixed	Fixed	Fixed	

Members

Name	Elements Start	Elements End
Column 1	1	1
Column 2	2	2
Beam 1	3	3

Loading

Self weight included (Self weight x 1)

Load combination factors

Load combination	Self weight	Permanent	Imposed	Wind
1.35G + 1.5Q + 1.5RQ (Strength)	1.35	1.35	1.50	
1.0G + 1.0Q + 1.0RQ (Service)	1.00	1.00	1.00	
1.35G + 1.5Q + 1.5ψ_0S (Strength)	1.35	1.35	1.50	
1.0G + 1.0Q + 0.5S (Service)	1.00	1.00	1.00	
1.35G + 1.5ψ_0Q + 1.5S (Strength)	1.35	1.35	1.05	

Member Loads

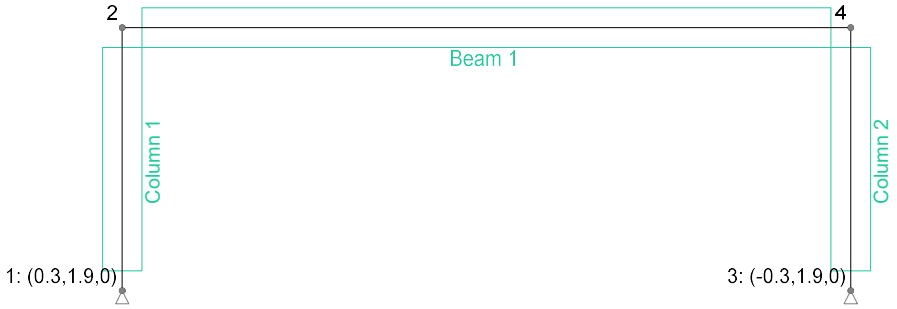
Member	Load case	Load Type	Orientation	Description
Beam 1	Permanent	VDL	GlobalZ	0 kN/m at 0 m to 1.72 kN/m at 4.15 m
Beam 1	Permanent	VDL	GlobalZ	1.72 kN/m at 4.15 m to 0 kN/m at 8.3 m
Column 1	Permanent	Point load	GlobalZ	5.6 kN at 3 m

Member	Load case	Load Type	Orientation	Description
Column 2	Permanent	Point load	GlobalZ	5.6 kN at 3 m
Column 1	Imposed	Point load	GlobalZ	4.3 kN at 3 m
Column 2	Imposed	Point load	GlobalZ	4.3 kN at 3 m

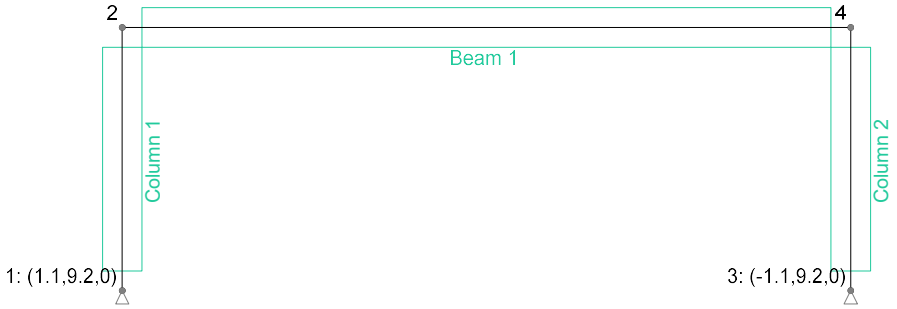
Results

Reactions

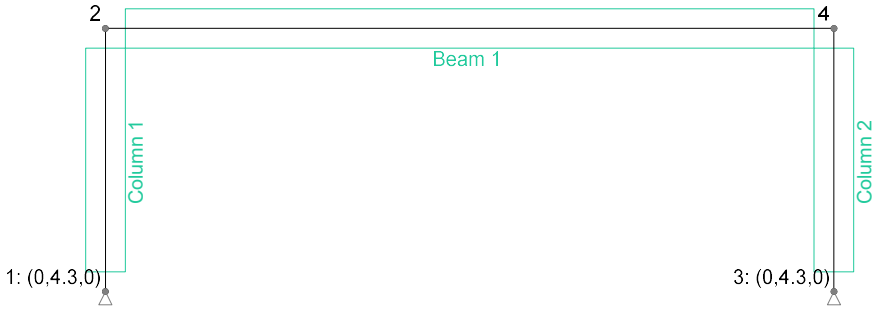
Self weight - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



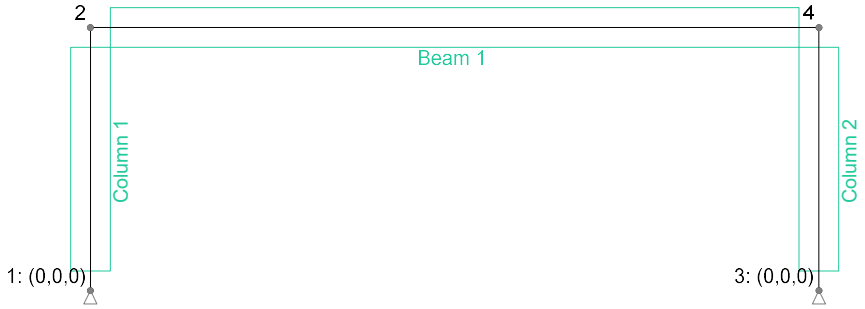
Permanent - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



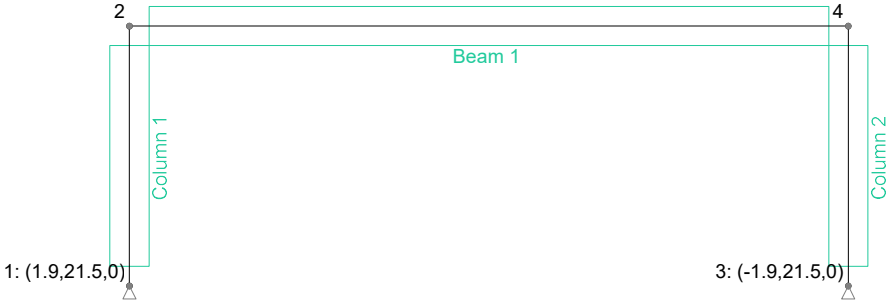
Imposed - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



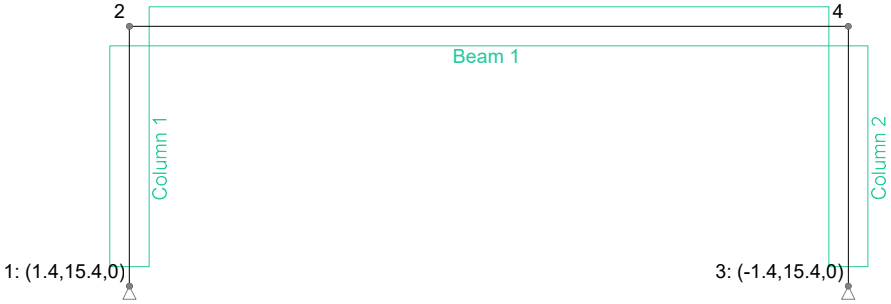
Wind - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



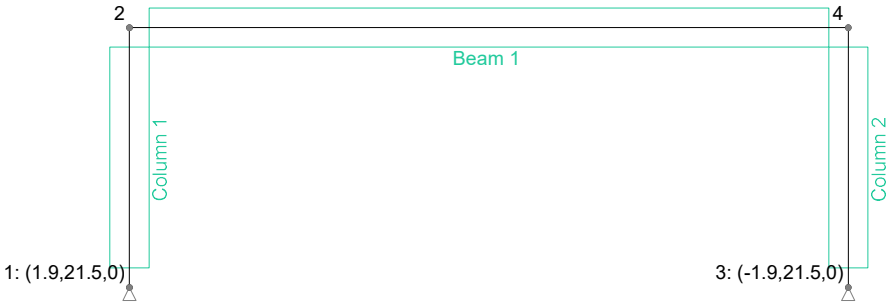
1.35G + 1.5Q + 1.5RQ (Strength) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



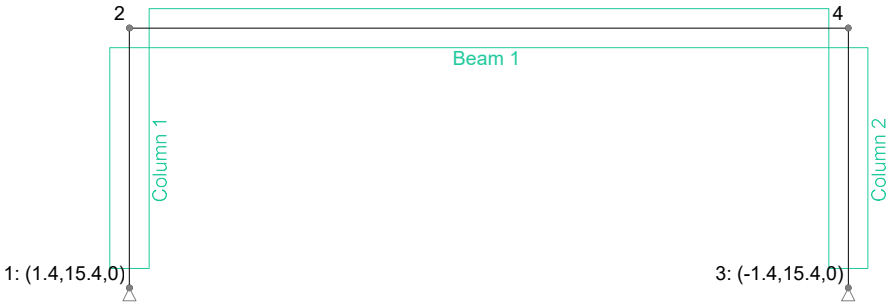
1.0G + 1.0Q + 1.0RQ (Service) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



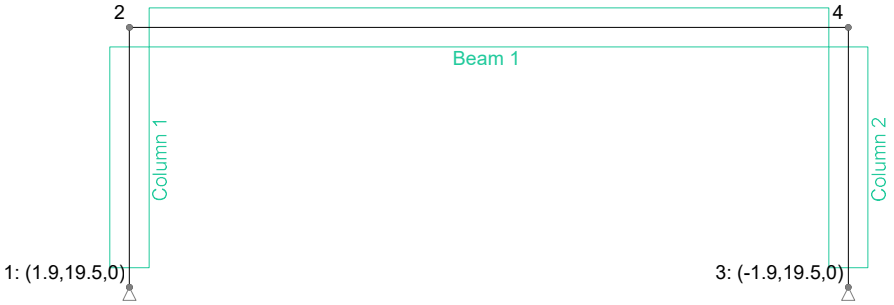
1.35G + 1.5Q + 1.5ψ_0S (Strength) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



1.0G + 1.0Q + 0.5S (Service) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



1.35G + 1.5ψ0Q + 1.5S (Strength) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



Element end forces

Load combination: 1.35G + 1.5Q + 1.5RQ (Strength)

Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-21.5	1.9	0
		2	6.5	-1.9	-5.7
2	3	3	-21.5	-1.9	0
		4	6.5	1.9	5.7
3	8.3	2	-1.9	-6.5	5.7
		4	1.9	-6.5	-5.7

Load combination: 1.0G + 1.0Q + 1.0RQ (Service)

Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-15.4	1.4	0
		2	4.8	-1.4	-4.3
2	3	3	-15.4	-1.4	0
		4	4.8	1.4	4.3
3	8.3	2	-1.4	-4.8	4.3
		4	1.4	-4.8	-4.3

Load combination: 1.35G + 1.5Q + 1.5ψ_0S (Strength)

Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-21.5	1.9	0
		2	6.5	-1.9	-5.7
2	3	3	-21.5	-1.9	0
		4	6.5	1.9	5.7
3	8.3	2	-1.9	-6.5	5.7
		4	1.9	-6.5	-5.7

Load combination: 1.0G + 1.0Q + 0.5S (Service)

Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-15.4	1.4	0
		2	4.8	-1.4	-4.3
2	3	3	-15.4	-1.4	0
		4	4.8	1.4	4.3
3	8.3	2	-1.4	-4.8	4.3

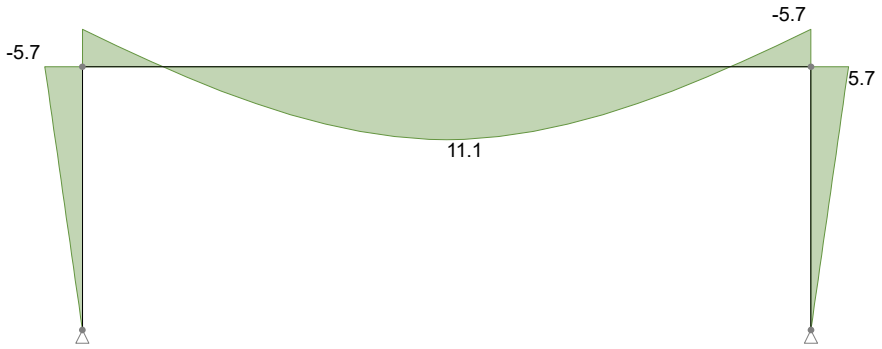
Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
		4	1.4	-4.8	-4.3

Load combination: 1.35G + 1.5ψ0Q + 1.5S (Strength)

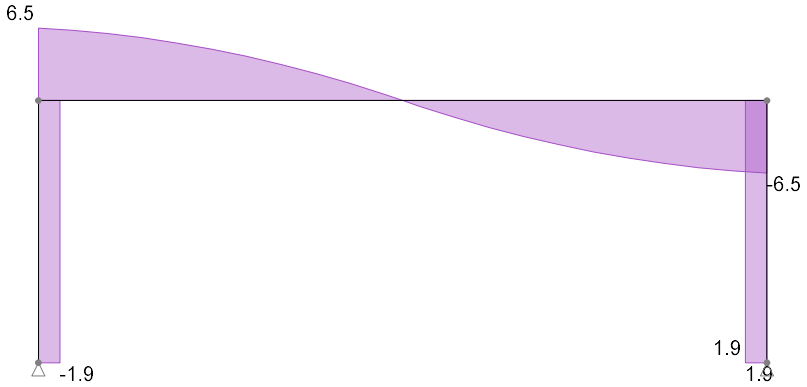
Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-19.5	1.9	0
		2	6.5	-1.9	-5.7
2	3	3	-19.5	-1.9	0
		4	6.5	1.9	5.7
3	8.3	2	-1.9	-6.5	5.7
		4	1.9	-6.5	-5.7

Forces

Strength combinations - Moment envelope (kNm)



Strength combinations - Shear envelope (kN)



Strength combinations - Axial force envelope (kN)

Member results

Envelope - Strength combinations

Member	Shear force		Moment			
	Pos (m)	Max abs (kN)	Pos (m)	Max (kNm)	Pos (m)	Min (kNm)
Column 1	0	-1.9	0	0	3	-5.7 (min)
Column 2	0	1.9	3	5.7	0	0
Beam 1	8.3	-6.5 (max abs)	4.15	11.1 (max)	8.3	-5.7 (min)

Envelope - Strength combinations

Member	Axial force			
	Pos (m)	Max (kN)	Pos (m)	Min (kN)
Column 1	0	21.5 (max)	3	0 (min)
Column 2	0	21.5 (max)	3	0 (min)
Beam 1	0	1.9	0	1.9

Envelope - Service combinations

Member	Deflection			
	Pos (m)	Max (mm)	Pos (m)	Min (mm)
Column 1	3	0	1.73	-0.9 (min)
Column 2	1.73	0.9	3	0
Beam 1	4.15	5.6 (max)	0	0.1

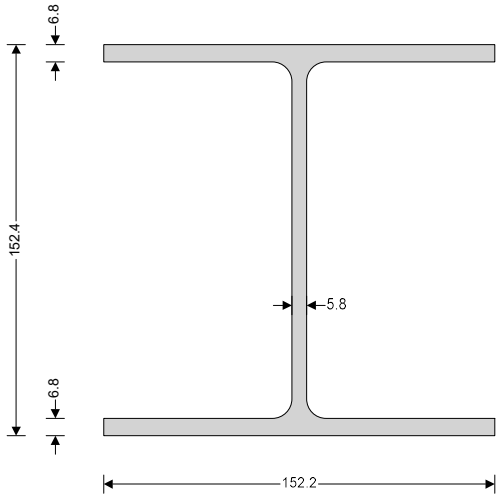
Partial factors - Section 6.1 γ_{M0} = **1** γ_{M1} = **1** γ_{M2} = **1.1**

Column 1 design

Section details UC 152x152x23 (BS4-1)

Steel grade S355 Modulus of elasticity E = **210000** N/mm²

Nominal yield strength f_y = **355** N/mm² Nominal ult.tensile strength f_u = **470** N/mm²



UC 152x152x23 (BS4-1)
Section depth, h, 152.4 mm
Section breadth, b, 152.2 mm
Mass of section, Mass, 23 kg/m
Flange thickness, t_f, 6.8 mm
Web thickness, t_w, 5.8 mm
Root radius, r, 7.6 mm
Area of section, A, 2925 mm²
Radius of gyration about y-axis, i_y, 65.372 mm
Radius of gyration about z-axis, i_z, 36.979 mm
Elastic section modulus about y-axis, $W_{el,y}$, 164016 mm³
Elastic section modulus about z-axis, $W_{el,z}$, 52552 mm³
Plastic section modulus about y-axis, $W_{pl,y}$, 181982 mm³
Plastic section modulus about z-axis, $W_{pl,z}$, 80156 mm³
Second moment of area about y-axis, I_y, 12498039 mm⁴
Second moment of area about z-axis, I_z, 3999186 mm⁴

Column 1 results summary	Unit	Capacity	Maximum	Utilisation	Result
Shear resistance (y-y)	kN	204.4	1.9	0.009	PASS
Bending resistance (y-y)	kNm	58.2	5.7	0.099	PASS
Compression resistance	kN	524.3	21.5	0.041	PASS
Comb. bending and axial force				0.147	PASS
Deflection (y-y)	mm	10	0.9	0.093	PASS

Lateral restraint

Both flanges have lateral restraint at supports only

Classification of cross sections - Section 5.5

Internal compression parts Class 1 Outstand flanges Class 3

Section is class 3

Check compression - Section 6.2.4

Design compression force N_{Ed} = **21.5** kN Design resistance of section $N_{c,Rd} = N_{pl,Rd}$ = **1038.2** kN

$N_{Ed} / N_{c,Rd}$ = **0.021**

PASS - Design compression resistance exceeds design compression

Check y-y axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **868.7** kN $N_{Ed} / N_{b,y,Rd}$ = **0.025**

PASS - Design buckling resistance exceeds design compression

Check z-z axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **524.3** kN $N_{Ed} / N_{b,z,Rd}$ = **0.041**

PASS - Design buckling resistance exceeds design compression

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **671.8** kN $N_{Ed} / N_{b,T,Rd}$ = **0.032**

PASS - Design buckling resistance exceeds design compression

Check design at end of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **1.9** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed} / V_{pl,y,Rd}$ = **0.009**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **5.7** kNm Bending resistance moment $M_{c,y,Rd}$ = **58.2** kNm

$M_{y,Ed} / M_{c,y,Rd}$ = **0.099**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **58.2** kNm $M_{y,Ed} / M_{b,y,Rd}$ = **0.099**

PASS - Design buckling resistance moment exceeds design bending moment

Check bending and axial force - Section 6.2.9

Maximum longitudinal stress $\sigma_{y,Ed} = M_{y,Ed} / W_{el,y} + N_{Ed} / A =$ **42** N/mm²

Limiting longitudinal stress - Eq.6.42 $\sigma_{y,lim} = f_y / \gamma_{M0} =$ **355** N/mm²

$\sigma_{y,Ed} / \sigma_{y,lim} =$ **0.118**

PASS - Maximum longitudinal stress is less than limiting longitudinal stress

Interaction formula - eq.6.2 $N_{Ed} / N_{c,Rd} + M_{y,Ed} / M_{c,y,Rd} =$ **0.118**

PASS - Utilisation of combined bending and axial force is acceptable

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.089, 0.147) = **0.147**

PASS - Combined bending and compression checks are satisfied

Consider Combination 4 - 1.0G + 1.0Q + 0.5S (Service)

Check design 1730 mm along span

Check y-y axis deflection - Section 7.2.1

Maximum deflection $\delta_y =$ **0.9** mm

Allowable deflection $\delta_{y,Allowable} =$ **10** mm

$\delta_y / \delta_{y,Allowable} =$ **0.093**

PASS - Allowable deflection exceeds design deflection

Column 2 design

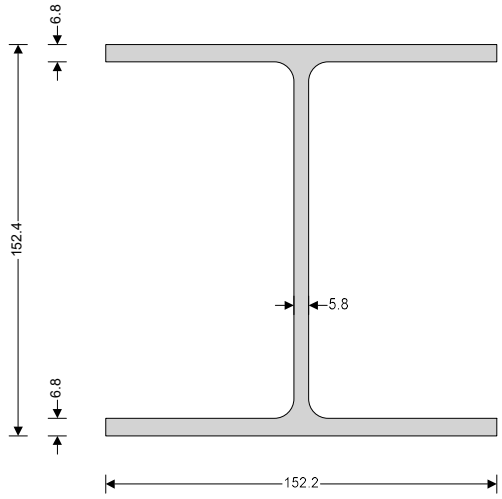
Section details UC 152x152x23 (BS4-1)

Steel grade S355

Modulus of elasticity E = **210000** N/mm²

Nominal yield strength $f_y =$ **355** N/mm²

Nominal ult.tensile strength $f_u =$ **470** N/mm²



UC 152x152x23 (BS4-1)
Section depth, h, 152.4 mm
Section breadth, b, 152.2 mm
Mass of section, Mass, 23 kg/m
Flange thickness, t_f 6.8 mm
Web thickness, t_y, 5.8 mm
Root radius, r, 7.6 mm
Area of section, A, 2925 mm²
Radius of gyration about y-axis, i_y, 65.372 mm
Radius of gyration about z-axis, i_z, 36.979 mm
Elastic section modulus about y-axis, $W_{el,y}$ 164016 mm³
Elastic section modulus about z-axis, $W_{el,z}$ 52552 mm³
Plastic section modulus about y-axis, $W_{pl,y}$ 181982 mm³
Plastic section modulus about z-axis, $W_{pl,z}$ 80156 mm³
Second moment of area about y-axis, I_y, 12498039 mm⁴
Second moment of area about z-axis, I_z, 3999186 mm⁴

Column 2 results summary	Unit	Capacity	Maximum	Utilisation	Result
Shear resistance (y-y)	kN	204.4	1.9	0.009	PASS
Bending resistance (y-y)	kNm	58.2	5.7	0.099	PASS
Compression resistance	kN	524.3	21.5	0.041	PASS

Comb. bending and axial force				0.147	PASS
Deflection (y-y)	mm	10	0.9	0.093	PASS

Lateral restraint

Both flanges have lateral restraint at supports only

Classification of cross sections - Section 5.5

Internal compression parts Class 1 Outstand flanges Class 3

Section is class 3

Check compression - Section 6.2.4

Design compression force N_{Ed} = **21.5** kN Design resistance of section $N_{c,Rd} = N_{pl,Rd}$ = **1038.2** kN

$N_{Ed} / N_{c,Rd}$ = **0.021**

PASS - Design compression resistance exceeds design compression

Check y-y axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **868.7** kN $N_{Ed} / N_{b,y,Rd}$ = **0.025**

PASS - Design buckling resistance exceeds design compression

Check z-z axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **524.3** kN $N_{Ed} / N_{b,z,Rd}$ = **0.041**

PASS - Design buckling resistance exceeds design compression

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **671.8** kN $N_{Ed} / N_{b,T,Rd}$ = **0.032**

PASS - Design buckling resistance exceeds design compression

Check design at end of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **1.9** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed} / V_{pl,y,Rd}$ = **0.009**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **5.7** kNm Bending resistance moment $M_{c,y,Rd}$ = **58.2** kNm

$M_{y,Ed} / M_{c,y,Rd}$ = **0.099**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **58.2** kNm $M_{y,Ed} / M_{b,y,Rd}$ = **0.099**

PASS - Design buckling resistance moment exceeds design bending moment

Check bending and axial force - Section 6.2.9

Maximum longitudinal stress $\sigma_{y,Ed} = M_{y,Ed} / W_{el,y} + N_{Ed} / A$ = **42** N/mm^2

Limiting longitudinal stress - Eq.6.42 $\sigma_{y,lim} = f_y / \gamma_{M0}$ = **355** N/mm^2

$\sigma_{y,Ed} / \sigma_{y,lim}$ = **0.118**

PASS - Maximum longitudinal stress is less than limiting longitudinal stress

Interaction formula - eq.6.2 $N_{Ed} / N_{c,Rd} + M_{y,Ed} / M_{c,y,Rd}$ = **0.118**

PASS - Utilisation of combined bending and axial force is acceptable

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.089, 0.147) = **0.147**

PASS - Combined bending and compression checks are satisfied

Consider Combination 4 - 1.0G + 1.0Q + 0.5S (Service)

Check design 1730 mm along span

Check y-y axis deflection - Section 7.2.1

Maximum deflection δ_y = **0.9** mm

Allowable deflection $\delta_{y,Allowable}$ = **10** mm

δ_y / $\delta_{y,Allowable}$ = **0.093**

PASS - Allowable deflection exceeds design deflection

Beam 1 design

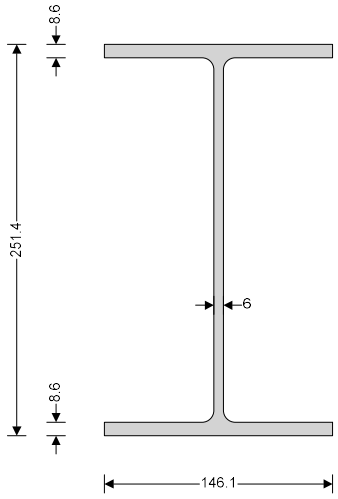
Section details UB 254x146x31 (BS4-1)

Steel grade S355

Modulus of elasticity E = **210000** N/mm^2

Nominal yield strength f_y = **355** N/mm^2

Nominal ult.tensile strength f_u = **470** N/mm^2



UB 254x146x31 (BS4-1)
Section depth, h, 251.4 mm
Section breadth, b, 146.1 mm
Mass of section, Mass, 31.1 kg/m
Flange thickness, t_f, 8.6 mm
Web thickness, t_w, 6 mm
Root radius, r, 7.6 mm
Area of section, A, 3968 mm^2
Radius of gyration about y-axis, i_y, 105.467 mm
Radius of gyration about z-axis, i_z, 33.585 mm
Elastic section modulus about y-axis, $W_{el,y}$, 351107 mm^3
Elastic section modulus about z-axis, $W_{el,z}$, 61264 mm^3
Plastic section modulus about y-axis, $W_{pl,y}$, 393065 mm^3
Plastic section modulus about z-axis, $W_{pl,z}$, 94125 mm^3
Second moment of area about y-axis, I_y, 44134110 mm^4
Second moment of area about z-axis, I_z, 4475311 mm^4

Beam 1 results summary	Unit	Capacity	Maximum	Utilisation	Result
Shear resistance (y-y)	kN	335.5	6.5	0.019	PASS
Bending resistance (y-y)	kNm	42.2	11.1	0.264	PASS
Compression resistance	kN	121.5	1.9	0.016	PASS
Comb. bending and axial force				0.279	PASS
Deflection (y-y)	mm	23.1	5.6	0.243	PASS

Lateral restraint

Both flanges have lateral restraint at supports only

Classification of cross sections - Section 5.5

Internal compression parts Class 1

Outstand flanges Class 1

Section is class 1

Check compression - Section 6.2.4

Design compression force N_{Ed} = **1.9** kN

Design resistance of section $N_{c,Rd} = N_{pl,Rd}$ = **1038.2** kN

$N_{Ed} / N_{c,Rd}$ = **0.002**

PASS - Design compression resistance exceeds design compression

Check y-y axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **908** kN

$N_{Ed} / N_{b,y,Rd}$ = **0.002**

PASS - Design buckling resistance exceeds design compression

Check z-z axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **121.5** kN

$N_{Ed} / N_{b,z,Rd}$ = **0.016**

PASS - Design buckling resistance exceeds design compression

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **541.7** kN

$N_{Ed} / N_{b,T,Rd}$ = **0.004**

PASS - Design buckling resistance exceeds design compression

Check design 4150 mm along span

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **11.1** kNm

Bending resistance moment $M_{c,y,Rd}$ = **139.5** kNm

$M_{y,Ed} / M_{c,y,Rd}$ = **0.08**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **42.2** kNm

$M_{y,Ed} / M_{b,y,Rd}$ = **0.264**

PASS - Design buckling resistance moment exceeds design bending moment

Check bending and axial force - Section 6.2.9

Bending and axial force check $N_{y,lim}$ = **142.9** kN

$N_{Ed} / N_{y,lim}$ = **0.013**

Allowance need not be made for the effect of the axial force on the plastic resistance moment about the y-y axis

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.247, 0.279) = **0.279**

PASS - Combined bending and compression checks are satisfied

Check design at end of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **6.5** kN

Design shear resistance $V_{c,y,Rd} = V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed} / V_{c,y,Rd}$ = **0.032**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **5.7** kNm

Bending resistance moment $M_{c,y,Rd}$ = **139.5** kNm

$M_{y,Ed} / M_{c,y,Rd}$ = **0.041**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **42.2** kNm

$M_{y,Ed} / M_{b,y,Rd}$ = **0.136**

PASS - Design buckling resistance moment exceeds design bending moment

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.128, 0.152) = **0.152**

PASS - Combined bending and compression checks are satisfied

Consider Combination 4 - 1.0G + 1.0Q + 0.5S (Service)

Check design 4150 mm along span

Check y-y axis deflection - Section 7.2.1

Maximum deflection δ_y = **5.6** mm

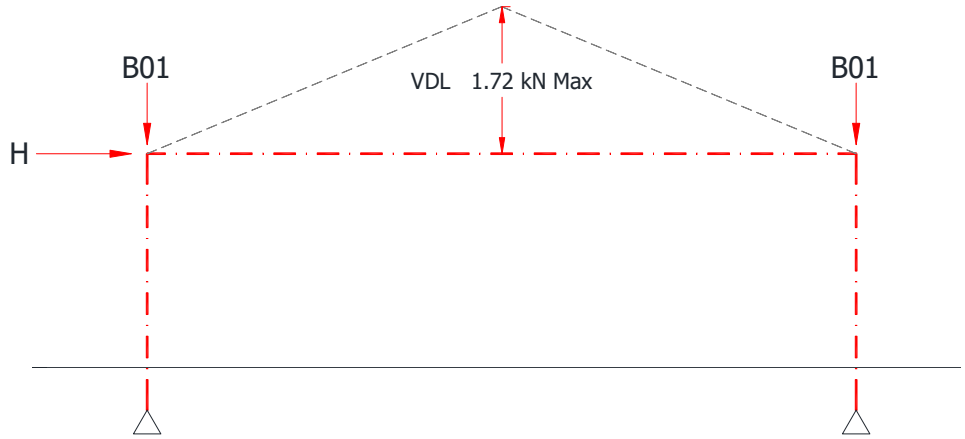
Allowable deflection $\delta_{y,Allowable}$ = **23.1** mm

δ_y / $\delta_{y,Allowable}$ = **0.243**

PASS - Allowable deflection exceeds design deflection

Load Case 2

Dead + Live + Side Wind



B01 Reaction S = 4.3 kN

D = 5.6 kN

W = 4.65 / 4 = 1.16 kN

H = 1.06 kN

Loadcase 2 - Dead + Live + Side Wind

STEEL 2D ANALYSIS & DESIGN (EN1993)

GOAL POST - DEAD + LIVE + SIDE WIND

In accordance with EN1993-1-1:2005 incorporating Corrigenda February 2006 and April 2009 and the UK national annex

Tedds calculation version 4.4.10

ANALYSIS

Tedds calculation version 1.0.37

Loading

Self weight included (Self weight x 1)

Load combination factors

Load combination	Self weight	Permanent	Imposed	Wind
1.35G + 1.5Q + 1.5ψ_0S + 1.5ψ_0W (Strength)	1.35	1.35	1.50	0.75
1.0G + 1.0Q + 0.5S + 0.5W (Service)	1.00	1.00	1.00	0.50

Load combination	Self weight	Permanent	Imposed	Wind
1.35G + 1.5ψ_0Q + 1.5S + 1.5ψ_0W (Strength)	1.35	1.35	1.05	0.75
1.0G + 1.0ψ_0Q + 1.0S + 0.5W (Service)	1.00	1.00	0.70	0.50
1.35G + 1.5ψ_0Q + 1.5ψ_0S + 1.5W (Strength)	1.35	1.35	1.05	1.50
1.0G + 1.0ψ_0Q + 0.5S + 1.0W (Service)	1.00	1.00	0.70	1.00

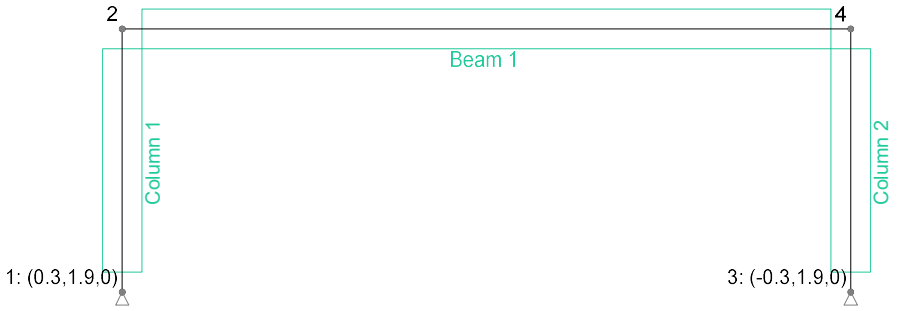
Member Loads

Member	Load case	Load Type	Orientation	Description
Beam 1	Permanent	VDL	GlobalZ	0 kN/m at 0 m to 1.72 kN/m at 4.15 m
Beam 1	Permanent	VDL	GlobalZ	1.72 kN/m at 4.15 m to 0 kN/m at 8.3 m
Column 1	Permanent	Point load	GlobalZ	5.6 kN at 3 m
Column 2	Permanent	Point load	GlobalZ	5.6 kN at 3 m
Column 1	Imposed	Point load	GlobalZ	4.3 kN at 3 m
Column 2	Imposed	Point load	GlobalZ	4.3 kN at 3 m
Column 1	Wind	Point load	GlobalZ	1.16 kN at 3 m
Column 1	Wind	Point load	GlobalX	1.06 kN at 3 m
Column 2	Wind	Point load	GlobalZ	1.16 kN at 3 m

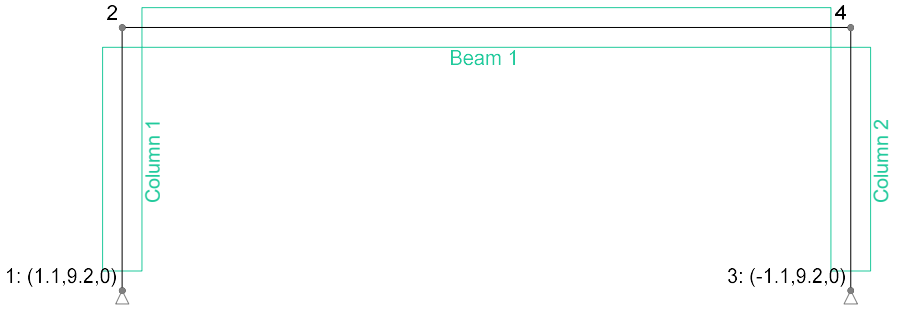
Results

Reactions

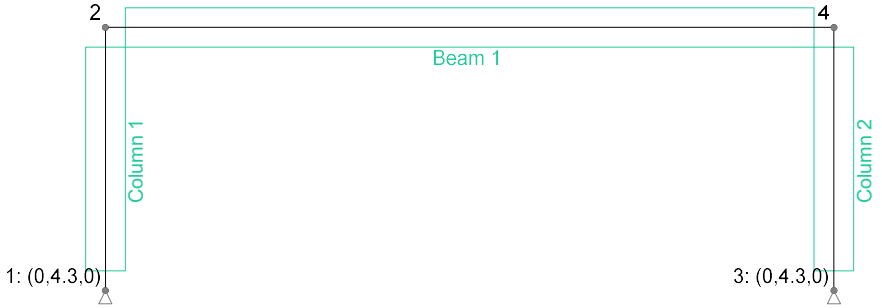
Self weight - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



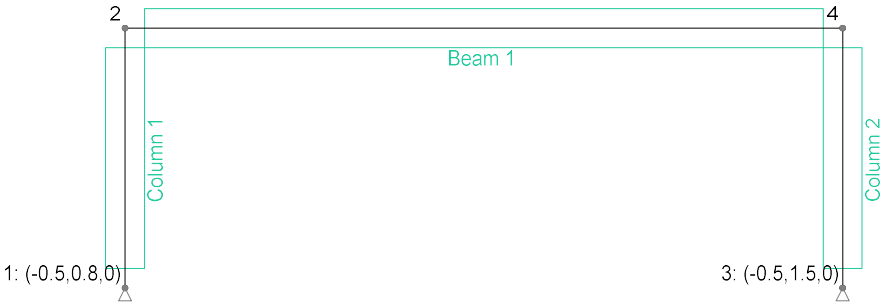
Permanent - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



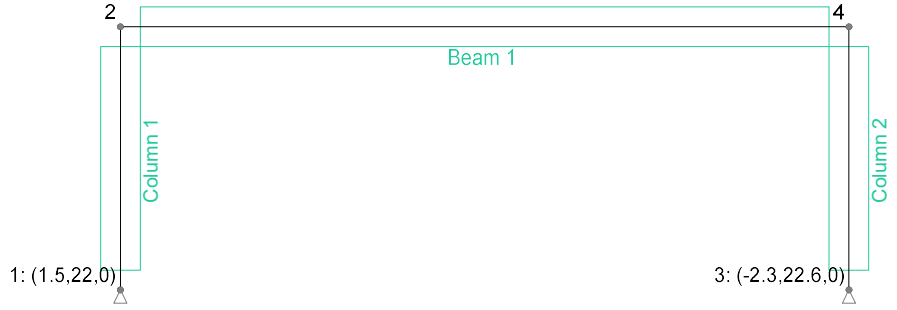
Imposed - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



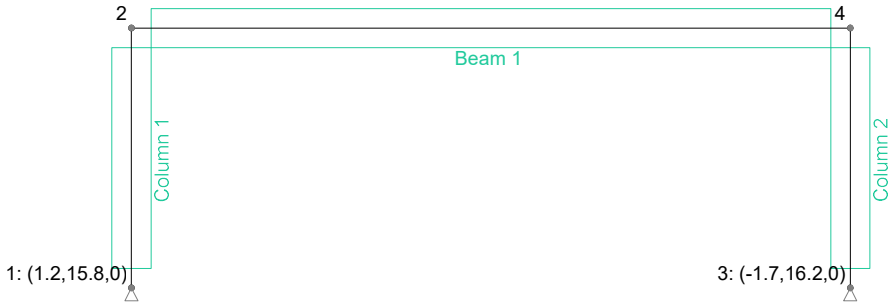
Wind - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



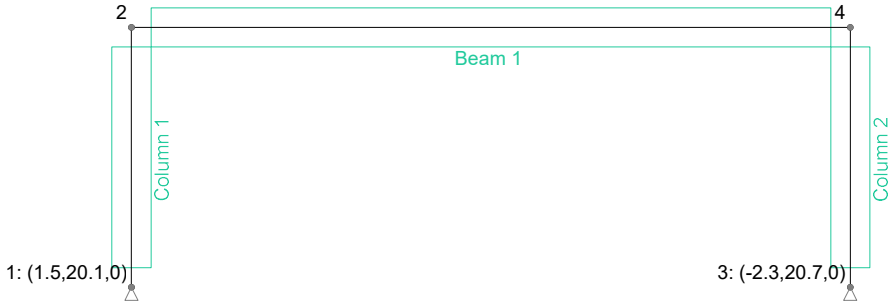
1.35G + 1.5Q + 1.5ψ₀S + 1.5ψ₀W (Strength) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



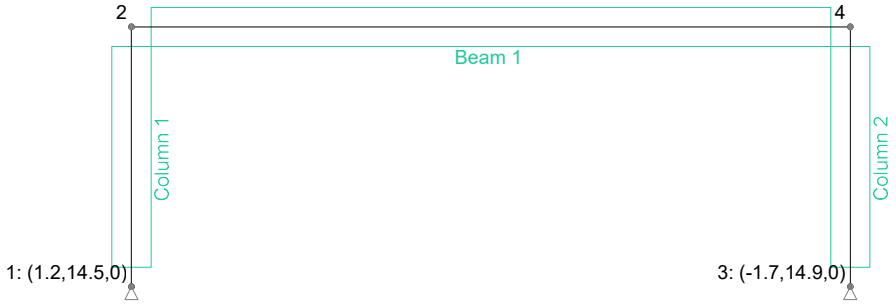
1.0G + 1.0Q + 0.5S + 0.5W (Service) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



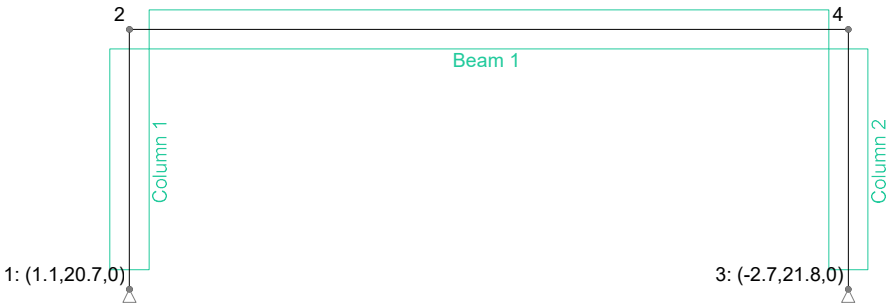
1.35G + 1.5ψ0Q + 1.5S + 1.5ψ0W (Strength) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



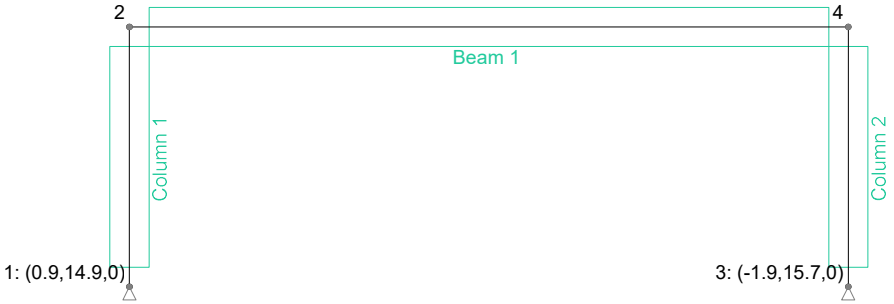
1.0G + 1.0ψ0Q + 1.0S + 0.5W (Service) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



1.35G + 1.5ψ0Q + 1.5ψ0S + 1.5W (Strength) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



1.0G + 1.0ψ0Q + 0.5S + 1.0W (Service) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



Element end forces

Load combination: 1.35G + 1.5Q + 1.5ψ0S + 1.5ψ0W (Strength)

Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-22	1.5	0
		2	6.2	-2.3	-4.6
2	3	3	-22.6	-2.3	0
		4	6.8	2.3	6.9
3	8.3	2	-2.3	-6.2	4.6
		4	2.3	-6.8	-6.9

Load combination: 1.0G + 1.0Q + 0.5S + 0.5W (Service)

Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-15.8	1.2	0
		2	4.6	-1.7	-3.5
2	3	3	-16.2	-1.7	0
		4	5	1.7	5
3	8.3	2	-1.7	-4.6	3.5
		4	1.7	-5	-5

Load combination: 1.35G + 1.5ψ_0Q + 1.5S + 1.5ψ_0W (Strength)

Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-20.1	1.5	0
		2	6.2	-2.3	-4.6
2	3	3	-20.7	-2.3	0
		4	6.8	2.3	6.9
3	8.3	2	-2.3	-6.2	4.6
		4	2.3	-6.8	-6.9

Load combination: 1.0G + 1.0ψ_0Q + 1.0S + 0.5W (Service)

Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-14.5	1.2	0
		2	4.6	-1.7	-3.5
2	3	3	-14.9	-1.7	0
		4	5	1.7	5
3	8.3	2	-1.7	-4.6	3.5

Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
		4	1.7	-5	-5

Load combination: 1.35G + 1.5ψ₀Q + 1.5ψ₀S + 1.5W (Strength)

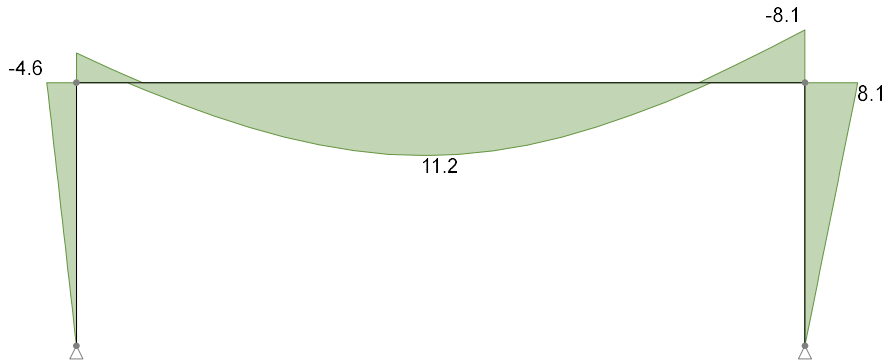
Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-20.7	1.1	0
		2	6	-2.7	-3.4
2	3	3	-21.8	-2.7	0
		4	7.1	2.7	8.1
3	8.3	2	-2.7	-6	3.4
		4	2.7	-7.1	-8.1

Load combination: 1.0G + 1.0ψ₀Q + 0.5S + 1.0W (Service)

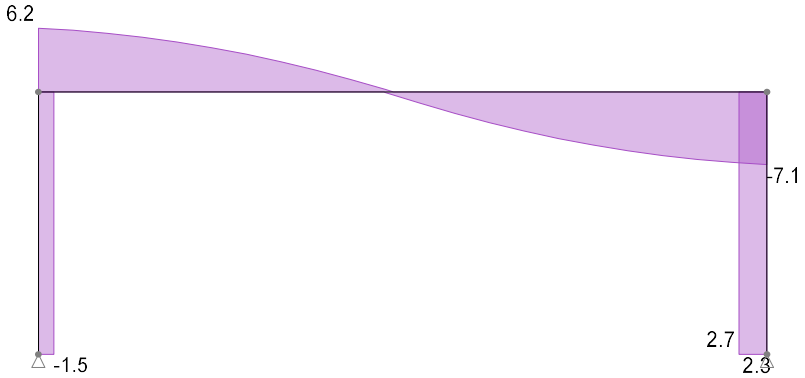
Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-14.9	0.9	0
		2	4.5	-1.9	-2.7
2	3	3	-15.7	-1.9	0
		4	5.2	1.9	5.8
3	8.3	2	-1.9	-4.5	2.7
		4	1.9	-5.2	-5.8

Forces

Strength combinations - Moment envelope (kNm)



Strength combinations - Shear envelope (kN)



Strength combinations - Axial force envelope (kN)

Member results

Envelope - Service combinations

Member	Deflection			
	Pos (m)	Max (mm)	Pos (m)	Min (mm)
Column 1	3	2.6	1.021	-0.2 (min)
Column 2	2.301	3	0	0
Beam 1	4.02	5.6 (max)	0	0.1

Partial factors - Section 6.1 γ_{M0} = **1** γ_{M1} = **1** γ_{M2} = **1.1**

Column 1 design

Section details UC 152x152x23 (BS4-1)

Steel grade S355 Modulus of elasticity E = **210000** N/mm^2

Nominal yield strength f_y = **355** N/mm^2 Nominal ult.tensile strength f_u = **470** N/mm^2

Column 1 results summary	Unit	Capacity	Maximum	Utilisation	Result
Shear resistance (y-y)	kN	204.4	1.5	0.007	PASS
Bending resistance (y-y)	kNm	58.2	4.6	0.078	PASS
Compression resistance	kN	524.3	22.0	0.042	PASS
Comb. bending and axial force				0.126	PASS
Deflection (y-y)	mm	10	2.6	0.257	PASS

Lateral restraint

Both flanges have lateral restraint at supports only

Consider Combination 1 - 1.35G + 1.5Q + 1.5ψ_0S + 1.5ψ_0W (Strength)

Classification of cross sections - Section 5.5

Internal compression parts Class 1 Outstand flanges Class 3

Section is class 3

Check compression - Section 6.2.4

Design compression force N_{Ed} = **22** kN Design resistance of section $N_{c,Rd} = N_{pl,Rd}$ = **1038.2** kN

$N_{Ed} / N_{c,Rd}$ = **0.021**

PASS - Design compression resistance exceeds design compression

Check y-y axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **868.7** kN $N_{Ed} / N_{b,y,Rd}$ = **0.025**

PASS - Design buckling resistance exceeds design compression

Check z-z axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **524.3** kN N_{Ed} / $N_{b,z,Rd}$ = **0.042**

PASS - Design buckling resistance exceeds design compression

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **671.8** kN N_{Ed} / $N_{b,T,Rd}$ = **0.033**

PASS - Design buckling resistance exceeds design compression

Check design at start of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **1.5** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed}$ / $V_{pl,y,Rd}$ = **0.007**

PASS - Design shear resistance exceeds design shear force

Check design at end of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **1.5** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed}$ / $V_{pl,y,Rd}$ = **0.007**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **4.6** kNm Bending resistance moment $M_{c,y,Rd}$ = **58.2** kNm

$M_{y,Ed}$ / $M_{c,y,Rd}$ = **0.078**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **58.2** kNm $M_{y,Ed}$ / $M_{b,y,Rd}$ = **0.078**

PASS - Design buckling resistance moment exceeds design bending moment

Check bending and axial force - Section 6.2.9

Maximum longitudinal stress $\sigma_{y,Ed} = M_{y,Ed} / W_{el,y} + N_{Ed} / A$ = **35** N/mm^2

Limiting longitudinal stress - Eq.6.42 $\sigma_{y,lim} = f_y / \gamma_{M0}$ = **355** N/mm^2

$\sigma_{y,Ed}$ / $\sigma_{y,lim}$ = **0.099**

PASS - Maximum longitudinal stress is less than limiting longitudinal stress

Interaction formula - eq.6.2 $N_{Ed} / N_{c,Rd} + M_{y,Ed} / M_{c,y,Rd}$ = **0.099**

PASS - Utilisation of combined bending and axial force is acceptable

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.076, 0.126) = **0.126**

PASS - Combined bending and compression checks are satisfied

Consider Combination 6 - 1.0G + 1.0ψ_0Q + 0.5S + 1.0W (Service)

Check design at end of span

Check y-y axis deflection - Section 7.2.1

Maximum deflection δ_y = **2.6** mm Allowable deflection $\delta_{y,Allowable}$ = **10** mm

δ_y / $\delta_{y,Allowable}$ = **0.257**

PASS - Allowable deflection exceeds design deflection

Column 2 design

Section details UC 152x152x23 (BS4-1)

Steel grade S355 Modulus of elasticity E = **210000** N/mm^2

Nominal yield strength f_y = **355** N/mm^2 Nominal ult.tensile strength f_u = **470** N/mm^2

Column 2 results summary	Unit	Capacity	Maximum	Utilisation	Result
Shear resistance (y-y)	kN	204.4	2.7	0.013	PASS
Bending resistance (y-y)	kNm	58.2	8.1	0.140	PASS
Compression resistance	kN	524.3	22.6	0.043	PASS
Comb. bending and axial force				0.193	PASS
Deflection (y-y)	mm	10	3.0	0.301	PASS

Lateral restraint

Both flanges have lateral restraint at supports only

Consider Combination 5 - 1.35G + 1.5ψ_0Q + 1.5ψ_0S + 1.5W (Strength)

Classification of cross sections - Section 5.5

Internal compression parts Class 1 Outstand flanges Class 3

Section is class 3

Check compression - Section 6.2.4

Design compression force N_{Ed} = **21.8** kN Design resistance of section $N_{c,Rd} = N_{pl,Rd}$ = **1038.2** kN

$N_{Ed} / N_{c,Rd}$ = **0.021**

PASS - Design compression resistance exceeds design compression

Check y-y axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **868.7** kN $N_{Ed} / N_{b,y,Rd}$ = **0.025**

PASS - Design buckling resistance exceeds design compression

Check z-z axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **524.3** kN $N_{Ed} / N_{b,z,Rd}$ = **0.042**

PASS - Design buckling resistance exceeds design compression

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **671.8** kN $N_{Ed} / N_{b,T,Rd}$ = **0.032**

PASS - Design buckling resistance exceeds design compression

Check design at start of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **2.7** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed} / V_{pl,y,Rd}$ = **0.013**

PASS - Design shear resistance exceeds design shear force

Check design at end of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **2.7** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed} / V_{pl,y,Rd}$ = **0.013**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **8.1** kNm Bending resistance moment $M_{c,y,Rd}$ = **58.2** kNm

$M_{y,Ed}$ / $M_{c,y,Rd}$ = **0.14**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **58.2** kNm $M_{y,Ed}$ / $M_{b,y,Rd}$ = **0.14**

PASS - Design buckling resistance moment exceeds design bending moment

Check bending and axial force - Section 6.2.9

Maximum longitudinal stress $\sigma_{y,Ed} = M_{y,Ed} / W_{el,y} + N_{Ed} / A$ = **57** N/mm^2

Limiting longitudinal stress - Eq.6.42 $\sigma_{y,lim} = f_y / \gamma_{M0}$ = **355** N/mm^2

$\sigma_{y,Ed} / \sigma_{y,lim}$ = **0.16**

PASS - Maximum longitudinal stress is less than limiting longitudinal stress

Interaction formula - eq.6.2 $N_{Ed} / N_{c,Rd} + M_{y,Ed} / M_{c,y,Rd}$ = **0.16**

PASS - Utilisation of combined bending and axial force is acceptable

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.117, 0.193) = **0.193**

PASS - Combined bending and compression checks are satisfied

Consider Combination 6 - 1.0G + 1.0ψ_0Q + 0.5S + 1.0W (Service)

Check design 2301 mm along span

Check y-y axis deflection - Section 7.2.1

Maximum deflection δ_y = **3** mm Allowable deflection $\delta_{y,Allowable}$ = **10** mm

$\delta_y / \delta_{y,Allowable}$ = **0.301**

PASS - Allowable deflection exceeds design deflection

Beam 1 design

Section details UB 254x146x31 (BS4-1)

Steel grade S355 Modulus of elasticity E = **210000** N/mm^2

Nominal yield strength f_y = **355** N/mm^2 Nominal ult.tensile strength f_u = **470** N/mm^2

Beam 1 results summary	Unit	Capacity	Maximum	Utilisation	Result
Shear resistance (y-y)	kN	335.5	7.1	0.021	PASS
Bending resistance (y-y)	kNm	41.8	11.2	0.268	PASS
Compression resistance	kN	121.5	2.7	0.022	PASS
Comb. bending and axial force				0.289	PASS
Deflection (y-y)	mm	23.1	5.6	0.243	PASS

Lateral restraint

Both flanges have lateral restraint at supports only

Consider Combination 5 - 1.35G + 1.5ψ_0Q + 1.5ψ_0S + 1.5W (Strength)

Classification of cross sections - Section 5.5

Internal compression parts Class 1 Outstand flanges Class 1

Section is class 1

Check compression - Section 6.2.4

Design compression force N_{Ed} = **2.7** kN

Design resistance of section $N_{c,Rd} = N_{pl,Rd}$ = **1038.2** kN

$N_{Ed} / N_{c,Rd}$ = **0.003**

PASS - Design compression resistance exceeds design compression

Check y-y axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **908** kN

$N_{Ed} / N_{b,y,Rd}$ = **0.003**

PASS - Design buckling resistance exceeds design compression

Check z-z axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **121.5** kN

$N_{Ed} / N_{b,z,Rd}$ = **0.022**

PASS - Design buckling resistance exceeds design compression

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **541.7** kN

$N_{Ed} / N_{b,T,Rd}$ = **0.005**

PASS - Design buckling resistance exceeds design compression

Check design 3935 mm along span

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **11.2** kNm

Bending resistance moment $M_{c,y,Rd}$ = **139.5** kNm

$M_{y,Ed} / M_{c,y,Rd}$ = **0.08**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **41.8** kNm

$M_{y,Ed} / M_{b,y,Rd}$ = **0.268**

PASS - Design buckling resistance moment exceeds design bending moment

Check bending and axial force - Section 6.2.9

Bending and axial force check $N_{y,lim}$ = **142.9** kN

$N_{Ed} / N_{y,lim}$ = **0.019**

Allowance need not be made for the effect of the axial force on the plastic resistance moment about the y-y axis

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.248, 0.289) = **0.289**

PASS - Combined bending and compression checks are satisfied

Check design at end of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **7.1** kN

Design shear resistance $V_{c,y,Rd} = V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed} / V_{c,y,Rd}$ = **0.035**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **8.1** kNm

Bending resistance moment $M_{c,y,Rd}$ = **139.5** kNm

$M_{y,Ed} / M_{c,y,Rd}$ = **0.058**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **41.8** kNm

$M_{y,Ed} / M_{b,y,Rd}$ = **0.195**

PASS - Design buckling resistance moment exceeds design bending moment

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.181, 0.216) = **0.216**

PASS - Combined bending and compression checks are satisfied

Consider Combination 6 - 1.0G + 1.0ψ_0Q + 0.5S + 1.0W (Service)

Check design 4020 mm along span

Check y-y axis deflection - Section 7.2.1

Maximum deflection δ_y = **5.6** mm

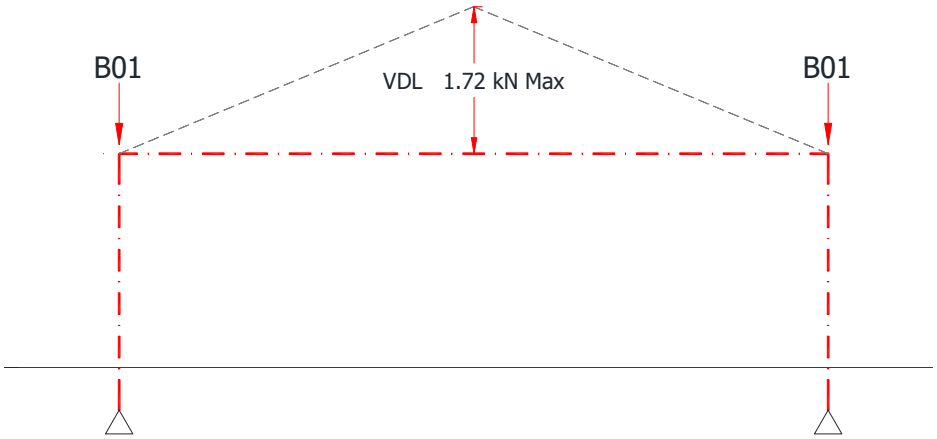
Allowable deflection $\delta_{y,Allowable}$ = **23.1** mm

δ_y / $\delta_{y,Allowable}$ = **0.243**

PASS - Allowable deflection exceeds design deflection

Load Case 3

Dead + Gable Wind (uplift)



B01 Reaction D = 5.6 kN

W = - 14.48 / 4 = - 3.62 kN

Loadcase 3 – Dead + Gable Wind

STEEL 2D ANALYSIS & DESIGN (EN1993)

GOAL POST - DEAD + GABLE WIND (UPLIFT)

In accordance with EN1993-1-1:2005 incorporating Corrigenda February 2006 and April 2009 and the UK national annex

Tedds calculation version 4.4.10

ANALYSIS

Tedds calculation version 1.0.37

Loading

Self weight included (Self weight x 1)

Load combination factors

Load combination	Self weight	Permanent	Imposed	Wind
1.0G + 1.5W (Strength)	1.00	1.00		1.50
1.0G + 1.0W (Service)	1.00	1.00		1.00

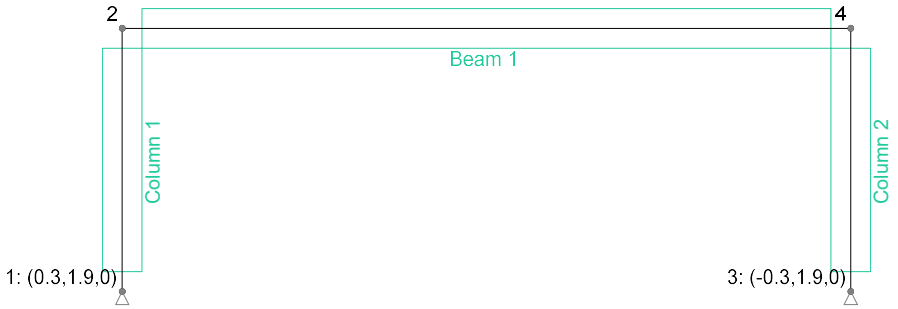
Member Loads

Member	Load case	Load Type	Orientation	Description
Beam 1	Permanent	VDL	GlobalZ	0 kN/m at 0 m to 1.72 kN/m at 4.15 m
Beam 1	Permanent	VDL	GlobalZ	1.72 kN/m at 4.15 m to 0 kN/m at 8.3 m
Column 1	Permanent	Point load	GlobalZ	5.6 kN at 3 m
Column 2	Permanent	Point load	GlobalZ	5.6 kN at 3 m
Column 1	Wind	Point load	GlobalZ	-3.62 kN at 3 m
Column 2	Wind	Point load	GlobalZ	-3.62 kN at 3 m

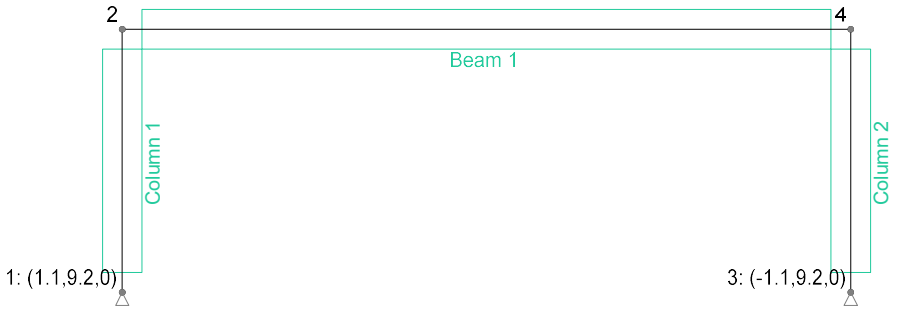
Results

Reactions

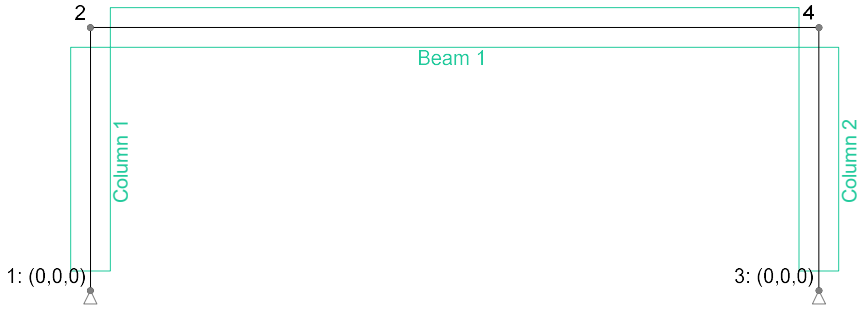
Self weight - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



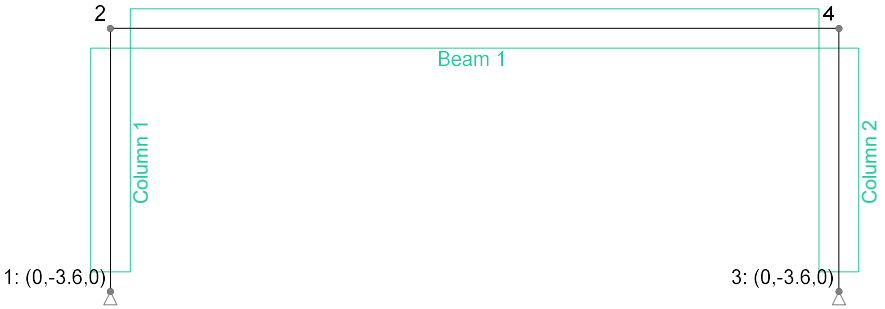
Permanent - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



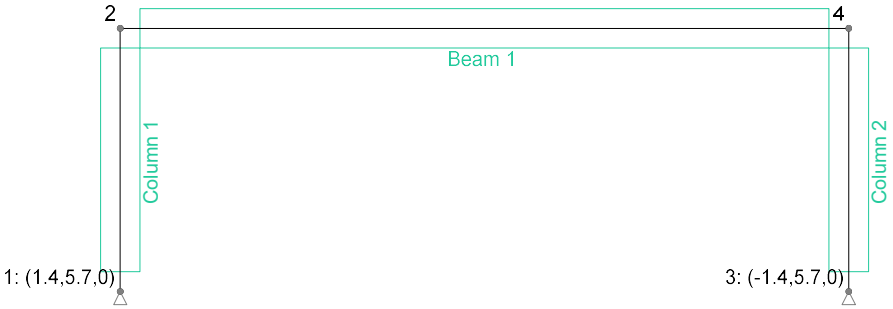
Imposed - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



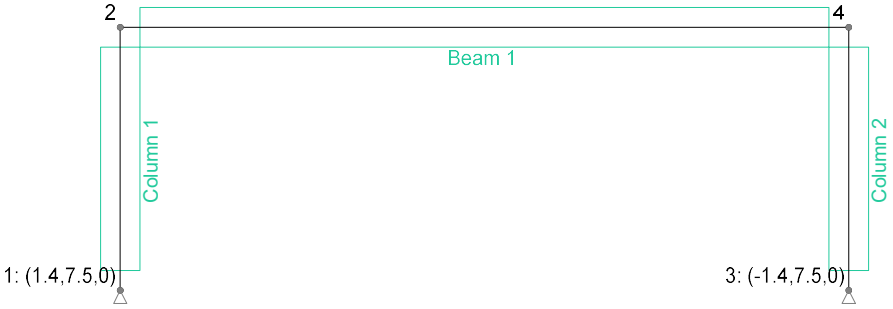
Wind - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



1.0G + 1.5W (Strength) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



1.0G + 1.0W (Service) - Local node reactions - Node: (Horiz (kN), Vert (kN), Mom (kNm))



Element end forces

Load combination: 1.0G + 1.5W (Strength)

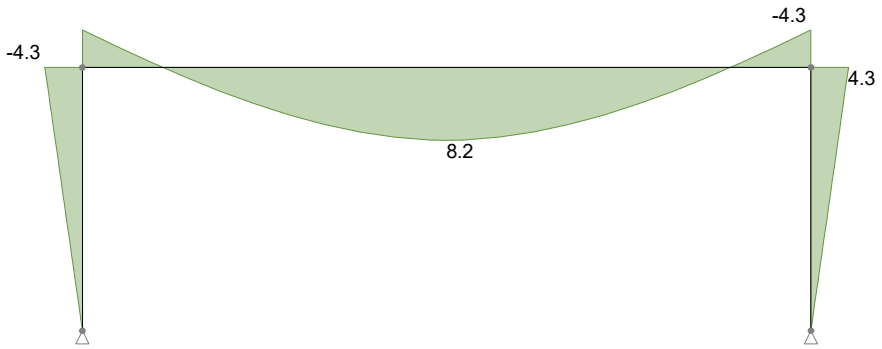
Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-5.7	1.4	0
		2	4.8	-1.4	-4.3
2	3	3	-5.7	-1.4	0
		4	4.8	1.4	4.3
3	8.3	2	-1.4	-4.8	4.3
		4	1.4	-4.8	-4.3

Load combination: 1.0G + 1.0W (Service)

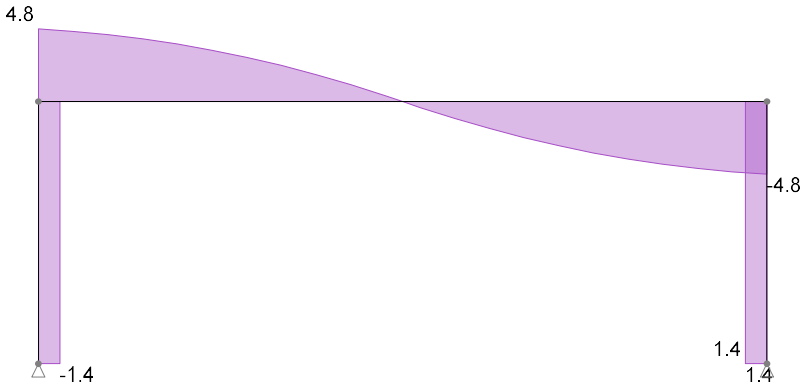
Element	Length (m)	Nodes Start/End	Axial force (kN)	Shear force (kN)	Moment (kNm)
1	3	1	-7.5	1.4	0
		2	4.8	-1.4	-4.3
2	3	3	-7.5	-1.4	0
		4	4.8	1.4	4.3
3	8.3	2	-1.4	-4.8	4.3
		4	1.4	-4.8	-4.3

Forces

Strength combinations - Moment envelope (kNm)



Strength combinations - Shear envelope (kN)



Strength combinations - Axial force envelope (kN)

Member results

Envelope - Service combinations

Member	Deflection			
	Pos (m)	Max (mm)	Pos (m)	Min (mm)
Column 1	3	0	1.73	-0.9 (min)
Column 2	1.73	0.9	3	0
Beam 1	4.15	5.6 (max)	0	0

Partial factors - Section 6.1 γ_{M0} = **1** γ_{M1} = **1** γ_{M2} = **1.1**

Column 1 design

Section details UC 152x152x23 (BS4-1)

Steel grade S355 Modulus of elasticity E = **210000** N/mm^2

Nominal yield strength f_y = **355** N/mm^2 Nominal ult.tensile strength f_u = **470** N/mm^2

Column 1 results summary	Unit	Capacity	Maximum	Utilisation	Result
Shear resistance (y-y)	kN	204.4	1.4	0.007	PASS
Bending resistance (y-y)	kNm	58.2	4.3	0.073	PASS
Compression resistance	kN	524.3	5.7	0.011	PASS
Comb. bending and axial force				0.090	PASS
Deflection (y-y)	mm	10	0.9	0.093	PASS

Lateral restraint

Both flanges have lateral restraint at supports only

Classification of cross sections - Section 5.5

Internal compression parts Class 1 Outstand flanges Class 3

Section is class 3

Check compression - Section 6.2.4

Design compression force N_{Ed} = **5.7** kN Design resistance of section $N_{c,Rd} = N_{pl,Rd}$ = **1038.2** kN

$N_{Ed} / N_{c,Rd}$ = **0.005**

PASS - Design compression resistance exceeds design compression

Check y-y axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **868.7** kN $N_{Ed} / N_{b,y,Rd}$ = **0.007**

PASS - Design buckling resistance exceeds design compression

Check z-z axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **524.3** kN N_{Ed} / $N_{b,z,Rd}$ = **0.011**

PASS - Design buckling resistance exceeds design compression

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **671.8** kN N_{Ed} / $N_{b,T,Rd}$ = **0.008**

PASS - Design buckling resistance exceeds design compression

Check design at start of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **1.4** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed}$ / $V_{pl,y,Rd}$ = **0.007**

PASS - Design shear resistance exceeds design shear force

Check design at end of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **1.4** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed}$ / $V_{pl,y,Rd}$ = **0.007**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **4.3** kNm Bending resistance moment $M_{c,y,Rd}$ = **58.2** kNm

$M_{y,Ed}$ / $M_{c,y,Rd}$ = **0.073**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **58.2** kNm $M_{y,Ed}$ / $M_{b,y,Rd}$ = **0.073**

PASS - Design buckling resistance moment exceeds design bending moment

Check bending and axial force - Section 6.2.9

Maximum longitudinal stress $\sigma_{y,Ed} = M_{y,Ed} / W_{el,y} + N_{Ed} / A$ = **28** N/mm^2

Limiting longitudinal stress - Eq.6.42 $\sigma_{y,lim} = f_y / \gamma_{M0}$ = **355** N/mm^2

$\sigma_{y,Ed}$ / $\sigma_{y,lim}$ = **0.078**

PASS - Maximum longitudinal stress is less than limiting longitudinal stress

Interaction formula - eq.6.2 $N_{Ed} / N_{c,Rd} + M_{y,Ed} / M_{c,y,Rd}$ = **0.078**

PASS - Utilisation of combined bending and axial force is acceptable

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.054, 0.09) = **0.090**

PASS - Combined bending and compression checks are satisfied

Consider Combination 2 - 1.0G + 1.0W (Service)

Check design 1730 mm along span

Check y-y axis deflection - Section 7.2.1

Maximum deflection δ_y = **0.9** mm Allowable deflection $\delta_{y,Allowable}$ = **10** mm

δ_y / $\delta_{y,Allowable}$ = **0.093**

PASS - Allowable deflection exceeds design deflection

Column 2 design

Section details UC 152x152x23 (BS4-1)

Steel grade S355 Modulus of elasticity E = **210000** N/mm^2

Nominal yield strength f_y = **355** N/mm^2 Nominal ult.tensile strength f_u = **470** N/mm^2

Column 2 results summary	Unit	Capacity	Maximum	Utilisation	Result
Shear resistance (y-y)	kN	204.4	1.4	0.007	PASS
Bending resistance (y-y)	kNm	58.2	4.3	0.073	PASS
Compression resistance	kN	524.3	5.7	0.011	PASS
Comb. bending and axial force				0.090	PASS
Deflection (y-y)	mm	10	0.9	0.093	PASS

Lateral restraint

Both flanges have lateral restraint at supports only

Classification of cross sections - Section 5.5

Internal compression parts Class 1 Outstand flanges Class 3

Section is class 3

Check compression - Section 6.2.4

Design compression force N_{Ed} = **5.7** kN Design resistance of section $N_{c,Rd} = N_{pl,Rd}$ = **1038.2** kN

$N_{Ed} / N_{c,Rd}$ = **0.005**

PASS - Design compression resistance exceeds design compression

Check y-y axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **868.7** kN $N_{Ed} / N_{b,y,Rd}$ = **0.007**

PASS - Design buckling resistance exceeds design compression

Check z-z axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **524.3** kN $N_{Ed} / N_{b,z,Rd}$ = **0.011**

PASS - Design buckling resistance exceeds design compression

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **671.8** kN $N_{Ed} / N_{b,T,Rd}$ = **0.008**

PASS - Design buckling resistance exceeds design compression

Check design at start of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **1.4** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed} / V_{pl,y,Rd}$ = **0.007**

PASS - Design shear resistance exceeds design shear force

Check design at end of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **1.4** kN Design shear resistance $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed} / V_{pl,y,Rd}$ = **0.007**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **4.3** kNm Bending resistance moment $M_{c,y,Rd}$ = **58.2** kNm

$M_{y,Ed} / M_{c,y,Rd}$ = **0.073**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **58.2** kNm $M_{y,Ed} / M_{b,y,Rd}$ = **0.073**

PASS - Design buckling resistance moment exceeds design bending moment

Check bending and axial force - Section 6.2.9

Maximum longitudinal stress $\sigma_{y,Ed} = M_{y,Ed} / W_{el,y} + N_{Ed} / A$ = **28** N/mm^2

Limiting longitudinal stress - Eq.6.42 $\sigma_{y,lim} = f_y / \gamma_{M0}$ = **355** N/mm^2

$\sigma_{y,Ed} / \sigma_{y,lim}$ = **0.078**

PASS - Maximum longitudinal stress is less than limiting longitudinal stress

Interaction formula - eq.6.2 $N_{Ed} / N_{c,Rd} + M_{y,Ed} / M_{c,y,Rd}$ = **0.078**

PASS - Utilisation of combined bending and axial force is acceptable

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.054, 0.09) = **0.090**

PASS - Combined bending and compression checks are satisfied

Consider Combination 2 - 1.0G + 1.0W (Service)

Check design 1730 mm along span

Check y-y axis deflection - Section 7.2.1

Maximum deflection δ_y = **0.9** mm Allowable deflection $\delta_{y,Allowable}$ = **10** mm

$\delta_y / \delta_{y,Allowable}$ = **0.093**

PASS - Allowable deflection exceeds design deflection

Beam 1 design

Section details UB 254x146x31 (BS4-1)

Steel grade S355 Modulus of elasticity E = **210000** N/mm^2

Nominal yield strength f_y = **355** N/mm^2 Nominal ult.tensile strength f_u = **470** N/mm^2

Beam 1 results summary	Unit	Capacity	Maximum	Utilisation	Result
Shear resistance (y-y)	kN	335.5	4.8	0.014	PASS
Bending resistance (y-y)	kNm	42.2	8.2	0.196	PASS
Compression resistance	kN	121.5	1.4	0.012	PASS
Comb. bending and axial force				0.207	PASS
Deflection (y-y)	mm	23.1	5.6	0.241	PASS

Lateral restraint

Both flanges have lateral restraint at supports only

Classification of cross sections - Section 5.5

Internal compression parts Class 1 Outstand flanges Class 1

Section is class 1

Check compression - Section 6.2.4

Design compression force N_{Ed} = **1.4** kN Design resistance of section $N_{c,Rd} = N_{pl,Rd}$ = **1038.2** kN

N_{Ed} / $N_{c,Rd}$ = **0.001**

PASS - Design compression resistance exceeds design compression

Check y-y axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,y,Rd}$ = **908** kN N_{Ed} / $N_{b,y,Rd}$ = **0.002**

PASS - Design buckling resistance exceeds design compression

Check z-z axis flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,z,Rd}$ = **121.5** kN N_{Ed} / $N_{b,z,Rd}$ = **0.012**

PASS - Design buckling resistance exceeds design compression

Check torsional and torsional-flexural buckling resistance - Section 6.3.1.1

Design buckling resistance $N_{b,T,Rd}$ = **541.7** kN N_{Ed} / $N_{b,T,Rd}$ = **0.003**

PASS - Design buckling resistance exceeds design compression

Check design at start of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **4.8** kN Design shear resistance $V_{c,y,Rd}$ = $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed}$ / $V_{c,y,Rd}$ = **0.024**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **4.3** kNm Bending resistance moment $M_{c,y,Rd}$ = **139.5** kNm

$M_{y,Ed}$ / $M_{c,y,Rd}$ = **0.03**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **42.2** kNm $M_{y,Ed}$ / $M_{b,y,Rd}$ = **0.101**

PASS - Design buckling resistance moment exceeds design bending moment

Check bending and axial force - Section 6.2.9

Bending and axial force check $N_{y,lim}$ = **142.9** kN N_{Ed} / $N_{y,lim}$ = **0.01**

Allowance need not be made for the effect of the axial force on the plastic resistance moment about the y-y axis

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.095, 0.112) = **0.112**

PASS - Combined bending and compression checks are satisfied

Check design 4150 mm along span

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **8.2** kNm Bending resistance moment $M_{c,y,Rd}$ = **139.5** kNm

$M_{y,Ed}$ / $M_{c,y,Rd}$ = **0.059**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **42.2** kNm $M_{y,Ed}$ / $M_{b,y,Rd}$ = **0.196**

PASS - Design buckling resistance moment exceeds design bending moment

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.183, 0.207) = **0.207**

PASS - Combined bending and compression checks are satisfied

Check design at end of span

Check shear - Section 6.2.6

Design shear force $V_{y,Ed}$ = **4.8** kN Design shear resistance $V_{c,y,Rd}$ = $V_{pl,y,Rd}$ = **204.4** kN

$V_{y,Ed}$ / $V_{c,y,Rd}$ = **0.024**

PASS - Design shear resistance exceeds design shear force

Check bending moment - Section 6.2.5

Design bending moment $M_{y,Ed}$ = **4.3** kNm

Bending resistance moment $M_{c,y,Rd}$ = **139.5** kNm

$M_{y,Ed}$ / $M_{c,y,Rd}$ = **0.03**

PASS - Design bending resistance moment exceeds design bending moment

Check buckling resistance - Section 6.3.2.1

Buckling resistance moment $M_{b,y,Rd}$ = **42.2** kNm

$M_{y,Ed}$ / $M_{b,y,Rd}$ = **0.101**

PASS - Design buckling resistance moment exceeds design bending moment

Interaction factors k_{ij} for members susceptible to torsional deformations - Table B.2

Interaction formulae max(0.095, 0.112) = **0.112**

PASS - Combined bending and compression checks are satisfied

Consider Combination 2 - 1.0G + 1.0W (Service)

Check design 4150 mm along span

Check y-y axis deflection - Section 7.2.1

Maximum deflection δ_y = **5.6** mm

Allowable deflection $\delta_{y,Allowable}$ = **23.1** mm

δ_y / $\delta_{y,Allowable}$ = **0.241**

PASS - Allowable deflection exceeds design deflection

USE 152 X 152 X 23KG UC S355 POSTS AND 254 X 146 X 31KGUB S355 FOR B02

CONNECTION OF B02 TO POST

Connection Forces (ultimate)

1. Dead + Live

M = - 5.7 kNm

S = 6.5 kN ↓

A = 1.9 kN Compression

2. Dead + Live + Side Wind * Governs

M = - 8.1 kNm

S = 7.1 kN ↓

A = 2.7 kN Compression

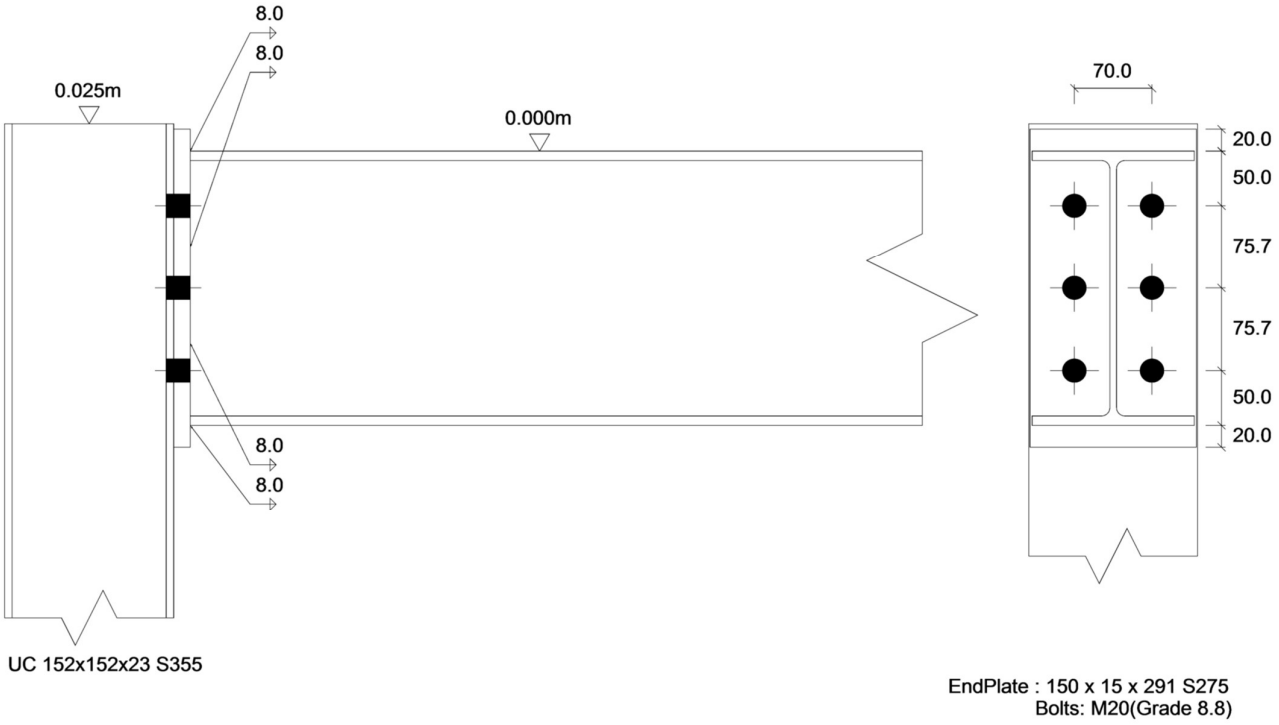
3. Dead + Gable Wind

M = - 4.3 kNm

S = 4.8 kN ↓

A = 1.4 kN Compression

Beam-Column Moment Connection 1



Design Code: BS 5950-1 : 2000

Design Summary

Item	Combination	Face	Utilisation	Status
Moment	1	A	0.333	Pass
Shear	1	A	0.024	Pass
Beam				Not Checked
Stiffener	1	A	0.093	Pass
Weld	1	A	0.750	Pass

Basic Details

Face A

No.	Combination Name	Moment [kNm]	Shear Force [kN]	Axial Load [kN]	Moment (Sharp End) [kNm]
1	Dead + Live + Side Wind	-8.1	7.1	2.7	0.0

Face A

Item	Value	Units	Remarks
S.O.P. Level	0.0	m	
Beam angle, θ_b	0.0	°	
Overall joint depth	251.4	mm	
Section geometry			

Design Combination: Dead + Live + Side Wind

Moment Capacity

Face A, critical

Item	Value	Units	Remarks
Tension bolt resistance, ΣP_r + N	148.5	kN	
Column web resistance, P_c	133.5	kN	
Beam flange bearing, P_c	624.5	kN	
Compression force, F_c	133.5	kN	
Moment capacity, M_c	23.3	kNm	
Modified moment, M_m	-7.8	kNm	

Item	Value	Units	Remarks
Utilisation ratio	0.333		
Pass			

Shear Capacity

Face A, critical

Item	Value	Units	Remarks
Bearing strength, p_b	460.0	N/mm^2	
Shear capacity, V_c	296.6	kN	
Shear force, V	7.1	kN	
Utilisation ratio	0.024		
Pass			

Beam Web Capacity

Face A, critical

Item	Utilisation	Status
Beam web	-	Not applicable
Not applicable		

Stiffener Checks

Face A, critical

Item	Utilisation	Status
Beam flange (top)		Not Checked
Beam flange (bottom)	0.093	Pass

Weld Checks

Face A, critical

Item	Utilisation	Status
Tension flange weld (beam btm. flange)	0.324	Pass
Compression flange weld (beam top flange)	0.750	Pass
Tension web weld	0.692	Pass
Shear web weld	0.040	Pass

Library: MomentConnections.dll, version: 18.1.0.0

FOUNDATION LOADS

Load Combination

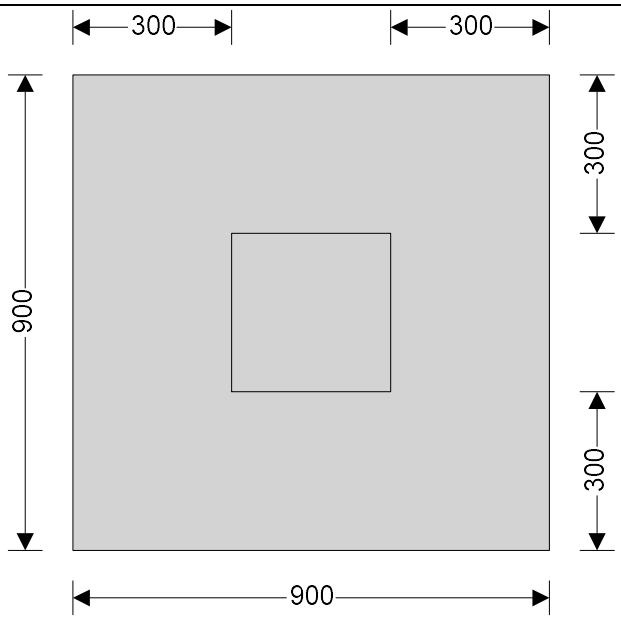
a. Dead + Live	V =	15.4 kN ↓	V =	15.4 kN ↓	
	H =	1.4 kN ←	H =	- 1.4 kN →	
	M =	0 kNm	M =	0 kNm	
b. Dead + Live + Side Wind	V =	14.6 kN ↓	V =	16.9 kN ↓	
* Governs	H =	0.9 kN ←	H =	- 1.9 kN →	
	M =	0 kNm	M =	0 kNm	
c. Dead + Gable Wind	V =	7.5 kN ↓	V =	7.5 kN ↓	
	H =	1.4 kN ←	H =	- 1.4 kN →	
	M =	0 kNm	M =	0 kNm	

FOUNDATION TO 152 X 23KG UC POSTS

PAD FOOTING ANALYSIS & DESIGN (BS8110)

PAD FOOTING ANALYSIS AND DESIGN (BS8110-1:1997)

Tedds calculation version 2.0.07



Pad footing details

Length of pad footing	L = **900** mm	Width of pad footing	B = **900** mm
Depth of pad footing	h = **600** mm	Depth of soil over pad footing	h_{soil} = **250** mm
Density of concrete	ρ_{conc} = **23.6** kN/m^3		

Column details

Column base length	l_A = **300** mm	Column base width	b_A = **300** mm
Column eccentricity in x	e_{PxA} = **0** mm	Column eccentricity in y	e_{PyA} = **0** mm

Soil details

Depth of soil over pad footing	h_{soil} = **250** mm	Density of soil	ρ_{soil} = **20.0** kN/m^3
Allowable bearing pressure	$P_{bearing}$ = **125** kN/m^2		

Axial loading on column

Dead axial load	P_{GA} = **17.0** kN	Imposed axial load	P_{QA} = **0.0** kN
Wind axial load	P_{WA} = **0.0** kN	Total axial load	P_A = **17.0** kN

Foundation loads

Dead surcharge load	F_{Gsur} = **0.000** kN/m^2	Imposed surcharge load	F_{Qsur} = **0.000** kN/m^2
Pad footing self weight	F_{swt} = **14.160** kN/m^2		
Soil self weight	F_{soil} = **5.000** kN/m^2	Total foundation load	F = **15.5** kN

Horizontal loading on pad footing

Dead load in x direction	H_{GxA} = **2.0** kN	Dead load in y direction	H_{GyA} = **0.0** kN
Imposed load in x direction	H_{QxA} = **0.0** kN	Imposed load in y direction	H_{QyA} = **0.0** kN
Wind load in x direction	H_{WxA} = **0.0** kN	Wind load in y direction	H_{WyA} = **0.0** kN
Total load in x direction	H_{xA} = **2.0** kN	Total load in y direction	H_{yA} = **0.0** kN

Check stability against sliding

Passive pressure coefficient K_p = **2.464**

Stability against sliding in x direction

Total sliding resistance in x dir H_{xres} = **26.0** kN

PASS - Resistance to sliding is greater than horizontal load in x direction

Check stability against overturning in x direction

Total overturning moment M_{xOT} = **1.200** kNm Total restoring moment M_{xres} = **14.634** kNm

PASS - Restoring moment is greater than overturning moment in x direction

Calculate pad base reaction

Total base reaction T = **32.5** kN

Base reaction eccentricity in x e_{Tx} = **37** mm Base reaction eccentricity in y e_{Ty} = **0** mm

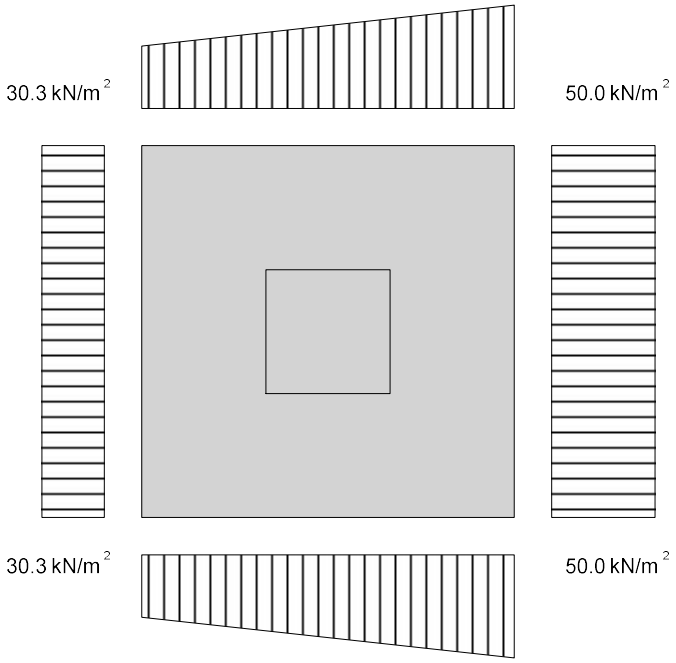
Base reaction acts within middle third of base

Calculate pad base pressures

q_1 = **30.271** kN/m^2 q_2 = **30.271** kN/m^2 q_3 = **50.024** kN/m^2 q_4 = **50.024** kN/m^2

Minimum base pressure q_{min} = **30.271** kN/m^2 Maximum base pressure q_{max} = **50.024** kN/m^2

PASS - Maximum base pressure is less than allowable bearing pressure

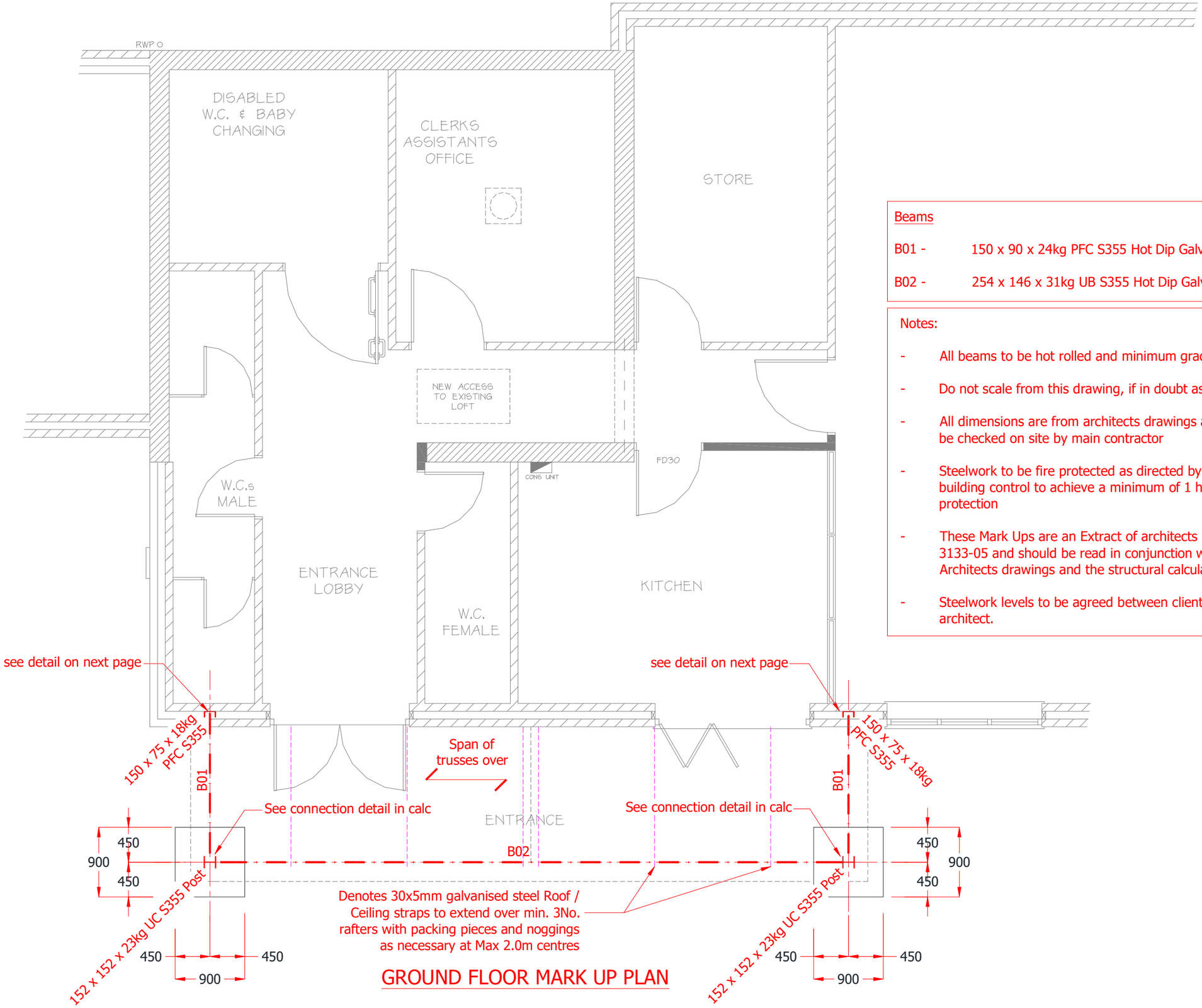


USE 900 X 900 X 600mm DEEP 25N MASS CONCRETE PAD FOUNDATION

CHECK FACTOR OF SAFETY AGAINST UPLIFT

Dead load from roof and frame =	9.2	+	1.9			= 11.1 kN ↓
Swt Concrete Base =	24	x	0.9^2	x	0.6	= 11.6 kN ↓
Overburden =	19	x	0.9^2	x	0.20	= 3.1 kN ↓
						= 25.8 kN ↓
Uplift from Wind =	7.76 / 2					= 3.88 kN ↑
∴ F. O . S =	25.8 / 3.88					= 6.65 OK

∴ UPLIFT DOES NOT OCCUR



GROUND FLOOR MARK UP PLAN

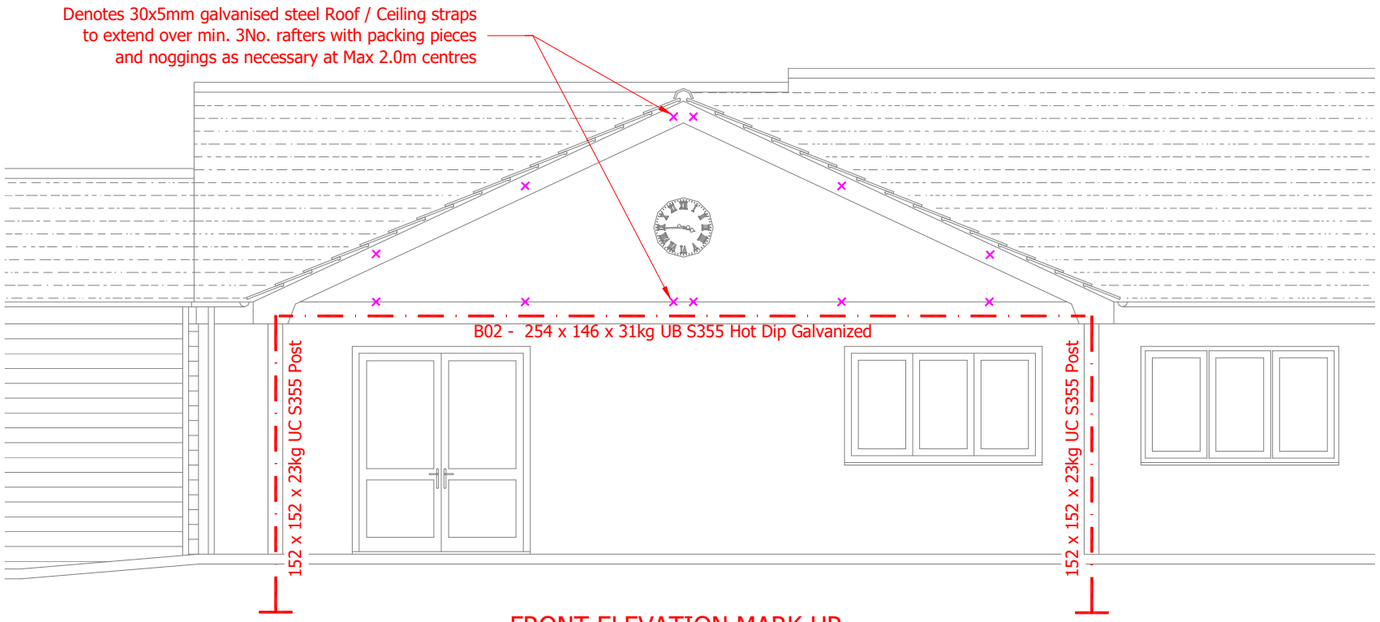
Beams

B01 - 150 x 90 x 24kg PFC S355 Hot Dip Galvanized

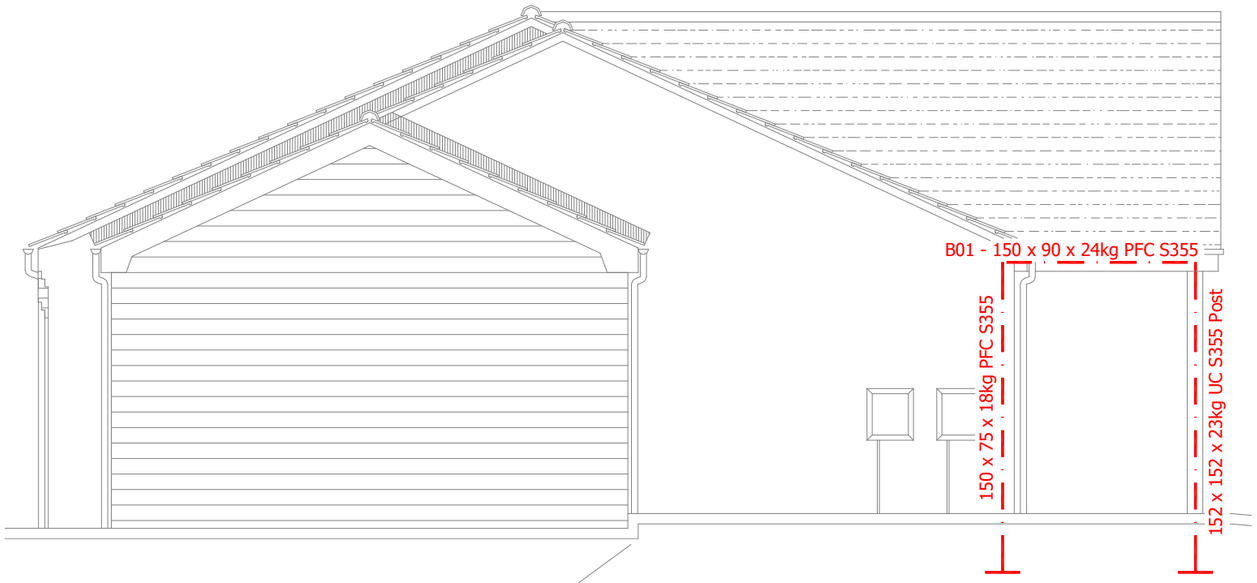
B02 - 254 x 146 x 31kg UB S355 Hot Dip Galvanized

Notes:

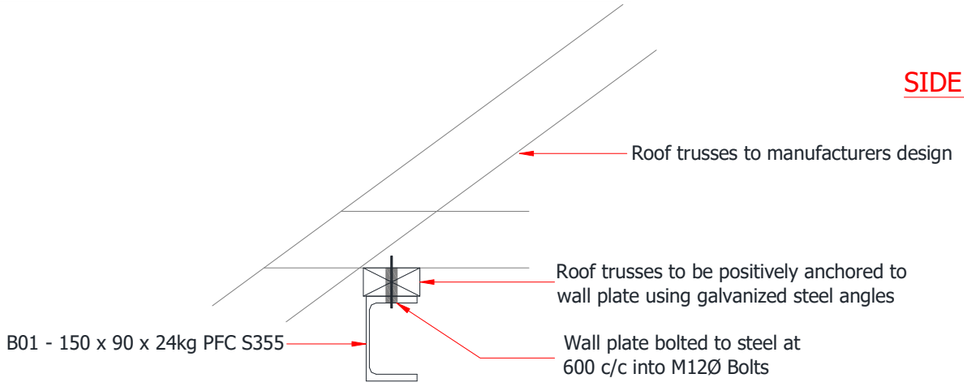
- All beams to be hot rolled and minimum grade 355 steel
- Do not scale from this drawing, if in doubt ask
- All dimensions are from architects drawings and are to be checked on site by main contractor
- Steelwork to be fire protected as directed by architect/ building control to achieve a minimum of 1 hour fire protection
- These Mark Ups are an Extract of architects Drawing No. 3133-05 and should be read in conjunction with the Architects drawings and the structural calculations.
- Steelwork levels to be agreed between client, builder and architect.

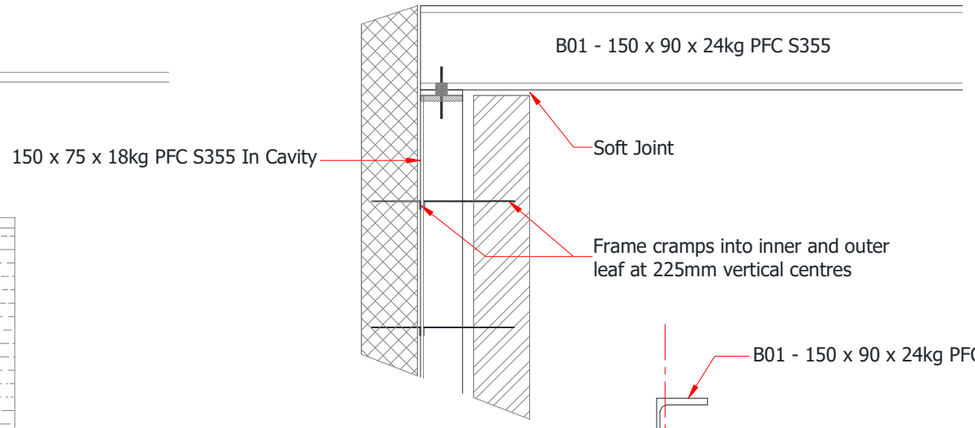


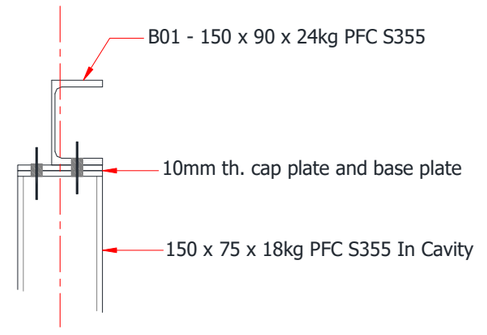
FRONT ELEVATION MARK UP



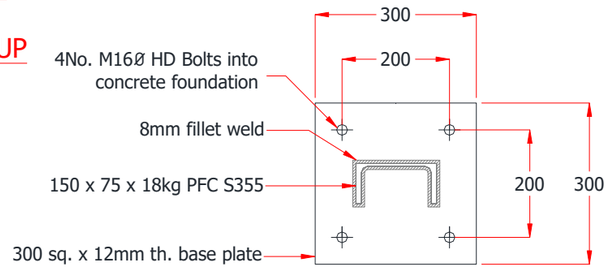
SIDE ELEVATION MARK UP



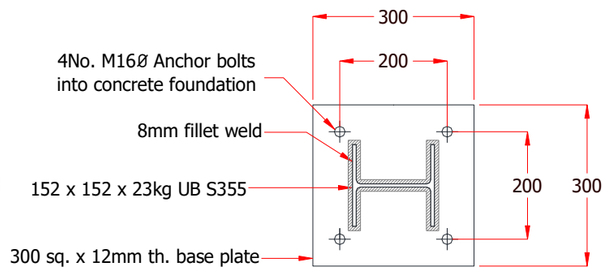




VIEW ON A - A



150 x 75 x 18 PFC
BASE PLATE DETAIL



152 x 152 x 23 UC
BASE PLATE DETAIL