Steel Beam Design

To Eurocode BS EN 1993-1-1/NA:2008

* You can add your own text, diagrams and photos here *

Design summary

	Resistance / Limit	Applied / Actual	Utilisation	
Shear	**231** kN	**32.2** kN	**14 %**	**OK**
Bending moment	**86.4** kNm	**40.2** kNm	**47 %**	**OK**
Buckling	**50.3** kNm	**40.2** kNm	**80 %**	**OK**
Total deflection	**25** mm	**12.2** mm	**49 %**	**OK**
Deflection due to variable actions	**13.9** mm	**5.1** mm	**37 %**	**OK**

Section details

Type	**Universal beam**
Section	**203 x 133 x 30 UB**
Steel grade	**S275**

Width	$b =$ **134** mm
Depth	$h =$ **207** mm
Web thickness	$t_w =$ **6.4** mm
Flange thickness	$t_f =$ **9.6** mm
Root radius	$r =$ **7.6** mm
Mass per metre	$w =$ **30** kg/m

9.6mm

206.8mm

6.4mm

133.9mm
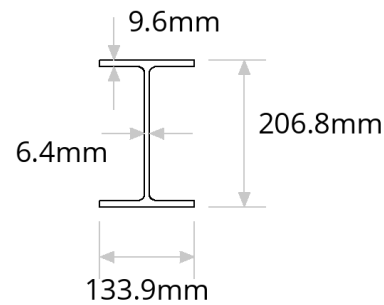
Span and restraints

Effective span	$L =$ **5,000** mm
Buckling length	$L_{cr} =$ **5,000** mm

Deflection limits

Variable action deflection limit	$\Delta_Q = L / 360 =$ **13.9** mm
Total deflection limit	$\Delta_{G+Q} = L / 200 =$ **25** mm

Safety factors

Partial factor for permanent actions	$\gamma_G =$ **1.35**
Partial factor for variable actions	$\gamma_Q =$ **1.5**

Loading details

Self weight

Permanent action

$SW = w \times 9.81 / 1000 = \mathbf{0.294}$ kN/m

Load 1: UDL - Flat roof, with no permanent access

Permanent action

$G_1 = \mathbf{1}$ kN/m² × **1.8** m = **1.8** kN/m

Variable action

$Q_1 = \mathbf{0.75}$ kN/m² × **1.8** m = **1.35** kN/m

Load 2: UDL - Timber floor (domestic dwelling)

Permanent action

$G_2 = \mathbf{0.6}$ kN/m² × **1.65** m = **0.99** kN/m

Variable action

$Q_2 = \mathbf{1.5}$ kN/m² × **1.65** m = **2.47** kN/m

Load 3: UDL - Timber Dormer Wall

Permanent action

$G_3 = \mathbf{1}$ kN/m² × **2.2** m = **2.2** kN/m

Variable action

$Q_3 = \mathbf{0}$ kN/m² × **2.2** m = **0** kN/m

Reactions

	Permanent (unfactored)	Variable (unfactored)	Total (unfactored)	Total (factored)
Left reaction	**13.2** kN	**9.56** kN	**22.8** kN	**32.2** kN
Right reaction	**13.2** kN	**9.56** kN	**22.8** kN	**32.2** kN

Design shear force
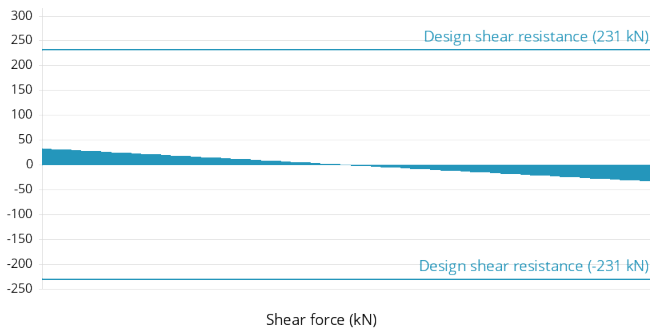
Design shear force

$V_{Ed} = \mathbf{32.2}$ kN

Design shear resistance

$V_{c,Rd} = \mathbf{231}$ kN

Utilisation
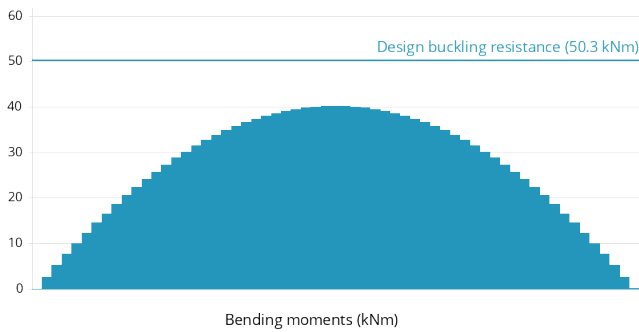
$V_{Ed} / V_{c,Rd} = \mathbf{14}$ % **OK**

Design shear resistance (231 kN)

Design shear resistance (-231 kN)

Shear force (kN)

Design bending moment

Bending moments (kNm)

Design bending moment, major axis	M_{Ed} = **40.2** kNm	
Design resistance for bending	$M_{c,Rd}$ = **86.4** kNm	
Bending utilisation	$M_{Ed} / M_{c,Rd}$ = **47** %	**OK**
Design resistance for buckling	$M_{b,Rd}$ = **50.3** kNm	
Buckling utilisation	$M_{Ed} / M_{b,Rd}$ = **80** %	**OK**

Deflection

Live load deflection (green) and total load deflection (blue) in mm
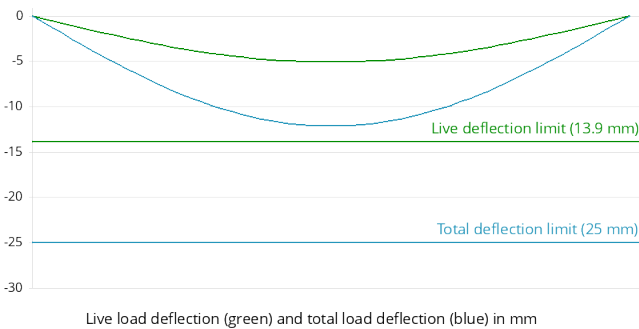
Variable action deflection limit	Δ_Q = **13.9** mm	
Variable action deflection	δ_Q = **5.1** mm	**OK**
Total deflection limit	Δ_{G+Q} = **25** mm	
Total deflection	δ_{G+Q} = **12.2** mm	**OK**

Section properties

Elastic modulus - major axis, yy	W_{el} = **280** cm^3
Plastic modulus - major axis, yy	W_{pl} = **314** cm^3
Second moment of area - major axis, yy	I_y = **2,900** cm^4
Second moment of area - minor axis, zz	I_z = **385** cm^4
Warping constant	I_w = **0.0374** dm^6
Torsional constant	I_T = **10.3** cm^4
Area of section	A = **3,820** mm^2

Factors and design values of material coefficients (EN 1993-1-1:2005 and National Annex)

Young's modulus of elasticity	E = **210,000** N/mm²	cl.3.2.6
Poisson's ratio in elastic stage	v = **0.3**	cl.3.2.6
Shear modulus	G_s = **81,000** N/mm²	cl.3.2.6
Partial factor for resistance of cross-sections	γ_{M0} = **1**	cl.6.1(1)B / BS-EN NA
Partial factor for resistance to instability	γ_{M1} = **1**	cl.6.1(1)B / BS-EN NA
Factor for shear area	η = **1**	EN 1993-1-5:2006 cl.5.1(2) / BS-EN NA
Limiting non dimensional slenderness ratio	$\bar{\lambda}_{LT,0}$ = **0.4**	cl.6.3.2.3(1) / BS-EN NA
Beta factor for buckling reduction factor calculation	β = **0.75**	cl.6.3.2.3(1) / BS-EN NA

Yield strength

Nominal yield strength for S275 grade and nominal section thickness 9.60 mm $\quad f_y = \textbf{275}$ N/mm^2 $\qquad$ *Tata blue book*

Section classification (EN 1993-1-1:2005 cl.5.5)

Epsilon	$\varepsilon = \textbf{0.924}$	*EN 1993-1-1:2005 Table 5.2*
Flange ratio for local buckling	$c_f / t_f = \textbf{5.85}$	
Flange ratio limit for class 1	$9\,\varepsilon = \textbf{8.32}$	*Table 5.2 (sheet 2 of 3)*
Flange class	$\text{Class}_f = \textbf{1}$	
Web ratio for local buckling	$c_w / t_w = \textbf{26.9}$	
Web ratio limit for class 1	$72\,\varepsilon = \textbf{66.6}$	*Table 5.2 (sheet 1 of 3)*
Web class	$\text{Class}_w = \textbf{1}$	
Section class	$\text{Class} = \textbf{1}$	

Shear resistance (EN 1993-1-1:2005 cl.6.2.6)

Height of web	$h_w = \textbf{188}$ mm	
Shear area for I and H sections	$A_v = \textbf{1,460}$ mm^2	*cl.6.2.6 (3)*
Design shear resistance	$V_{pl,Rd} = \textbf{231}$ kN	*eq (6.18)*

Shear buckling (EN 1993-1-5:2006 cl.5)

The shear buckling resistance for webs should be verified according to Section 5 of EN 1993-1-5 if $(h_w / t_w) > (72\,\varepsilon / \eta)$

Web ratio for shear buckling	$h_w / t_w = \textbf{29.3}$	*EN 1993-1-5:2006 cl.5.1 (2)*
Shear buckling limit	$72\,\varepsilon / \eta = \textbf{66.6}$	*EN 1993-1-5:2006 cl.5.1 (2)*

$(h_w / t_w) <= (72\,\varepsilon / \eta)$ therefore shear buckling calculation not required

Bending resistance (EN 1993-1-1:2005 cl.6.2.5)

The shear force (32 kN) is less than half of the plastic shear resistance (231 kN / 2 = 116 kN), therefore its effect on moment resistance may be neglected.

Class 1 section, therefore use plastic modulus	$W_{pl} = \textbf{314,000}$ mm^3	
Design bending resistance	$M_{c,Rd} = \textbf{86.4}$ kNm	*eq (6.13)*

Design buckling resistance (EN 1993-1-1:2005 cl.6.3.2)

C1 factor	$C1 = \textbf{1}$	
Shear modulus of elasticity	$G_s = \textbf{81,000}$ N/mm^2	*cl.3.2.6 (1)*
Buckling length	$L_{cr} = \textbf{5,000}$ mm	
Critical buckling moment	$M_{CR} = \textbf{60.4}$ kNm	*NCCI SN003b-EN-EU*
Class 1 section, therefore use plastic modulus	$W_{pl} = \textbf{314,000}$ mm^3	*cl.6.3.2.1(3)*
Non-dimensional slenderness ratio	$\overline{\lambda}_{LT} = \textbf{1.2}$	*cl.6.3.2.2 (1)*
Depth to width ratio for buckling curve	$h / b = \textbf{1.54}$	
Buckling curve for h / b ratio	$\text{Buckling curve} = \textbf{b}$	*Table 6.5 / BS-EN NA*
Imperfection factor for buckling curve b	$\alpha_{LT} = \textbf{0.34}$	*Table 6.3 / BS-EN NA*
Intermediate factor for reduction factor calculation	$\phi_{LT} = \textbf{1.17}$	*cl.6.3.2.3 (1)*
Buckling reduction factor	$\chi_{LT} = \textbf{0.582}$	*eq (6.57)*
Correction factor for moment distribution	$k_c = \textbf{1}$	*Table 6.6*
Moment distribution modification factor	$f = \textbf{1}$	*cl.6.3.2.3 (2)*
Modified buckling reduction factor	$\chi_{LT,mod} = \textbf{0.582}$	*eq (6.58)*
Design buckling resistance	$M_{b,Rd} = \textbf{50.3}$ kNm	*eq (6.55)*

Notes

C1 value conservatively taken as 1.0

Ends of beam are to be laterally restrained. Ends of beams can be laterally restrained using one of the following methods;

1) End of beam built into masonry wall.
2) End of beam fixed to a masonry wall.
3) End of beam fixed to a column or a beam.

The designer is to ensure that the proposed detail adequately ensures that the end of the beam is laterally restrained.

No allowance has been made for destabilising loads which are outside the scope of these calculations (Destabilising loads would not normally occur in a traditional masonry structure)