Compressive Strength (AISC 360-10)

Section E3: Flexural Buckling

Beam: Welded Beam WB1200X500X18X32

$b_f = 500$ mm
$h = 1184$ mm
$t_f = 32$ mm
$t_w = 18$ mm

$A = 52160\ \text{mm}^2$
$r_x = 494$ mm
$r_y = 113.1$ mm

Material:

$E = 200000$ MPa
$F_y = 250$ MPa

Local slenderness:

Flanges:

$$\lambda_{pf} = 0.38\sqrt{\frac{E}{F_y}} = 0.38\sqrt{\frac{200000}{250}} = 10.748$$

$$\lambda_f = \frac{b_f}{2t_f} = \frac{500}{2\times 32} = 7.8125$$

$$\lambda_f \le \lambda_{pf} \rightarrow \text{Compact}$$

Web:

$$\lambda_{pw} = 3.76\sqrt{\frac{E}{F_y}} = 3.76\sqrt{\frac{200000}{250}} = 106.35$$

$$\lambda_w = \frac{h}{t_w} = \frac{d-2t_f}{t_w} = \frac{1184-2\times 32}{18} = 62.22$$

$$\lambda_w \le \lambda_{pw} \rightarrow \text{Compact}$$

Unbraced Length and K-factor:

$Lb_x = 18800$ mm
$Lb_y = Lb_z = 4000$ mm
$K_x = K_y = K_z = 1$ (analyzed as beam)

Global Slenderness:

$$\lambda_x = \frac{K_x Lb_x}{r_x} = \frac{1\times 18800}{494} = 38.057$$

$$\lambda_y = \frac{K_y Lb_y}{r_y} = \frac{1\times 4000}{113.1} = 35.367$$

$$\lambda = \max\left[\lambda_x \quad \lambda_y\right] = 38.057$$

Nominal Compressive Strength:

$$F_e = \frac{\pi^2 E}{\lambda^2} = \frac{\pi^2\times 200000}{38.057} = 1362.912\ \text{MPa}\ (\text{Eq. } E3-4)$$

$$4.71\sqrt{\frac{E}{F_y}} = 4.71\sqrt{\frac{200000}{250}} = 133.219$$

$$\lambda \le 4.71\sqrt{\frac{E}{F_y}} \rightarrow \text{Inelastic Buckling}$$

$$F_{cr} = \left[0.658^{\left(\frac{F_y}{F_e}\right)}\right]F_y = \left[0.658^{\left(\frac{250}{1362.912}\right)}\right]\times 250 = 231.525\ \text{MPa}\ (\text{Eq. } E3-2)$$

$$P_n = F_{cr}A_g = 231.525\times 52160\times\frac{1\ \text{kN}}{1000\ \text{N}} = 12076.32\ \text{kN}\ (\text{Eq. } E3-1)$$

$$\phi_c = 0.9$$

$$\phi_c P_n = 0.9\times 12076.32 = 10868.689\ \text{kN}$$

ETABS Steel Frame Design

AISC 360-10 Steel Section Check (Strength Summary)

Element Details

Level	Element	Unique Name	Location (mm)	Combo	Element Type	Section	Classification
LEVEL 2	B2956	4193	660.4	DStlS2	Special Moment Frame	WB1200X500X18X32	Compact

LLRF and Demand/Capacity Ratio

L (mm)	LLRF	Stress Ratio Limit
20000.0	0.5	0.95

Analysis and Design Parameters

Provision	Analysis	2nd Order	Reduction
LRFD	Direct Analysis	General 2nd Order	Tau-b Fixed

Stiffness Reduction Factors

$\alpha P_r/P_y$	$\alpha P_r/P_e$	τ_b	EA factor	EI factor
0.016	0.003	1	0.8	0.8

Design Code Parameters

Φ_b	Φ_c	Φ_{TY}	Φ_{TF}	Φ_V	Φ_{V-RI}	Φ_{VT}
0.9	0.9	0.9	0.75	0.9	1	1

Section Properties

A (cm²)	J (cm⁴)	I_{33} (cm⁴)	I_{22} (cm⁴)	A_{v3} (cm²)	A_{v2} (cm²)
521.6	1316.2	1272695.5	66721.1	320	213.1

Design Properties

S_{33} (cm³)	S_{22} (cm³)	Z_{33} (cm³)	Z_{22} (cm³)	r_{33} (mm)	r_{22} (mm)	C_w (cm⁶)
21498.2	2668.8	24076.8	4090.7	494	113.1	221184000

Material Properties

E (MPa)	f_y (MPa)	R_y	α
200000	250	1.517	NA

Stress Check forces and Moments

Location (mm)	P_u (kN)	M_{u33} (kN-m)	M_{u22} (kN-m)	V_{u2} (kN)	V_{u3} (kN)	T_u (kN-m)
660.4	-205.8756	-4851.8279	0.2519	-1439.2912	-0.1099	0.0005

Axial Force & Biaxial Moment Design Factors (H1-1b)

	L Factor	K_1	K_2	B_1	B_2	C_m
Major Bending	0.939	1	1	1	1	1
Minor Bending	0.2	1	1	1	1	1

Parameters for Lateral Torsion Buckling

L_{ltb}	K_{ltb}	C_b
0.2	1	1.029

Demand/Capacity (D/C) Ratio Eqn.(H1-1b)

D/C Ratio =	$(P_r/2P_c) + (M_{r33}/M_{c33}) + (M_{r22}/M_{c22})$
0.906 =	0.01 + 0.896 + 2.737E-04

Axial Force and Capacities

P_u Force (kN)	ϕP_{nc} Capacity (kN)	ϕP_{nt} Capacity (kN)
205.8756	9937.1165	11736

Moments and Capacities

	M_u Moment (kN-m)	ϕM_n (kN-m)	ϕM_n No LTB (kN-m)	ϕM_n Cb=1 (kN-m)
Major Bending	4851.8279	5417.28	5417.28	5417.28
Minor Bending	0.2519	920.412		

Shear Design

	V_u Force (kN)	ϕV_n Capacity (kN)	Stress Ratio
Major Shear	1439.2912	2877.12	0.5
Minor Shear	0.1099	4320	2.545E-05

End Reaction Major Shear Forces

Left End Reaction (kN)	Load Combo	Right End Reaction (kN)	Load Combo
2261.5563	DStlS31	2165.4854	DStlS31