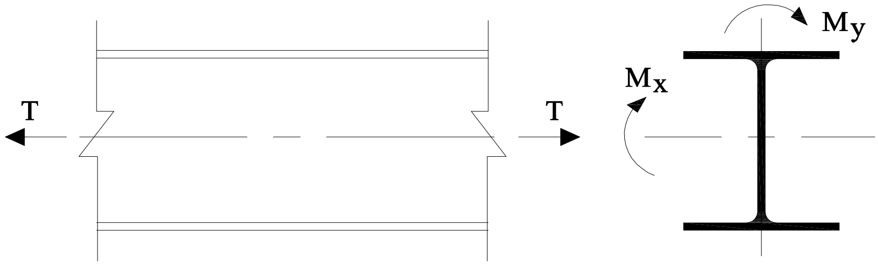
Design of W-Shapes Subjected to Tension Force and Bending Moments



Materials

Grade:	SEL("Material/ASTM"; NAME;)	=	A992
F_y=	TAB("Material/ASTM";F_y;NAME=Grade)	=	50 ksi
E=			29000 ksi

Beam Length and Cb

Unsupported length, L_b=	30.00 ft
kL_{in}=	14.00 ft
kL_{out}=	30.00 ft

(kL_{in} and kL_{out} are the strong and weak/torsional unbraced lengths, respectively)

From Table 3-1 (AISC), C_{b1}= 1.14

Given Straining Actions

Dead Load:

T_D=	29.0 kips
M_{xD}=	32.0 kip*ft
M_{yD}=	11.3 kip*ft

Live Load:

T_L=	87.0 kips
M_{xL}=	96.0 kip*ft
M_{yL}=	33.8 kip*ft

Ultimate Tension Force and Bending Moments

T_u=	$1.2*T_D+1.6*T_L$	=	174.0 kips
M_{ux}=	$1.2*M_{xD}+1.6*M_{xL}$	=	192.0 kip*ft
M_{uy}=	$1.2*M_{yD}+1.6*M_{yL}$	=	67.6 kip*ft

Section Details

sec.:	SEL("AISC/W";NAME;)	=	W14X82
depth, d=	TAB("AISC/W";d;NAME=sec.)	=	14.30 in
Web th., t_w=	TAB("AISC/W";t_w;NAME=sec.)	=	0.51 in
Flange width, b_f=	TAB("AISC/W";b_f;NAME=sec.)	=	10.10 in

Flange th., t_f= TAB("AISC/W";t_f;NAME=sec.) = 0.85 in

Gross Area, A= TAB("AISC/W";A;NAME=sec.) = 24.00 in^2

I_x= TAB("AISC/W";I_x;NAME=sec.) = 881.00 in^4

I_y= TAB("AISC/W";I_y;NAME=sec.) = 148.00 in^4

(I_x and I_y are the moment of inertia about x-and y-axes, respectively)

Plastic sec. modulus, Z_x= TAB("AISC/W";Z_x;NAME=sec.) = 139.00 in^3

Elastic sec. modulus, S_x= TAB("AISC/W";S_x;NAME=sec.) = 123.00 in^3

Plastic sec. modulus, Z_y= TAB("AISC/W";Z_y;NAME=sec.) = 44.80 in^3

Elastic sec. modulus, S_y= TAB("AISC/W";S_y;NAME=sec.) = 29.30 in^3

r_x= TAB("AISC/W";r_x;NAME=sec.) = 6.05 in

r_y= TAB("AISC/W";r_y;NAME=sec.) = 2.48 in

(r_x and r_y are the radius of gyration about x- and y-axis, respectively)

Torsional constant, J= TAB("AISC/W";J;NAME=sec.) = 5.07 in^4

r_{ts}= TAB("AISC/W";r_{ts};NAME=sec.) = 2.85 in

h_o= TAB("AISC/W";h_o;NAME=sec.) = 13.40 in

(r_{ts} is the Effective radius of gyration for the L.T.B. and h_o is distance between C.L. of flanges)

AISC Specification Eqn. (F6-1), the yielding moment in minor axis (M_{py}):

M_{py}= MIN (Z_y*F_y*1/12;1.6/12*S_y*F_y) = 187 kip*ft

Slenderness Check (According to section E2)

For members designed on the basis of compression, the slenderness ratio KL/r should not exceed 300.

λ_x= $\frac{kL_{in}}{r_x}*12$ = 27.8

λ_y= $\frac{kL_{out}}{r_y}*12$ = 145.2

Then, the governed slenderness (λ_{max}):

λ_{max}= MAX(λ_x;λ_y) = 145.2

Slenderness_check= IF($\lambda_{max} \leq 300$; "Safe"; "Unsafe") = Safe

Nominal Tensile Strength

From AISC Specification Section D2(a), the nominal tensile strength due to tensile yielding on the gross section is:

T_n= F_y*A = 1200.0 kips

Nominal Flexural Strength about x-x Axis

Yielding: from AISC specification section F2.1, the nominal flexural strength due to yielding (plastic moment) is:

M_{px}= Z_x*F_y*1/12 = 579 kip*ft

Lateral torsional buckling (LTB): the limiting lengths L_p and L_r are determined according to the AISC spec. eqns. F2-5 and F2-6, as follows:

L_p= 1.76*r_y*√(E/F_y)/12 = 8.76 ft

$$L_{r1} = \sqrt{\frac{J*1.0}{S_x*h_o}} = 0.06$$

$$L_{r2} = \sqrt{1+\sqrt{6.76*\left(\frac{0.7*F_y*S_x*h_o}{E*J*1.0}\right)^2}} = 1.42$$

$$L_r = 1.95/12*r_{ts}*\frac{E}{0.7*F_y}*L_{r1}*L_{r2} = 32.69 \text{ ft}$$

Case= IF(L_b>L_r;"ELTB";IF(L_b≤L_p; "No LTB";"InLTB")) = InLTB

("ELTB" refers to elastic lateral torsional buckling and "InLTB" refers to inelastic lateral torsional buckling).

The lateral torsional buckling modification factor, C_b:

$$T_{ey} = \frac{\pi^2*E*I_y}{(L_b*12)^2} = 326.9 \text{ kips}$$

$$C_b = C_{b1}*\sqrt{1+\frac{T_u}{T_{ey}}} = 1.41$$

According to the AISC Spec. Eqn. F2-2:

M_{1a}= M_{px}-0.7*1/12*F_y*S_x = 220 kip*ft

M_1= MIN(M_{px}; C_b*(M_{px}-M_{1a}*(L_b-L_p)/(L_r-L_p))) = 541 kip*ft

According to the AISC Spec. Eqn. F2-4:

$$F_{cr} = \frac{C_b*\pi^2*E}{\left(\frac{(L_b+0.01)*12}{r_{ts}}\right)^2} = 25.28 \text{ ksi}$$

$$F_{cr,mod} = \sqrt{1+\frac{0.078*J*1.0}{S_x*h_o}*\left(\frac{L_b*12}{r_{ts}}\right)^2} = 2.20 \text{ ksi}$$

According to the AISC Spec. Eqns. F2-3:

M_2= MIN(M_{px};F_{cr}*S_x/12*$F_{cr,mod}$) = 570 kip*ft

According to the AISC Spec. Eqn. F2-2:

M_{nx2}= IF (Case="No LTB";M_{px};IF(Case="InLTB";M_1;M_2)) = 541 kip*ft

Element Classification

(1) Web:

h/tw, λ_w= TAB("AISC/W";h/t_w;NAME=sec.) = 22.40

According to AISC Specification Table B4.1 Case 9, the limiting width-to-thickness ratio for the web is:

Web_Class= IF($\lambda_w \le 3.76 * \sqrt{(E/F_y)}$;"Compact"; "Non-Compact") = Compact

(2) Comp. flange:

$b_f/2t_f$, λ_f= TAB("AISC/W";$b_f/2t_f$;NAME=sec.) = 5.92

According to AISC Specification Table B4.1 Case 1, the limiting width-to-thickness ratios for the compression flange are:

λ_{pf}= $0.38*\sqrt{(E/F_y)}$ = 9

λ_{rf}= $1.00*\sqrt{(E/F_y)}$ = 24

Fl_Class= IF($\lambda_f \le \lambda_{pf}$;"Compact";IF($\lambda_f > \lambda_{rf}$;"Slender";"Non-Compact")) = Compact

The available strength provided by AISC Specification Sections F3.1, F3.2, F6.1 and F6.2, the nominal flexural moments in strong/weak axes are calculated as follows, satisfying the condition of compression Flange Local Buckling:

M_{nx1a}= M_{px}-0.7*F_y*S_x*1/12 = 220 kip*ft

M_{nx1}= IF(Fl_Class="Compact"; M_{px}; M_{px}-M_{nx1a}*$\left(\frac{\lambda_f - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)$) = 579 kip*ft

M_{ny1a}= M_{py}-0.7*F_y*S_y*1/12 = 102 kip*ft

M_{ny1}= IF(Fl_Class="Compact"; M_{py}; M_{py}- M_{ny1a}*$\left(\frac{\lambda_f - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)$) = 187 kip*ft

Design Flexure Moment in Major/Minor Axes

M_{nx}= MIN(M_{px};M_{nx1};M_{nx2}) = 541 kip*ft

M_{ny}= MIN(M_{py};M_{ny1}) = 187 kip*ft

Calculate The Available Flexural and Axial Strengths

Φ_b= 0.90

Φ_t= 0.90

T_c= Φ_t * T_n = 1080 kips

M_{cx}= Φ_b * M_{nx} = 487 kip*ft

M_{cy}= Φ_b * M_{ny} = 168 kip*ft

Interaction of Tension and Flexure

Check limit for AISC Specification Equation H1-1a.

Tension_ratio, t= $\frac{T_u}{T_c}$ = 0.16

Moment_ratio, m= $\frac{M_{ux}}{M_{cx}} + \frac{M_{uy}}{M_{cy}}$ = 0.80

Safety_ratio, r= IF(t ≥0.2; t+8/9*m; t/2+m) = 0.88

Safety= IF(r≤1;"Safe";"Unsafe") = Safe

Design Summary

T_u=	$1.2*T_D+1.6*T_L$	=	174.0 kips
M_{ux}=	$1.2*M_{xD}+1.6*M_{xL}$	=	192.0 kip*ft
M_{uy}=	$1.2*M_{yD}+1.6*M_{yL}$	=	67.6 kip*ft
T_c=	$\Phi_t * T_n$	=	1080 kips
M_{cx}=	$\Phi_b * M_{nx}$	=	487 kip*ft
M_{cy}=	$\Phi_b * M_{ny}$	=	168 kip*ft
Slenderness_check=	IF($\lambda_{max} \leq 300$; "Safe"; "Unsafe")	=	Safe
Safety_ratio, r=	IF(t ≥ 0.2; t+8/9*m; t/2+m)	=	0.88
Safety=	IF(r≤1;"Safe";"Unsafe")	=	Safe