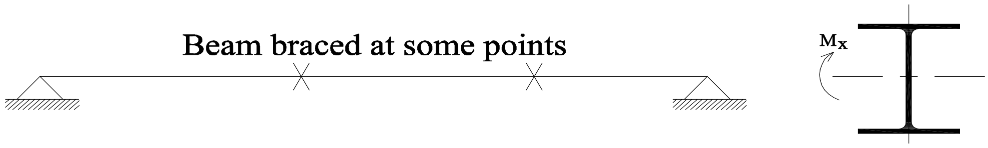
Design of W-Shapes Subjected to Bending Moment about Strong Axis and Braced at Some Points



Materials

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

Beam Length and Cb

Total length, L=	35.00 ft
Unsupported length, L_b=	17.50 ft
From Table 3-1 (AISC), C_b=	1.50

Design Moments and Uniform Live Load

Ultimate moment, M_u=	200.00 kip*ft
Ultimate moment due to live load case, M_L=	140.00 kip*ft
Ultimate shear, Q_u=	30.00 kips

Section Details

sec.:	SEL("AISC/W";NAME;)	=	W21X48
depth, d=	TAB("AISC/W";d;NAME=sec.)	=	20.60 in
Web th., t_w=	TAB("AISC/W";t_w;NAME=sec.)	=	0.35 in
Flange width, b_f=	TAB("AISC/W";b_f,NAME=sec.)	=	8.14 in
Flange th., t_f=	TAB("AISC/W";t_f;NAME=sec.)	=	0.43 in
Plastic sec. modulus, Z_x=	TAB("AISC/W";Z_x;NAME=sec.)	=	107.00 in^3
Elastic sec. modulus, S_x=	TAB("AISC/W";S_x;NAME=sec.)	=	93.00 in^3
Inertia about x-axis, I_x=	TAB("AISC/W";I_x;NAME=sec.)	=	959.00 in^4
r_y=	TAB("AISC/W";r_y;NAME=sec.)	=	1.66 in
r_{ts}=	TAB("AISC/W";r_{ts};NAME=sec.)	=	2.05 in

(r_y is radius of gyration about y-axis and r_{ts} : is effective radius of gyration for the L.T.B.)

Torsional constant, J=	TAB("AISC/W";J;NAME=sec.)	=	0.80 in^4
h_o=	TAB("AISC/W";h_o;NAME=sec.)	=	20.20 in

(h_o : is the distance between C.L. of flanges)

AISC Specification Eqn. (F2-1):

Yielding Moment, Mp=	Z_x*F_y*1/12	=	446 kip*ft

Element Classification

(1) Web:

h/t_w, λ_w= TAB("AISC/W";h/t_w;NAME=sec.) = 53.60

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";bf/2tf;NAME=sec.) = 9.47

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")) = Non-Compact

The available strength provided by AISC Specification Sections F3.1 and F3.2, the nominal flexural moment is calculated as follows, satisfying the condition of compression Flange Local Buckling:

M_{n1a}= $M_p-0.7*F_y*S_x*1/12$ = 175 kip*ft

M_{n1}= IF(Fl_Class="Compact"; M_p; $(M_p - M_{n1a}*(\frac{\lambda_f - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}))$) = 441 kip*ft

Lateral Torsional Buckling (LTB)

The limiting lengths Lp and Lr are determined according to the AISC Spec. Eqns. F2-5 and F2-6, as follows:

L_p= $1.76*r_y*\sqrt{(E/F_y)}/12$ = 5.86 ft

L_{r1}= $\sqrt{\frac{J*1.0}{S_x*h_o}}$ = 0.02

L_{r2}= $\sqrt{1+\sqrt{6.76*\left(\frac{0.7*F_y*S_x*h_o}{E*J*1.0}\right)^2}}$ = 2.89

L_r= $1.95/12*r_{ts}*\frac{E}{0.7*F_y}*L_{r1}*L_{r2}$ = 15.95 ft

Case= IF($L_b > L_r$;"ELTB";IF($L_b \le L_p$; "No LTB";"InLTB")) = ELTB

("ELTB" refers to elastic LTB. and "InLTB" refers to Inelastic LTB.)

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

M_1= MIN(M_p; $C_b*(M_p-(M_p-0.7*1/12*F_y*S_x)*(L_b-L_p)/(L_r-L_p))$) = 367 kip*ft

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

F_{cr}= $C_b*\pi^2*E/((L_b+0.01)*12/r_{ts})^2$ = 40.87 ksi

$F_{cr,mod}$= $\sqrt{(1+0.078*J*1.0/(S_x*h_o)*(L_b*12/r_{ts})^2)}$ = 1.16 ksi

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

M_2= MIN(M_p;$F_{cr}*S_x/12*F_{cr,mod}$) = 367 kip*ft

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

M_{n2}= IF (Case="No LTB";M_p;IF(Case="InLTB";M_1;M_2)) = 367 kip*ft

Check The Available Flexure Strength

ΦM_n= 0.90*MIN(M_p;M_{n1};M_{n2}) = 330 kip*ft

Safety= IF($\Phi M_n \geq M_u$;"Safe";"Unsafe") = Safe

Moment_ratio= $M_u/\Phi M_n$ = 0.61

Check Shear Strength

h/t_w, λ_w= TAB("AISC/W";h/t_w;NAME=sec.) = 53.60

λ_{w0}= $2.24*\sqrt{(E/F_y)}$ = 54

λ_{w1}= $1.10*\sqrt{(5*E/F_y)}$ = 59

λ_{w2}= $1.37*\sqrt{(5*E/F_y)}$ = 74

Except for very few sections, which are listed in the User Note, AISC Specification Section G2.1(a) is applicable to the I-shaped beams published in the AISC Manual for Fy ƒ- 50 ksi. Cv is calculated exactly according to Eqns. G2-2, G2-3, G2-4, and G2-5

C_{va}= $1.51*5*E/(F_y*\lambda_w^2)$ = 1.52

C_v= IF($\lambda_w \leq \lambda_{w0}$;1;IF(($\lambda_w > \lambda_{w1}$ AND $\lambda_w \leq \lambda_{w2}$);$\lambda_{w1}/l_w$;$C_{va}$)) = 1.00

From AISC Specification Section G2.1b,

A_w= $d*t_w$ = 7 in^2

From AISC Specification Section G2.1, the available shear strength is:

V_n= $0.6*F_y*A_w*C_v$ = 210 kips

Φ_v= 1.00

$\Phi_v V_n$= Φ_v*V_n = 210 kips

Shear_safety= IF($\Phi_v*V_n>Q_u$;"Safe";"Unsafe") = Safe

Check Deflection

Δ_{all}= 12*L/360 = 1.17 in

W_{eq} (LL), W_L= $\frac{8*M_L}{L^2}$ = 0.91 kip/ft

Δ_{act}= $\frac{5*W_L*L^4}{384*E*I_x}*12^3$ = 1.10 in

Deflection safety (D_s):

D_s= IF($\Delta_{all} \geq \Delta_{act}$;"Safe";"Unsafe") = Safe

Design Summary

ΦM_n= 0.90*MIN(M_p;M_{n1};M_{n2}) = 330 kip*ft

Safety=	IF($\Phi M_n \geq M_u$;"Safe";"Unsafe")	=	Safe
Moment_ratio=	$M_u/\Phi M_n$	=	0.61
$\Phi_v V_n$=	$\Phi_v * V_n$	=	210 kips
Shear_safety=	IF($\Phi_v * V_n > Q_u$;"Safe";"Unsafe")	=	Safe
Δ_{all}=	12*L/360	=	1.17 in
Δ_{act}=	$12 * \frac{5 * W_L * L^4}{384 * E * I_x}$	=	0.01 in
D_s=	IF($\Delta_{all} \geq \Delta_{act}$;"Safe";"Unsafe")	=	Safe