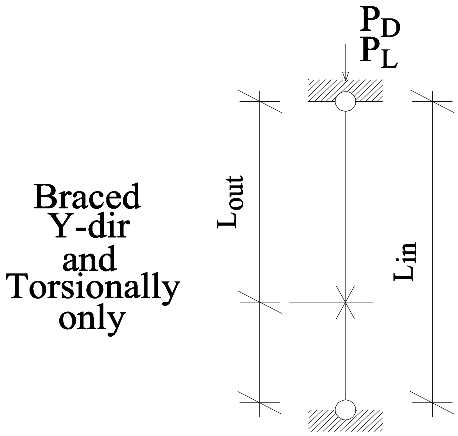
Design of Built-Up W-Shapes with Slender Elements Subjected to Compression Axial Force



Materials

Grade:	SEL("Material/ASTM";NAME;)	=	A992
F_y=	TAB("Material/ASTM";F_y;NAME=Grade)	=	50 ksi
E=			29000 ksi
G=			11200 ksi

Buckling Lengths

kL_{in}=	30.00 ft
kL_{out}=	15.00 ft
k_zL=	15.00 ft

(kL_{in} and kL_{out} are unbraced lengths for the strong- and weak- axes, respectively; k_zL is the torsional unbraced length)

Axial Loads

Dead load, P_D=		140 kips
Live load, P_L=		200 kips

From Chapter 2 of ASCE/SEI 7, the required compressive strength is:

Ultimate load, $P_u=1.2*P_D+1.6*P_L$	=	488 kips

Section Details

Web height, h=	15.0 in
Web th., t_w=	0.25 in
Flange width, b_f=	8.00 in
Flange th., t_f=	1.00 in

Built-Up Section Properties (ignoring fillet welds):

Area, A=	$h*t_w+2*b_f*t_f$	=	19.75 in^2

$I_x=\Sigma Ad^2+\Sigma bh^3/12$

$I_x=$ $2*(b_f*t_f)*(t_f/2+h/2)^2 + \frac{t_w*h^3}{12} + \frac{b_f*(t_f)^3*2}{12}$ = 1096 in^4

$I_y=$ $\frac{2*b_f^3*t_f}{12} + \frac{h*t_w^3}{12}$ = 85.35 in^4

$r_x=$ $\sqrt{\frac{I_x}{A}}$ = 7.45 in

$r_y=$ $\sqrt{\frac{I_y}{A}}$ = 2.08 in

Slenderness Check

For members designed on the basis of compression, the slenderness ratio *KL*/*r* preferably should not exceed 200.

$\lambda_x=$ $\frac{kL_{in}}{r_x}*12$ = 48.3

$\lambda_y=$ $\frac{kL_{out}}{r_y}*12$ = 86.5

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

$\lambda_{max}=$ $MAX(\lambda_x;\lambda_y)$ = 86.5

Elastic Flexural Buckling Stress

The available critical stresses may be interpolated from AISC Manual Table 4-22 or calculated directly As follows:

$F_{e1}=$ $\frac{\pi^2*E}{\lambda_{max}^2}$ = 38.3 ksi

Elastic Critical Torsional Buckling Stress

From the User Note in AISC *Specification* Section E4,

$h_o=$ $h+t_f$ = 16 in

$C_w=$ $\frac{I_y*h_o^2}{4}$ = 5462 in^6

From AISC Design Guide 9, Equation 3.4,

$J= \Sigma\, bt^3/3$

$J=$ $\frac{2*b_f*t_f^3+h*t_w^3}{3}$ = 5.41 in^4

According to AISC Specification (Eqn. E4-4),

$F_{e2}=$ $\left(\frac{\pi^2*E*C_w}{(kzL*12)^2}+G*J\right)*\frac{1}{I_x+I_y}$ = 92.1 ksi

Elastic Governed Stress

F_e=	MIN(F_{e1}; F_{e2})	=	38.3 ksi

Element Classification

(1) Flanges: Check for slender flanges using AISC *Specification* Table B4.1a, then determine Q_s, the unstiffened element (flange) reduction factor using AISC *Specification* Section E7.1.

Calculate k_c using AISC *Specification* Table B4.1b note [a].

k_c=	MIN(MAX(4/√(h/t_w);0.35);0.76)	=	0.52
$b_f/2t_f$, λ_f=	$b_f/(2*t_f)$	=	4.00

Determine the flange limiting slenderness ratio, λrf, from AISC *Specification* Table B4.1a case 2

λ_{rf}=	0.64*√(k_c*E/F_y)	=	11.11
Fl_Class=	IF($\lambda_f \leq \lambda_{rf}$;"Non-Compact";"Slender")	=	Non-Compact

Calculate Qs, according to the AISC Specification Eqns. E7-4, E7-5 and E7-6

λ_{rf1}=	1.17*√(k_c*E/F_y)	=	20.32
Q_{s1}=	0.9*E*k_c/(F_y*λ_f^2)	=	16.97
Q_{s2}=	1.415- 0.65*λ_f*√(F_y/(E*k_c))	=	1.27
Qs=	IF($\lambda_f \leq \lambda_{rf}$; 1; IF($\lambda_f > \lambda_{rf1}$; Q_{s1}; Q_{s2}))	=	1.00

Web: Check for a slender web, then determine Qa, the stiffened element (web) reduction factor using AISC Specification, Section E7.2.

h/t_w, λ_w=	h/t_w	=	60.00

Determine the slender web limit from AISC *Specification* Table B4.1a case 5

λ_{rw}=	1.49*√(E/F_y)	=	35.88
Web_Class=	IF($\lambda_w \leq \lambda_{rw}$;"Non-compact"; "Slender")	=	Slender

$$Q_a = \frac{A_e}{A_g}$$

where A_e is the effective area based on the reduced effective width (b_e). For AISC *Specification* Equation E7-17, take *f* as F_{cr} with F_{cr} calculated based on Q = 1.0. Select between AISC *Specification* Equations E7-2 and E7-3 based on KL/r_y.

λ_1=	$4.71 * \sqrt{\frac{E}{F_y}}$	=	113

Calculate the flexural buckling stress, F_{cr}:

F_{cr1}=	IF($\lambda_{max} \leq \lambda_1$; $0.658^{(F_y/F_e)}*F_y$;0.877*F_e)	=	29.0 ksi
b_e=	$MIN(1.92*t_w*\sqrt{\frac{E}{F_{cr1}}}*(1-\frac{0.34}{\lambda_w}*\sqrt{\frac{E}{F_{cr1}}}); h)$	=	12.5 in

(Note that be should be less than the web height)

A_e=	$b_e*t_w+2*b_f*t_f$	=	19.1 in^2

Q_a=	$\frac{A_e}{A}$	=	0.967
Q=	Q_s*Q_a	=	0.967

Flexural Buckling Strength

Determine another time whether AISC *Specification* Equation E7-2 or E7-3 applies.

λ_2=	$4.71*\sqrt{(E/(Q*F_y))}$	=	115
F_{cr2}=	$IF(\lambda_{max} \leq \lambda_1; Q*0.658^{(F_y*Q/F_e)}*F_y; 0.877*F_e)$	=	28.5 ksi

Nominal Compressive Strength

P_n=	$F_{cr2}*A$	=	563 kips
Φ_v=			0.90
$\Phi_v P_n$=	Φ_v*P_n	=	507 kips

Compressive stress safety (S_s):

S_s=	IF($\Phi_v*P_n>P_u$;"Safe";"Unsafe")	=	Safe
Stress_ratio=	$\frac{P_u}{\Phi_v*P_n}$	=	0.96

Design Summary

Ultimate load, P_u=	$1.2*P_D+1.6*P_L$	=	488 kips
$\Phi_v P_n$=	Φ_v*P_n	=	507 kips
Stress_ratio=	$\frac{P_u}{\Phi_v*P_n}$	=	0.96
S_s=	IF($\Phi_v*P_n>P_u$;"Safe";"Unsafe")	=	Safe