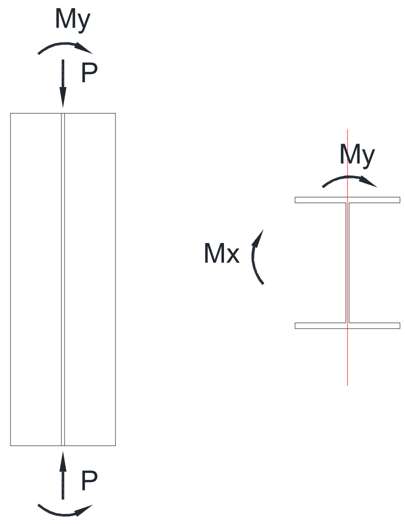
## Design of W-Shapes Subjected to Compression Force and Bending Moment




### Materials

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

### Beam Length and Cb

| | |
|---|---|
| Unsupported length, $L_b$= | 14.00 ft |
| $kL_{in}$= | 14.00 ft |
| $kL_{out}$= | 14.00 ft |

($kL_{in}$ and $kL_{out}$ are strong- and weak/torsional- axes unbraced length, respectively)

| | |
|---|---|
| From Table 3-1 (AISC ), $C_b$= | 1.00 |

### Ultimate Compression Force and Bending Moments

(obtained from a second-order analysis that includes P- $\delta$ effects)

| | |
|---|---|
| $P_u$= | 200.0 kips |
| $M_{ux}$= | 50.0 kip*ft |
| $M_{uy}$= | 50.0 kip*ft |

### Section Details

| | | | |
|---|---|---|---|
| sec.: | SEL("AISC/W";NAME; ) | = | W14X68 |
| depth, d= | TAB("AISC/W";d;NAME=sec.) | = | 14.00 in |
| Web th., $t_w$= | TAB("AISC/W";$t_w$;NAME=sec.) | = | 0.41 in |
| Flange width, $b_f$= | TAB("AISC/W";$b_f$;NAME=sec.) | = | 10.00 in |
| Flange th., $t_f$= | TAB("AISC/W";$t_f$;NAME=sec.) | = | 0.72 in |
| Gross Area, A= | TAB("AISC/W";A;NAME=sec.) | = | 20.00 $in^2$ |
| $I_x$= | TAB("AISC/W";$I_x$;NAME=sec.) | = | 722.00 $in^4$ |

$I_y$= TAB("AISC/W";$I_y$;NAME=sec.) = 121.00 $in^4$

*($I_x$ 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.) = 115.00 $in^3$

Elastic sec. modulus, $S_x$= TAB("AISC/W";$S_x$;NAME=sec.) = 103.00 $in^3$

Plastic sec. modulus, $Z_y$= TAB("AISC/W";$Z_y$;NAME=sec.) = 36.90 $in^3$

Elastic sec. modulus, $S_y$= TAB("AISC/W";$S_y$;NAME=sec.) = 24.20 $in^3$

Radius of gyration about x-axis, $r_x$= TAB("AISC/W";$r_x$;NAME=sec.) = 6.01 in

Radius of gyration about y-axis, $r_y$= TAB("AISC/W";$r_y$;NAME=sec.) = 2.46 in

Torsional constant, J= TAB("AISC/W";J;NAME=sec.) = 3.01 $in^4$

$r_{ts}$= TAB("AISC/W";$r_{ts}$;NAME=sec.) = 2.80 in

$h_o$= TAB("AISC/W";$h_o$;NAME=sec.) = 13.30 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. (F2-1):

Yielding Moment in major axis, $M_{px}$= $Z_x$*$F_y$*1/12 = 479 kip*ft

AISC Specification Eqn. (F6-1):

Yielding Moment in minor axis, $M_{py}$= MIN ($Z_y$*$F_y$*1/12;1.6/12*$S_y$*$F_y$) = 154 kip*ft

**Element Classification**

(1) Web:

h/tw, $\lambda_w$= TAB("AISC/W";h/$t_w$;NAME=sec.) = 27.50

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:

$b_f/2t_f$, $\lambda_f$= TAB("AISC/W";$b_f/2t_f$;NAME=sec.) = 6.97

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

$\lambda_{pf}$= $0.38 * \sqrt{\frac{E}{F_y}}$ = 9

$\lambda_{rf}$= $1.00 * \sqrt{\frac{E}{F_y}}$ = 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:

$M_{px1}$= $M_{px}$-0.7*$F_y$*$S_x$*1/12 = 179 kip*ft

$M_{nx1}$= IF(Fl_Class="Compact"; $M_{px}$; ($M_{px}$-($M_{px1}$)*($\frac{\lambda_f - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}$))) = 479 kip*ft

$M_{py1}$= $M_{py}$-0.7*$F_y$*$S_y$*1/12 = 83 kip*ft

$M_{ny1}$= IF(Fl_Class="Compact"; $M_{py}$; ($M_{py}$-($M_{py1}$)*($\frac{\lambda_f - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}$))) = 154 kip*ft

**Slenderness Check: (According to Section E2)**

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

$\lambda_x$= $\frac{kL_{in}}{r_x}*12$ = 28.0

$\lambda_y$= $\frac{kL_{out}}{r_y}*12$ = 68.3

Then, the governed slenderness ($\lambda_{max}$):

$\lambda_{max}$= MAX($\lambda_x$;$\lambda_y$) = 68.3

**Critical Stresses**

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

-Calculate the elastic critical buckling stress, $F_e$:

$F_e$= $\frac{\pi^2 * E}{\lambda_{max}^2}$ = 61.4 ksi

-Calculate the flexural buckling stress, $F_{cr}$ (Eqns. E3-2 and E3-3):

$\lambda_1$= $4.71 * \sqrt{\frac{E}{F_y}}$ = 113

$F_{cr}$= IF($\lambda_{max} \le \lambda_1$; $0.658^{(Fy/Fe)} * F_y$;0.877*$F_e$) = 35.6 ksi

**Design Compressive Strength**

(Eqn. E3-1)

$P_n$= $F_{cr}$*A = 712.0 kips

$\Phi_c$= 0.90

$\Phi_c P_n$= $\Phi_c$*$P_n$ = 640.8 kips

**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:

$L_p$= $1.76 * r_y * \sqrt{\frac{E}{F_y}} / 12$ = 8.69 ft

$L_{r1}$= $\sqrt{\frac{J*1.0}{S_x*h_o}}$ = 0.05

$L_{r2}$= $\sqrt{1+\sqrt{6.76*\left(\frac{0.7*F_y*S_x*h_o}{E*J*1.0}\right)^2}}$ = 1.56

$L_r$= $1.95/12*r_{ts}*\frac{E}{0.7*F_y}*L_{r1}*L_{r2}$ = 29.41 ft

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

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

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

$M_1$= MIN($M_{px}$; $C_b$*($M_{px}$-($M_{px}$-0.7*1/12*$F_y$*$S_x$)*($L_b$-$L_p$)/($L_r$-$L_p$))) = 433 kip*ft

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

$F_{cr}$= $C_b*\pi^2*\frac{E}{((L_b+0.01)*12/r_{ts})^2}$ = 79.4 ksi

$F_{cr,mod}$= $\sqrt{1+0.078*J*\frac{1.0}{S_x*h_o}*\left(L_b*\frac{12}{r_{ts}}\right)^2}$ = 1.3 ksi

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

$M_2$= MIN($M_{px}$;$F_{cr}$*$S_x$/12*$F_{cr,mod}$) = 479 kip*ft

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

$M_{nx2}$= IF (Case="No L.T.B.";$M_{px}$;IF(Case="InLTB";$M_1$;$M_2$)) = 433 kip*ft

**Design Flexure Moments in Major/Minor Axes**

$\Phi_b$= 0.90

$M_{nx}$= MIN($M_{px}$;$M_{nx1}$;$M_{nx2}$) = 433 kip*ft

$M_{ny}$= MIN($M_{py}$;$M_{ny1}$) = 154 kip*ft

**Calculate the Available Flexural and Axial Strengths**

$F_{ca}$= $\frac{\Phi_c*P_n}{A}$ = 32.04 ksi

$F_{bcx}$= $12*\frac{\Phi_b*M_{nx}}{S_x}$ = 45.40 ksi

$F_{bcy}$= $12*\frac{\Phi_b*M_{ny}}{S_y}$ = 68.73 ksi

**Calculate the Actual Flexural and Axial Stresses**

$f_{ra}$= $\frac{P_u}{A}$ = 10.00 ksi

$f_{rbx}$= $12*\frac{M_{ux}}{S_x}$ = 5.83 ksi

$f_{rby}$= $12^* \frac{M_{uy}}{S_y}$ = 24.79 ksi

**Check the Combined Stress Ratio**

(AISC Specification Section H2)

Stress_ratio= $\frac{f_{ra}}{F_{ca}} + \frac{f_{rbx}}{F_{bcx}} + \frac{f_{rby}}{F_{bcy}}$ = 0.80

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

**Design Summary**

$f_{ra}$= $\frac{P_u}{A}$ = 10.0 ksi

$F_{ca}$= $\frac{\Phi_c * P_n}{A}$ = 32.0 ksi

$f_{rbx}$= $12^* \frac{M_{ux}}{S_x}$ = 5.8 ksi

$F_{bcx}$= $12^* \frac{\Phi_b * M_{nx}}{S_x}$ = 45.4 ksi

$f_{rby}$= $12^* \frac{M_{uy}}{S_y}$ = 24.8 ksi

Fbcy= $12^* \frac{\Phi_b * M_{ny}}{S_y}$ = 68.7 ksi

Stress_ratio= $\frac{f_{ra}}{F_{ca}} + \frac{f_{rbx}}{F_{bcx}} + \frac{f_{rby}}{F_{bcy}}$ = 0.80

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