

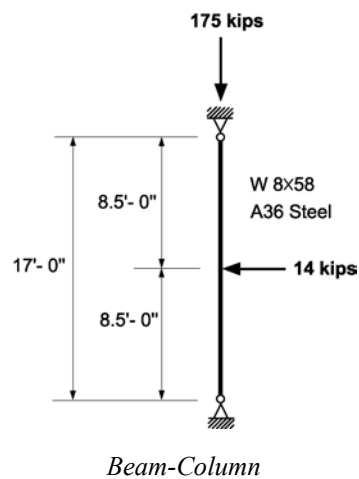
# AISC-LRFD93-1

## Title

Design of Beam-Column

## Description

The beam-column in Figure is pinned at both ends and subjected to the factored loads shown. Bending is about the strong axis. Investigate the acceptability of a W8×58 of A36 steel used as a beam-column.



### Theoretical Results (AISC-LRFD93)

The axial compressive design strength of a  $W8 \times 58$  of A36 steel with an effective length of  $K_y L = 1.0 \times 17 = 17$  ft is

$$\phi_c P_n = 318 \text{ kips}$$

For an unbraced length  $L_b = 17$  ft

$$\phi_b M_n = 151.5 \text{ ft-kips}$$

For the end conditions and loading of this problem,  $C_b = 1.32$

$$\phi_b M_n = 1.32(151.5) = 200.0 \text{ ft-kips}$$

But this is larger than  $\phi_b M_p = 161.5$  ft-kips, so the design moment must be limited to  $\phi_b M_p$ .

$$\phi_b M_p = 161.5 \text{ ft-kips}$$

The maximum bending moment occurs at midheight

$$M_u = \frac{14(17)}{4} = 59.5 \text{ ft-kips}$$

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9} \left( \frac{M_u}{\phi_b M_n} \right) = \frac{175}{318} + \frac{8}{9} \left( \frac{59.5}{161.5} \right) = 0.878 < 1.0 \quad \text{OK}$$

### Results by MIDAS/Gen

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MIDAS/Gen - Steel Code Checking [ AISC-LRFD93 ]  
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\*.DEFINITION OF LOAD COMBINATIONS WITH SCALING UP FACTORS.

-----  
LCB C Loadcase Name(Factor) + Loadcase Name(Factor) + Loadcase Name(Factor)  
-----

1 0 DL( 1.400)  
-----

\*. LOADCOMB NO = 1,

\*. UNIT SYSTEM : kip, ft

\*. SECTION PROPERTIES : Designation = W8x58

\*. DESIGN PARAMETERS FOR STRENGTH EVALUATION :

$$L_y = 1.70000\text{e}+001, \quad L_z = 1.70000\text{e}+001, \quad L_u = 1.70000\text{e}+001$$

$$K_y = 1.00000\text{e}+000, \quad K_z = 1.00000\text{e}+000$$

[[[\*]]] COMPUTE MOMENT MAGNIFICATION FACTORS AND MAGNIFIED MOMENTS.

( ). Factored force/moments caused by unit load case.

\*.Load combination ID = 1

( ). Compute moment magnification factors(B1y,B1z).

$$-. \text{ Pu} = \text{Pu}(\text{DL}+\text{LL}) + \text{Pu}(\text{WL}(\text{EL})) = 175.00 \text{ kip.}$$

-. About major(Local-y) axis.

$$\text{Cmy}(\text{User Defined or Default Value}) = 0.85$$

$$\text{SLEny} = K_y * L_y / R_{oy} = 55.89$$

$$\text{Lambda} = (\text{SLEny}/\pi) * \text{SQRT}(\text{Fy}/\text{Es}) = 0.6268$$

$$\text{Pey} = (\text{Area} * \text{Fy}) / \text{Lambda}^2 = 1566.82 \text{ kip.}$$

$$\text{B1y} = \text{Cmy} / (1 - \text{Pu}/\text{Pey}) = 0.96$$

$$\text{B1y} < 1.0 \text{ ---> } \text{B1y} = 1.00$$

-. About minor(Local-z) axis.

$$\text{Cmz}(\text{User Defined or Default Value}) = 0.85$$

$$\text{SLEnz} = K_z * L_z / R_{oz} = 97.14$$

$$\text{Lambda} = (\text{SLEnz}/\pi) * \text{SQRT}(\text{Fy}/\text{Es}) = 1.0895$$

$$\text{Pez} = (\text{Area} * \text{Fy}) / \text{Lambda}^2 = 518.65 \text{ kip.}$$

$$\text{B1z} = \text{Cmz} / (1 - \text{Pu}/\text{Pez}) = 1.28$$

( ). Given factored axial forces and moments at <1/2>.

Load Case	Pu	My	Mz
DL	-175.00	59.50	0.00
LL	0.00	0.00	0.00
DL+LL	-175.00	59.50	0.00
WL or EL	0.00	0.00	0.00
DL+LL+WL(EL)	-175.00	59.50	0.00

( ). Compute magnified moments.

$$-. \text{ Muy} = \text{B1y} * \text{My}(\text{DL}+\text{LL}) + \text{B2y} * \text{My}(\text{WL}(\text{EL})) = 59.50 \text{ kip-ft.}$$

$$-. \text{ Muz} = \text{B1z} * \text{Mz}(\text{DL}+\text{LL}) + \text{B2z} * \text{Mz}(\text{WL}(\text{EL})) = 0.00 \text{ kip-ft.}$$

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[[[\*]]] CHECK AXIAL STRENGTH.

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- ( ). Calculate axial compressive strength ( $\phi P_n$ ).  
 [ AISC-LRFD93 Specification E2. (E2-1), Appendix E3. (A-E3-1) ]  
 -.  $F_{cr} = \text{MIN}[ F_{cr1}, F_{cr2} ] = 3154.3593 \text{ kip/ft}^2$ .  
 -. Resistance factor for compression :  $\phi = 0.85$   
 -.  $\phi P_n = \phi \cdot A_{eff} \cdot F_{cr} = 318.39 \text{ kip}$ .
- ( ). Check ratio of axial strength ( $P_u/\phi P_n$ ).  

$$\frac{P_u}{\phi P_n} = \frac{175.00}{318.39} = 0.550 < 1.000 \text{ ---> O.K.}$$

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[[[\*]]] CHECK FLEXURAL STRENGTH ABOUT MAJOR AXIS.

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- ( ). Compute flexural strength about major axis ( $\phi M_n$ ).  
 [ AISC-LRFD93 Specification F1.2. ]  
 -.  $M_n = \text{MIN}[ M_{n1}, M_{n2}, M_{n3} ] = 179.40 \text{ kip-ft}$ .  
 -. Resistance factor for flexure :  $\phi = 0.90$   
 -.  $\phi M_n = \phi \cdot M_n = 161.46 \text{ kip-ft}$ .
- ( ). Check ratio of flexural strength ( $M_u/\phi M_n$ ).  

$$\frac{M_u}{\phi M_n} = \frac{59.50}{161.46} = 0.369 < 1.000 \text{ ---> O.K.}$$

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[[[\*]]] CHECK INTERACTION OF COMBINED STRENGTH.

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- ( ). Check interaction ratio of combined strength.  
 [ AISC-LRFD93 Specification H1.1. ]  
 -.  $P_u/\phi P_n > 0.20 \text{ ---> Formula (H1-1a)}$
- $$\begin{aligned} \text{-. ComRat} &= \frac{P_u}{\phi P_n} + \frac{8}{9} \left[ \frac{M_u}{\phi M_n} + \frac{M_{uz}}{\phi M_{nz}} \right] \\ &= 0.550 + (8/9) \cdot [ 0.369 + 0.000 ] \\ &= 0.877 < 1.000 \text{ ---> O.K.} \end{aligned}$$

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[+] Check Flange Local Buckling (FLB).

( ). Calculate limiting width-thickness ratios for FLB.
[ AISC-LRFD93 Specification B5.1. ]
-. For Rolled Shapes
-. Lambda_p(Lp) = 65/SQRT[Fy] = 10.83
-. Lambda_r(Lr) = 141/SQRT[Fy-10] = 27.65

( ). Check width-thickness ratio of flange (BTR).
[ AISC-LRFD93 Specification B5.1. ]
-. BTR = bf/2tf = 5.07 < Lambda_p ----> COMPACT.

( ). Compute nominal flexural strength (Mn2).
[ AISC-LRFD93 Specification Appendix F1. (A-F1-1) ]
-. Mn2 = Mp = 179.40 kip-ft.

( ). Compute flexural strength about major axis (phiMny).
[ AISC-LRFD93 Specification F1.2. ]
-. Mny = MIN[ Mn1, Mn2, Mn3 ] = 179.40 kip-ft.
-. Resistance factor for flexure, phi = 0.90
-. phiMny = phi*Mny = 161.46 kip-ft.

( ). Check ratio of flexural strength (Muy/phiMny).
-. Muy = 59.50
-. phiMny = 161.46 = 0.369 < 1.000 ----> O.K.

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[[[+]]] CHECK INTERACTION OF COMBINED STRENGTH.
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( ). Check interaction ratio of combined strength.
[ AISC-LRFD93 Specification H1.1. ]
-. Pu/phiPn > 0.20 ----> Formula (H1-1a)

-. ComRat = Pu/phiPn + 8/9 * [ Muy/phiMny + Muz/phiMnz ]
           = 0.877 + (8/9) * [ 0.369 + 0.000 ]
           = 0.877 < 1.000 ----> O.K.

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## Comparison of Results

	Reference	MIDAS/Gen
$\phi_c P_n$ (axial compressive strength)	318 kips	318 kips
$C_b$ (bending coefficient)	1.32	1.32
$M_u$ (maximum bending moment)	59.5 ft-kips	59.5 ft-kips
$\phi_b M_n$ (flexural strength)	161.5 ft-kips	161.5 ft-kips
$\frac{P_u}{\phi_c P_n} + \frac{8}{9} \left( \frac{M_u}{\phi_b M_n} \right)$	0.878	0.877
(interaction ratio of Combined strength)		

## Reference

WILLIAM T. SEGUI, "LRFD Steel Design", Example 6.1

# AISC-LRFD93-2

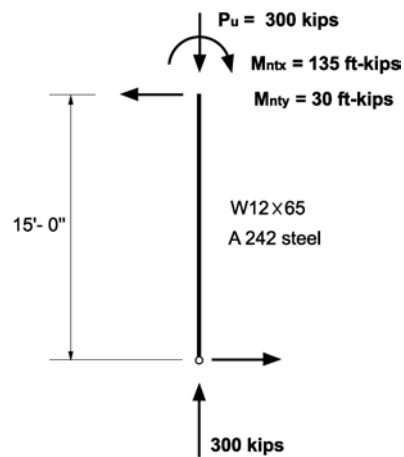
## Title

Design of Member in Braced Frames

## Description

Investigate the acceptability of a W12×65 of A242 steel used as a beam-column under the loading shown the Figure.

$$\begin{aligned}M_{ntx} &= 135 \text{ ft-kips} \\M_{nty} &= 30 \text{ ft-kips} \\P_u &= 300 \text{ kips} \\f_y &= 50 \text{ ksi}\end{aligned}$$



*Beam-column in braced frames*

## Theoretical Results (AISC-LRFD93)

Load Combination ID = 2  
1.2D+1.6L

Strong axis bending

$$C_{mx} = 0.6 - 0.4 \frac{M_1}{M_2} = 0.6 - 0.4(0) = 0.6$$

$$\frac{K_x L}{r_x} = \frac{15(12)}{5.28} = 34.09$$

$$P_{e1x} = \frac{\pi^2 E A_g}{(K_x L / r_x)^2} = \frac{\pi^2 (29,000)(19.1)}{(34.09)^2} = 4704 \text{ kips}$$

$$B_{1x} = \frac{C_{mx}}{1 - \frac{P_u}{P_{e1x}}} = \frac{0.6}{1 - \frac{300}{4704}} = 0.641 < 1.0 \quad \therefore \text{use } B_{1x} = 1.0.$$

$$M_{ux} = B_{1x} M_{nx} + B_{2x} M_{lx} = 1.0(135) + 0 = 135 \text{ ft-kips}$$

This is larger than  $\phi_b M_{px}$ ,  $\therefore$  use  $\phi_b M_{nx} = \phi_b M_{px} = 357.8 \text{ ft-kips}$ .

Weak-axis bending

$$C_{my} = 0.6 - 0.4 \frac{M_1}{M_2} = 0.6 - 0.4(0) = 0.6$$

$$\frac{K_y L}{r_y} = \frac{15(12)}{3.02} = 59.60$$

$$P_{e1y} = \frac{\pi^2 E A_g}{(K_y L / r_y)^2} = \frac{\pi^2 (29,000)(19.1)}{(59.60)^2} = 1539 \text{ kips}$$

$$B_{1y} = \frac{C_{my}}{1 - \frac{P_u}{P_{e1y}}} = \frac{0.6}{1 - \frac{300}{1539}} = 0.745 < 1.0 \quad \therefore \text{use } B_{1y} = 1.0$$

$$M_{uy} = B_{1y} M_{ny} + B_{2y} M_{ly} = 1.0(30) + 0 = 30 \text{ ft-kips}$$

Because the flange of this is noncompact, the weak-axis bending strength is limited by FLB.

$$\lambda = \frac{b_f}{2t_f} = 9.9$$

$$\lambda_p = \frac{65}{\sqrt{F_y}} = \frac{65}{\sqrt{50}} = 9.19$$

$$\lambda_r = \frac{141}{\sqrt{F_y - 10}} = \frac{141}{\sqrt{50 - 10}} = 22.29$$

Since  $\lambda_p < \lambda < \lambda_r$

$$\phi_b M_{ny} = 0.90(179.1) = 161.2 \text{ ft-kips}$$

Interaction of combined strength

$$\begin{aligned} \frac{P_u}{\phi_b P_n} + \frac{8}{9} \left( \frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}} \right) &= 0.4792 + \frac{8}{9} \left( \frac{135}{357.8} + \frac{30}{161.2} \right) \\ &= 0.980 < 1.0 \quad \text{OK} \end{aligned}$$

## Results by MIDAS/Gen

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MIDAS/Gen - Steel Code Checking [ AISC-LRFD93 ]  
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[[[*]]]  COMPUTE MOMENT MAGNIFICATION FACTORS AND MAGNIFIED
          MOMENTS.
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\*. UNIT SYSTEM : kip, ft

( ). Factored force/moments caused by unit load case.

\*.Load combination ID = 2

\*.Member end moments caused by gravity load(DL+LL).

M1yG = 0.00, M2yG = 135.00

M1zG = 0.00, M2zG = 30.00

( ). Compute moment magnification factors(B1y,B1z).

-. About major(Local-y) axis.

-. Single Curvature Bending.

Cmy = 0.6 - 0.4\*(M1yG/M2yG) = 0.60

SLEny = Ky\*Ly / Roy = 34.09

Lambda = (SLEny/pi)\*SQRT(Fy/Es) = 0.4506

Pey = (Area\*Fy)/Lambda^2 = 4703.86 kip.

B1y = Cmy / (1-Pu/Pey) = 0.64



$$\begin{aligned}
 B1y &< 1.0 \rightarrow B1y = 1.00 \\
 \text{-. About minor(Local-z) axis.} \\
 \text{-. Single Curvature Bending.} \\
 Cmz &= 0.6 - 0.4*(M1zG/M2zG) = 0.60 \\
 SLEnz &= Kz*Lz / Roz = 59.60 \\
 Lambda &= (SLEnz/pi)*SQRT(Fy/Es) = 0.7878 \\
 Pez &= (Area*Fy)/Lambda^2 = 1538.86 \text{ kip.} \\
 B1z &= Cmz / (1-Pu/Pez) = 0.75 \\
 B1z &< 1.0 \rightarrow B1z = 1.00
 \end{aligned}$$

( ). Given factored axial forces and moments at <J>.

Load Case	Pu	My	Mz
DL	-108.00	0.00	10.80
LL	-192.00	135.00	19.20
DL+LL	-300.00	135.00	30.00
WL or EL	0.00	0.00	0.00
DL+LL+WL(EL)	-300.00	135.00	30.00

( ). Compute magnified moments.

$$\begin{aligned}
 \text{-. } M_{uy} &= B1y*My(DL+LL) + B2y*My(WL(EL)) = 135.00 \text{ kip-ft.} \\
 \text{-. } M_{uz} &= B1z*Mz(DL+LL) + B2z*Mz(WL(EL)) = 30.00 \text{ kip-ft.}
 \end{aligned}$$

[[[\*]]] CHECK AXIAL STRENGTH.

( ). Calculate axial compressive strength ( $\phi P_n$ ).

[ AISC-LRFD93 Specification E2. (E2-1), Appendix E3. (A-E3-1) ]

$$\begin{aligned}
 \text{-. } F_{cr} &= \text{MIN}[ F_{cr1}, F_{cr2} ] = 5552.9743 \text{ kip/ft}^2. \\
 \text{-. Resistance factor for compression : } \phi &= 0.85 \\
 \text{-. } \phi P_n &= \phi * \text{Area} * F_{cr} = 626.06 \text{ kip.}
 \end{aligned}$$

( ). Check ratio of axial strength ( $P_u/\phi P_n$ ).

$$\text{-. } \frac{P_u}{\phi P_n} = \frac{300.00}{626.06} = 0.479 < 1.000 \rightarrow \text{O.K.}$$

[[[\*]]] CHECK FLEXURAL STRENGTH ABOUT MAJOR AXIS.

( ). Compute flexural strength about major axis ( $\phi M_n$ ).

[ AISC-LRFD93 Specification F1.2. ]

- $M_{ny} = \text{MIN}[M_{n1}, M_{n2}, M_{n3}] = 397.23 \text{ kip-ft.}$
- Resistance factor for flexure :  $\phi = 0.90$
- $\phi M_{ny} = \phi * M_{ny} = 357.51 \text{ kip-ft.}$

( ). Check ratio of flexural strength ( $M_{uy}/\phi M_{ny}$ ).

$$-\frac{M_{uy}}{\phi M_{ny}} = \frac{135.00}{357.51} = 0.378 < 1.000 \text{ ---> O.K.}$$

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[[[\*]]] CHECK FLEXURAL STRENGTH ABOUT MINOR AXIS.

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( ). Compute flexural strength about minor axis ( $\phi M_{nz}$ ).

[ AISC-LRFD93 Specification F1.2. ]

- $M_{nz} = 178.52 \text{ kip-ft.}$
- Resistance factor for flexure :  $\phi = 0.90$
- $\phi M_{nz} = \phi * M_{nz} = 160.67 \text{ kip-ft.}$

( ). Check ratio of flexural strength ( $M_{uz}/\phi M_{nz}$ ).

$$-\frac{M_{uz}}{\phi M_{nz}} = \frac{30.00}{160.67} = 0.187 < 1.000 \text{ ---> O.K.}$$

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[[[\*]]] CHECK INTERACTION OF COMBINED STRENGTH.

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( ). Check interaction ratio of combined strength.

[ AISC-LRFD93 Specification H1.1. ]

- $P_u/\phi P_n > 0.20 \text{ ---> Formula (H1-1a)}$

$$\begin{aligned}
 - \text{ComRat} &= \frac{P_u}{\phi P_n} + \frac{8}{9} \left[ \frac{M_{uy}}{\phi M_{ny}} + \frac{M_{uz}}{\phi M_{nz}} \right] \\
 &= 0.479 + (8/9) * [ 0.378 + 0.187 ] \\
 &= 0.981 < 1.000 \text{ ---> O.K.}
 \end{aligned}$$

## Verification Example

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MIDAS/Text Editor - [Design_4.acs]
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00331  [[(+)]] CHECK FLEXURAL STRENGTH ABOUT MINOR AXIS.
00332  =====
00333
00334
00335  ( ). Compute plastic bending moment (Mp).
00336  [ AISI-LRFD93 Specification Appendix F1, Table A-F1.1 ]
00337  -. Mp = MIN[ Fy*Zzz, 1.5*Fy*Szz ] = 181.88 kip-ft.
00338
00339  ( ). Compute limiting buckling moment (Mr).
00340  [ AISI-LRFD93 Specification Appendix F1, Table A-F1.1 ]
00341  -. Mr = Fy*Szz = 121.25 kip-ft.
00342
00343  [+ ] Check Flange Local Buckling (FLB).
00344  =====
00345
00346  ( ). Calculate limiting width-thickness ratios for FLB.
00347  [ AISI-LRFD93 Specification B5.1. ]
00348  -. For Rolled Shapes
00349  -. Lambda_p(Lp) = 65/SQRT[Fy] = 9.19
00350  -. Lambda_r(Lr) = 141/SQRT[Fy-10] = 22.29
00351
00352  ( ). Check width-thickness ratio of flange (BTR).
00353  [ AISI-LRFD93 Specification B5.1. ]
00354  -. BTR = bf/2tf = 9.92 < Lambda_r ----> NON COMPACT.
00355  ♀
00356  =====
00357  MIDAS/Gen - Steel Code Checking [ AISI-LRFD93 ]
00358  =====
00359
00360  ( ). Compute nominal flexural strength (Mn).
00361  [ AISI-LRFD93 Specification Appendix F1, (A-F1-3) ]
00362  (BTR-Lp)
00363  -. Mo = Mp - (Mp-Mr) * (BTR-Lp) / (Lp-Lr) = 178.52 kip-ft.
00364  -. Mn = MIN[ Mo, Mp ] = 178.52 kip-ft.
00365
00366  ( ). Compute flexural strength about minor axis (phiMnz).
00367  [ AISI-LRFD93 Specification F1.2. ]
00368  -. Mnz = 178.52 kip-ft.
00369  -. Resistance factor for flexure, phi = 0.90
00370  -. phiMnz = phi*Mnz = 160.67 kip-ft.
00371
00372  ( ). Check ratio of flexural strength (Muz/phiMnz).
00373  Muz = 30.00
00374  -. Muz / phiMnz = 30.00 / 160.67 = 0.187 < 1.000 ----> O.K.
00375
00376  =====
00377  [[(+)]] CHECK INTERACTION OF COMBINED STRENGTH.
00378  =====
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00380  ( ). Check interaction ratio of combined strength.
00381  [ AISI-LRFD93 Specification H1.1. ]
00382  -. Pu/phiPn > 0.20 ----> Formula (H1-1a)
00383
00384  -. ComRat = Pu / phiPn + 8 / 9 * [ Mux / phiMnx + Muz / phiMnz ]
00385  = 0.428 + (8/9) * [ 0.378 + 0.187 ]
00386  = 0.981 < 1.000 ----> O.K.
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## Comparison of Results

	Reference	MIDAS/Gen
$C_{mx}$ (equivalent moment correction factor)	0.6	0.6
$P_{e1x}$ (elastic Euler buckling load)	4,704 kips	4,704 kips
$M_{ux}$ (service loads about major axis)	135 ft-kips	135 ft-kips
$\phi_b M_{nx}$ (flexural strength about major axis)	357.8 ft-kips	357.5 ft-kips
$M_{uy}$ (service loads about minor axis)	30 ft-kips	30 ft-kips
$\phi_b M_{ny}$ (flexural strength about minor axis)	161.2 ft-kips	160.7 ft-kips
$\frac{P_u}{\phi_b P_n} + \frac{8}{9} \left( \frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}} \right)$ (interaction ratio of combined strength)	0.980	0.981

## Reference

WILLIAM T. SEGUI, "LRFD Steel Design", Example 6.6

# AISC-LRFD93-3

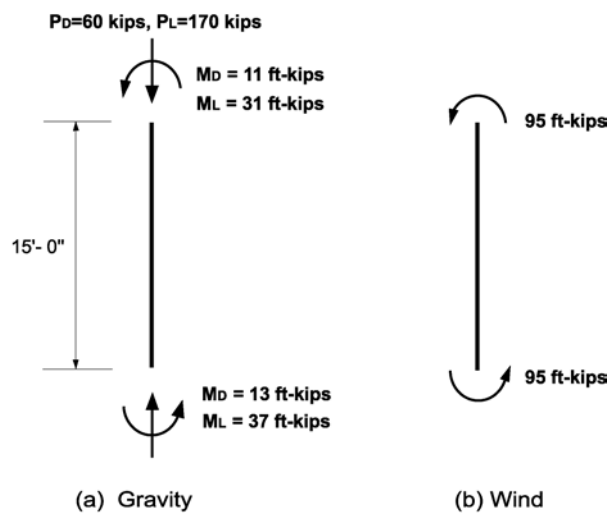
## Title

Design of Member in Unbraced Frames

## Description

Investigate the acceptability of a  $W12 \times 65$  of A36 steel used as a beam-column in unbraced frames. The axial load and end moments obtained from a first order analysis of the gravity loads (dead load and live load) are shown in Figure (a). The frame is symmetric, and the gravity loads are symmetrically placed.

Figure (b) shows the wind load moments obtained from a first-order analysis. All bending moments are about the strong axis. Effective length factors are  $K_x = 1.0$  for the nonsway case, and  $K_y = 1.0$ .



*Beam-column in unbraced frames*

## Theoretical Results (AISC-LRFD93)

Load Combination ID = 2  
1.2D+1.6L

For this load condition,  $P_u = 344.0$  kips,  $M_{nt} = 74.80$  ft-kips, and  $M_{lt} = 0$  (because of symmetry, there are no sidesway moments).

$$C_{mx} = 0.6 - 0.4 \frac{M_1}{M_2} = 0.6 - 0.4 \left( \frac{62.80}{74.80} \right) = 0.2642$$

For the axis of bending,

$$\frac{KL}{r} = \frac{K_x L}{r_x} = \frac{15(12)}{5.28} = 34.09$$

(Since this is the no-sidesway case,  $K_x$  for the braced condition is used.)

$$P_{elx} = \frac{\pi^2 EA_g}{(KL/r)^2} = \frac{\pi^2 (29,000)(19.1)}{(34.09)^2} = 4,704 \text{ kips}$$

$$B_1 = \frac{C_m}{1 - \frac{P_u}{P_{elx}}} = \frac{0.2642}{1 - \frac{344.0}{4,704}} = 0.285 < 1.0 \quad \therefore \text{use } B_1 = 1.0$$

$$M_u = B_1 M_{nt} + B_2 M_{lt} = 1.0(74.80) + 0 = 74.80 \text{ ft-kips}$$

$$\begin{aligned} C_b &= \frac{12.5 M_{\max}}{2.5 M_{\max} + 3 M_A + 4 M_A + 3 M_C} \\ &= \frac{12.5(74.80)}{2.5(74.80) + 3(28.40) + 4(6.002) + 3(40.40)} \\ &= 2.24 \end{aligned}$$

For  $C_b = 2.24$ ,

$$\phi_b M_n = 2.24(254.5) > \phi_b M_p = 261.4 \text{ ft-kips}$$

$$\therefore \text{use } \phi_b M_n = 261.4 \text{ ft-kips}$$

Determine the critical axis for axial compressive strength

$$K_y L = 15 \text{ ft}$$

$$\frac{K_x L}{r_x / r_y} = \frac{1.2(15)}{1.75} = 10.29 \text{ ft} < 15 \text{ ft} \quad \therefore \text{use } KL = 15 \text{ ft}$$

From the Column Load Tables, with  $KL = 15$  ft ,  $\phi_c P_n = 485$  kips.

$$\frac{P_u}{\phi_c P_n} = \frac{344.0}{485} = 0.7903 > 0.2$$

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9} \left( \frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}} \right) = 0.793 + \frac{8}{9} \left( \frac{74.80}{261.4} + 0 \right) = 0.964 < 1.0 \quad \text{OK}$$

## Results by the MIDAS/Gen

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MIDAS/Gen - Steel Code Checking [ AISC-LRFD93 ]

=====

\*.DEFINITION OF LOAD COMBINATIONS WITH SCALING UP FACTORS.

LCB	C	Loadcase Name(Factor) + Loadcase Name(Factor) + Loadcase Name(Factor)
1	0	DL( 1.400)
2	0	DL( 1.200) + LL( 1.600)
3	0	DL( 1.200) + W( 1.300) + LL( 0.500)
4	0	DL( 0.900) + W( 1.300)
5	0	DL( 0.900) + W(-1.300)

\*. LOADCOMB NO = 2      \*. UNIT SYSTEM : kip, ft

\*. SECTION PROPERTIES : Designation = W12x65

\*. DESIGN PARAMETERS FOR STRENGTH EVALUATION :

Ly = 1.50000e+001, Lz = 1.50000e+001, Lu = 1.50000e+001

Ky = 1.00000e+000, Kz = 1.00000e+000

=====  
 [[[\*]]] COMPUTE MOMENT MAGNIFICATION FACTORS AND MAGNIFIED  
 MOMENTS.  
 =====

( ). Factored force/moments caused by unit load case.

\*.Load combination ID = 2

Load Case	Pu	Myi
DL+LL+WL(EL)	-344.00	-74.80

\*.Member end moments caused by gravity load (DL+LL).

$$\begin{aligned} M1yG &= 62.80, & M2yG &= -74.80 \\ M1zG &= 0.00, & M2zG &= 0.00 \end{aligned}$$

( ). Compute moment magnification factors( $B1y, B1z$ ).

$$\begin{aligned} C_{my} &= 0.6 - 0.4 \cdot (M1yG/M2yG) = 0.26 \\ SLE_{Ny} &= K_y \cdot L_y / R_{oy} = 34.09 \\ \lambda &= (SLE_{Ny}/\pi) \cdot \sqrt{F_y/E_s} = 0.3823 \\ P_{ey} &= (Area \cdot F_y) / \lambda^2 = 4703.86 \text{ kip.} \\ B1y &= C_{my} / (1 - P_u/P_{ey}) = 0.29 \\ B1y &< 1.0 \text{ ---> } B1y = 1.00 \end{aligned}$$

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[[[\*]]] CHECK AXIAL STRENGTH.

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( ). Calculate axial compressive strength ( $\phi P_n$ ).

$$\begin{aligned} &[ \text{AISC-LRFD93 Specification E2. (E2-1), Appendix E3. (A-E3-1) } ] \\ - . F_{cr} &= \text{MIN}[ F_{cr1}, F_{cr2} ] = 4299.7586 \text{ kip/ft}^2. \\ - . \text{Resistance factor for compression : } \phi &= 0.85 \\ - . \phi P_n &= \phi \cdot Area \cdot F_{cr} = 484.77 \text{ kip.} \end{aligned}$$

( ). Check ratio of axial strength ( $P_u/\phi P_n$ ).

$$\begin{aligned} P_u &= 344.00 \\ - . \frac{P_u}{\phi P_n} &= \frac{344.00}{484.77} = 0.710 < 1.000 \text{ ---> O.K.} \end{aligned}$$

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[[[\*]]] CHECK FLEXURAL STRENGTH ABOUT MAJOR AXIS.

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( ). Compute plastic bending moment ( $M_p$ ).

$$\begin{aligned} &[ \text{AISC-LRFD93 Specification F1.1. (F1-1) } ] \\ - . M_p &= \text{MIN}[ F_y \cdot Z_{yy}, 1.5 \cdot F_y \cdot S_{yy} ] = 290.40 \text{ kip-ft.} \end{aligned}$$

( ). Compute limiting buckling moment ( $M_r$ ).

$$\begin{aligned} &[ \text{AISC-LRFD93 Specification F1.1. (F1-7) } ] \\ - \text{For rolled shapes : } F_r &= 10.0 \text{ ksi.} \\ F_o &= \text{MIN}[ F_{yw}, F_{yf} - F_r ] = 3744.0000 \text{ kip/ft}^2. \\ - . M_r &= F_o \cdot S_{yy} = 190.45 \text{ kip-ft.} \end{aligned}$$

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[\*] Check Web Local Buckling (WLB).

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( ). Check width-thickness ratio of web (DTR).



[ AISC-LRFD93 Specification B5.1. ]  
 -. DTR =  $h_c/t_w = 27.97 < \lambda_{p\_}$  ---> COMPACT.

( ). Compute nominal flexural strength ( $M_{n3}$ ).  
 [ AISC-LRFD93 Specification Appendix F1. (A-F1-1) ]  
 -.  $M_{n3} = M_p = 290.40$  kip-ft.

-----  
 [\*] Check Lateral-Torsional Buckling (LTB).  
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( ). Calculate bending coefficient ( $C_b$ ).  
 [ AISC-LRFD93 Specification F1.2a. (C-F1-3) ]  
 -.  $M_{max} = 74.80$  kip-ft. (Maximum moment).  
 -.  $M_A = 40.40$  kip-ft. (Moment at quarter point).  
 -.  $M_B = 6.00$  kip-ft. (Moment at centerline).  
 -.  $M_C = 28.40$  kip-ft. (Moment at three-quarter point).  
 -.  $C_b = 12.5 * M_{max} / (2.5 * M_{max} + 3 * M_A + 4 * M_B + 3 * M_C) = 2.240$

( ). Compute nominal flexural strength ( $M_{n1}$ )  
 [ AISC-LRFD93 Specification F1.2a. (F1-2) ]  
 -.  $M_n = C_b \left[ M_p - (M_p - M_r) \frac{(L_u - L_p)}{(L_r - L_p)} \right] = 633.63$  kip-ft.  
 -.  $M_{n1} = \text{MIN}[ M_n, M_p ] = 290.40$  kip-ft.

-----  
 [\*] Check Flange Local Buckling (FLB).  
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( ). Check width-thickness ratio of flange (BTR).  
 [ AISC-LRFD93 Specification B5.1. ]  
 -. BTR =  $b_f/2t_f = 9.92 < \lambda_{p\_}$  ---> COMPACT.

( ). Compute nominal flexural strength ( $M_{n2}$ ).  
 [ AISC-LRFD93 Specification Appendix F1. (A-F1-1) ]  
 -.  $M_{n2} = M_p = 290.40$  kip-ft.

( ). Compute flexural strength about major axis ( $\phi M_{ny}$ ).  
 [ AISC-LRFD93 Specification F1.2. ]  
 -.  $M_{ny} = \text{MIN}[ M_{n1}, M_{n2}, M_{n3} ] = 290.40$  kip-ft.  
 -. Resistance factor for flexure :  $\phi = 0.90$   
 -.  $\phi M_{ny} = \phi * M_{ny} = 261.36$  kip-ft.

( ). Check ratio of flexural strength ( $M_u/\phi M_n$ ).

$$-\frac{M_u}{\phi M_n} = \frac{74.80}{261.36} = 0.286 < 1.000 \rightarrow \text{O.K.}$$

=====  
 [[[\*]]] CHECK INTERACTION OF COMBINED STRENGTH.  
 =====

( ). Check interaction ratio of combined strength.  
 [ AISC-LRFD93 Specification H1.1. ]  
 -.  $P_u/\phi P_n > 0.20$   
 -. ComRat =  $\frac{P_u}{\phi P_n} + \frac{8}{9} \left[ \frac{M_u}{\phi M_n} + \frac{M_{uz}}{\phi M_{nz}} \right]$   
 $= 0.710 + (8/9) * [ 0.286 + 0.000 ]$   
 $= 0.964 < 1.000 \rightarrow \text{O.K.}$

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MIDAS/Text Editor - [Design_5.acs]
File Edit View Window Help
[+] Check Flange Local Buckling (FLB).

( ). Calculate limiting width-thickness ratios for FLB.
[ AISC-LRFD93 Specification B5.1. ]
-. For Rolled Shapes
-. Lambda_p(Lp) = 65/SQRT[Fy] = 10.83
-. Lambda_r(Lr) = 141/SQRT[Fy-10] = 27.65

( ). Check width-thickness ratio of flange (BTR).
[ AISC-LRFD93 Specification B5.1. ]
-. BTR = bf/2tf = 9.92 < Lambda_p ---> COMPACT.

( ). Compute nominal flexural strength (Mn2).
[ AISC-LRFD93 Specification Appendix F1. (A-F1-1) ]
-. Mn2 = Mp = 290.40 kip-ft.

( ). Compute flexural strength about major axis (phiMn).
[ AISC-LRFD93 Specification F1.2. ]
-. Mn = MIN[ Mn1, Mn2, Mn3 ] = 290.40 kip-ft.
-. Resistance factor for flexure, phi = 0.90
-. phiMn = phi*Mn = 261.36 kip-ft.

( ). Check ratio of flexural strength (Mu/phiMn).
-. Mu/phiMn = 74.80/261.36 = 0.286 < 1.000 ---> O.K.

=====[[*]]====
CHECK INTERACTION OF COMBINED STRENGTH.
=====

( ). Check interaction ratio of combined strength.
[ AISC-LRFD93 Specification H1.1. ]
-. Pu/phiPn > 0.20 ---> Formula (H1-1a)

-. ComRat = Pu/phiPn + 8/9 * [ Mu/phiMn + Muz/phiMnz ]
           0.710 + (8/9) * [ 0.286 + 0.000 ]
           0.964 < 1.000 ---> O.K.
  
```

## Comparison of Results

	Reference	MIDAS/Gen
$C_{mx}$ (equivalent moment correction factor)	0.26	0.26
$M_u$ (service loads)	74.80 ft-kips	74.80 ft-kips
$C_b$ (bending coefficient)	2.24	2.24
$\phi_b M_n$ (flexural strength)	261.4 ft-kips	261.4 ft-kips
$\phi_c P_n$ (axial compressive strength)	485 kips	485 kips
$\frac{P_u}{\phi_b P_n} + \frac{8}{9} \left( \frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}} \right)$ (interaction ratio of combined strength)	0.964	0.964

## Reference

WILLIAM T. SEGUI, *LRFD Steel Design*, Example 6.7