Hand Calculation

Problem Statement:
Determine if HSS 8 x 6 x 1/4 steel column is safe and meet all the required demands

Column size: HSS 8 x 6 x 1/4
Column Height $L := 18\ ft$
Axial Dead load $D_L := 29\ kip$
Axial Live load $L_L := 50\ kip$
Girt Wind load (parallel to Y-axis) $W_L := 5\ kip$
Wind load location above base $Y := 9\ ft$
Beam Stabilility Flexure about X-X $L_{ux} := 18\ ft$
Buckling unbraced length about X-X $L_{uxx} := 18\ ft$ (strong axis)
Buckling unbraced length about Y-Y $L_{uyy} := 9\ ft$ (weak axis)
A500 Grade C material Yield strength $F_y := 50\ ksi$
Steel Modulus of Elasticity $E := 29000\ ksi$
Use AISC 360-22 for properties of HSS 8 x 6 x 1/4
Design Method: ASD
Column is pinned at the top and at the bottom
$K_x := 1$ and $K_y := 1$

Solution:

Step 1: Calculate Max Axial Load

$$P_{u1} := D_L + L_L = 79\ kip$$

Axial Wind Load is zero, hence, $W := 0\ kip$

$$P_{u2} := D_L + 0.75 \cdot L_L + 0.45 \cdot W = 66.5\ kip$$

Step 2: Calculate Max Applied Moment (X-X Strong Axis)

$a := 9\ ft$
$b := 9\ ft$

$$M_W := \frac{W_L \cdot a \cdot b}{L} = 22.5\ kip \cdot ft$$

Moment due to dead load $M_{DL} := 0\ kip \cdot ft$
Moment due to live load $M_{LL} := 0\ kip \cdot ft$

$$M_{x\_x1} := M_{DL} + 0.6 \cdot M_W = 13.5\ kip \cdot ft$$

$$M_{x\_x2} := M_{DL} + 0.75 \cdot M_{LL} + 0.45 \cdot M_W = 10.125\ (kip \cdot ft)$$

Step 3: Calculate Max Applied Shear (X-X Strong Axis)

$V_W := \frac{W_L}{2} = 2.5\ kip$

Applied Shear due to dead load $V_{DL} := 0\ kip$

$V_{x\_x} := V_{DL} + 0.6 \cdot V_W = 1.5\ kip$

Step 4: Axial Design- Check member for Slender Elements (AISC-SPEC Table B4.1a)

From AISC-Table 1-11, we obtain the following:
Wall 1 - Width to thickness ratio
$\lambda_1 := 31.3$

Wall 2 - Width to thickness ratio
$\lambda_2 := 22.8$

The limiting width to thickness ratio

$\lambda_r := 1.4 \cdot \sqrt{\frac{E}{F_y}} = 33.72$

λ_1 and λ_2 are smaller than λ_r; hence, the walls of the HSS section are non-slender

Step 5: Axial Design-Check the controlling slenderness Ratio

Radius of Gyration $r_x := 3.03\ in$
Radius of Gyration $r_y := 2.43\ in$

Effective Slenderness Ratio about X-X axis:

$\frac{K_x \cdot L_{uxx}}{r_x} = 71.287$

Effective Slenderness Ratio about Y-Y axis:

$\frac{K_y \cdot L_{uyy}}{r_y} = 44.444$

The controlling slenderness ratio axis is the X-X axis, hence
$L_c := K_x \cdot L_{uxx}$ $r := r_x$

$\frac{L_c}{r} = 71.287$

Step 6: Axial Design- Determine the Flexural Elastic Buckling Stress

Elastic Buckling Stress, $F_e := \dfrac{\pi^2 \cdot E}{\left(\dfrac{L_c}{r}\right)^2} = 56.32\ ksi$

$\dfrac{F_y}{F_e} = 0.888$ < 2.25

Hence, we use AISC SPEC Eq E3-2 to determine the Nominal Flexural Buckling stress, F_n

$$F_n := \left(0.658^{\frac{F_y}{F_e}}\right) \cdot F_y = 34.48\ ksi$$

Step 7: Axial Design - Determine the Nonimal Compressive Strength

$A_g := 6.17 \cdot in^2$

$P_n := F_n \cdot A_g = 212.76\ kip$

Step 8: Axial Design - Determine the Allowable Compressive Strength

$\Omega := 1.67$

$P_{all} := \dfrac{P_n}{\Omega} = 127.399\ kip$

Step 9: Flexural Design - Determine the Nominal Flexural Strength due to Yielding limit state

From AISC Table 1-11, the plastic section modulus $Z_x := 16.9\ in^3$

$M_{n\_yield} := Z_x \cdot F_y = 845\ kip \cdot in$ (SPEC Eq F7-1)

Note: Member flange and web are compact. Hence, Nominal Flexural Strength due to web and flange local buckling does not apply to this section (SPEC F7-2 and F7-3 do not apply)

Step 10: Flexural Design- Determine the Nominal Flexrual Strength due to Lateral Torsional Buckling (LTB)

Beam Stability Flexure about X-X: $L_{ux} = 18\ ft$

From AISC SPEC Section F7-4: $L_{ux} = 216\ in$

From AISC Table 1-11: $J := 70.3\ in^4$

$M_p := Z_x \cdot F_y = 845\ kip \cdot in$

$L_p := 0.13 \cdot E \cdot r_y \cdot \frac{\sqrt{J \cdot A_g}}{M_p} = 225.793\ in$ (SPEC Eq F7-12)

L_{ux} < L_p ; hence, the limit state of lateral torsional buckling does not control

Step 11: Determine the Allowable Flexural Capacity

$\Omega = 1.67$

$M_{nx} := M_{n\_yield} = 845\ kip \cdot in$

$M_{x\_all} := \frac{M_{nx}}{\Omega} = 42.166\ kip \cdot ft$

Step 12: Determine the Nominal Shear Strength

$K_v := 5$

$\frac{h}{t_w} = 31.3$

$1.1 \cdot \sqrt{\frac{K_v \cdot E}{F_y}} = 59.24$

31.3 < 59.24 ; hence, $C_{V2} := 1$ based on AISC SPEC Eq G2-9

$A_w := 3.4\ in^2$

$V_n := 0.6 \cdot F_y \cdot A_w \cdot C_{V2} = 102\ kip$

Step 13: Determine the Allowable Shear Strength

$\Omega = 1.67$

$V_{x\_all} := \frac{V_n}{\Omega} = 61.08\ kip$

Step 14: Demand to Capacity Ratio Check

- Axial check:

$P_{u1} = 79\ kip$ $P_{u2} = 66.5\ kip$

$DCR_{axial1} := \frac{P_{u1}}{P_{all}} = 0.62$ < 1 **PASS** ✔

$DCR_{axial2} := \frac{P_{u2}}{P_{all}} = 0.52$ < 1 **PASS** ✔

- Flexural Check:

$DCR_{flex1} := \frac{M_{x\_x1}}{M_{x\_all}} = 0.32$ < 1 **PASS** ✔

$DCR_{flex2} := \frac{M_{x\_x2}}{M_{x\_all}} = 0.24$ < 1 **PASS** ✔

- Shear Check:

$DCR_{shear} := \frac{V_{x\_x}}{V_{x\_all}} = 0.025$ < 1 **PASS** ✔

- Combined Loading Check:

This check only applies with the factoral loads based on the controlling load combination
In this example, the controlling load combination is:

$D + 0.75 \cdot L + 0.45 \cdot W$

Based on AISC SPEC Section H 1. 1, we must check $\frac{P_r}{P_c}$ ratio to determine which interaction equation to use

$P_r := P_{u2} = 66.5\ kip$ $\quad P_c := P_{all} = 127.399\ kip$

$\frac{P_r}{P_c} = 0.522$ > 0.2

Hence, use Equation H1-a

$DCR_{comb} := \frac{P_r}{P_c} + \frac{8}{9} \cdot \frac{M_{x\_x2}}{M_{x\_all}} = 0.735$ < 1 **PASS** ✔

Step 15: Lateral Deflection Check

Lateral Deflection Limit: $\frac{L}{360} = 0.6\ in$

From AISC Table 1-11, $I := 56.6\ in^4$

$\Delta := \frac{W_L \cdot L^3}{48 \cdot E \cdot I} = 0.64\ in$

The controlling load combination for deflection is

$\Delta_w := 0.42 \cdot \Delta = 0.269\ in$ < 0.64 **PASS** ✔

See the following ENERCALC printed calc report for comparison

Steel Column

Project File: Steel Column.ec6

DESCRIPTION: Steel Column Calculation

Code References

Governing Code : IBC 2027
Referenced Design Standard(s) : AISC 360-22
Load Combinations Used : IBC 2018

General Information

Steel Section Name : **HSS8x6x1/4**
Analysis Method : Allowable Strength
Steel Stress Grade , A500, Grade C, Fy = 50 ksi, Carbon Steel
Fy : Steel Yield 50.0 ksi
E : Elastic Bending Modulus 29,000.0 ksi

Overall Column Height 18.0 ft
Top & Bottom Fixity Top & Bottom Pinned
Brace condition :
Unbraced Length for buckling ABOUT X-X Axis = 18.0 ft, K = 1.0
Unbraced Length for buckling ABOUT Y-Y Axis = 9 ft, K = 1.0

Applied Loads

Service loads entered. Load Factors will be applied for calculations.

AXIAL LOADS . . .
Gravity Roof Loads: Axial Load at 18.0 ft, D = 29.0, L = 50.0 k
BENDING LOADS . . .
Lat. Point Load at 9.0 ft creating Mx-x, W = 5.0 k

DESIGN SUMMARY

Bending & Shear Check Results

PASS Max. Axial+Bending Stress Ratio =	**0.7340**	: 1
Load Combination	+D+0.750L+0.450W	
Location of max.above base	8.940	ft
At maximum location values are . . .		
Pa : Axial	66.50	k
Pn / Omega : Allowable	127.399	k
Ma-x : Applied	10.057	k-ft
Mn-x / Omega : Allowable	42.166	k-ft
Ma-y : Applied	0.0	k-ft
Mn-y / Omega : Allowable	34.681	k-ft
PASS Maximum Shear Stress Ratio	**0.02454**	: 1
Load Combination	+D+0.60W	
Location of max.above base	9.060	ft
At maximum location values are . . .		
Va : Applied	1.50	k
Vn / Omega : Allowable	61.119	k

Maximum Load Reactions . .

Top along X-X	0.0	k
Bottom along X-X	0.0	k
Top along Y-Y	1.50	k
Bottom along Y-Y	1.50	k

Maximum Load Deflections . . .

Along Y-Y 0.2713 in at 9.060 ft above base
for load combination : +D+0.420W

Along X-X 0.0 in at 0.0 ft above base
for load combination :

Load Combination Results

Load Combination	Maximum Axial + Bending Stress Ratios Stress Ratio	Status	Location	Cbx	Cby	KxLx/Rx	KyLy/Ry	Maximum Shear Ratios Stress Ratio	Status	Location
D Only	0.228	PASS	0.00 ft	1.00	1.00	71.29	44.44	0.000	PASS	0.00 ft
+D+L	0.620	PASS	0.00 ft	1.00	1.00	71.29	44.44	0.000	PASS	0.00 ft
+D+0.750L	0.522	PASS	0.00 ft	1.00	1.00	71.29	44.44	0.000	PASS	0.00 ft
+D+0.60W	0.510	PASS	8.94 ft	1.00	1.00	71.29	44.44	0.025	PASS	9.06 ft
+D+0.750L+0.450W	0.734	PASS	8.94 ft	1.00	1.00	71.29	44.44	0.018	PASS	0.00 ft
+0.60D+0.60W	0.386	PASS	8.94 ft	1.00	1.00	71.29	44.44	0.025	PASS	9.06 ft
+0.60D	0.137	PASS	0.00 ft	1.00	1.00	71.29	44.44	0.000	PASS	9.06 ft

Maximum Reactions

Note: Only non-zero reactions are listed.

Load Combination	Axial (k) @ Base	Rx (k) @ Base	Rx (k) @ Top	Ry (k) @ Base	Ry (k) @ Top	Mx (k-ft) @ Base	Mx (k-ft) @ Top	My (k-ft) @ Base	My (k-ft) @ Top
D Only	29.000								
+D+L	79.000								
+D+0.750L	66.500								
+D+0.60W	29.000			-1.500	-1.500				
+D+0.750L+0.450W	66.500			-1.125	-1.125				
+0.60D+0.60W	17.400			-1.500	-1.500				
+0.60D	17.400								

Steel Column

DESCRIPTION: Steel Column Calculation

Extreme Reactions

Item	Extreme Value	Axial (k) @ Base	Rx (k) @ Base	Rx (k) @ Top	Ry (k) @ Base	Ry (k) @ Top	Mx (k-ft) @ Base	Mx (k-ft) @ Top	My (k-ft) @ Base	My (k-ft) @ Top
Axial, Base Max		79.000								
Axial, Base Min		17.400								
Rx, Base Max										
Rx, Base Min										
Rx, Top Max										
Rx, Top Min										
Ry, Base Max										
Ry, Base Min					-1.500					
Ry, Top Max										
Ry, Top Min						-1.500				

Maximum Deflections for Load Combinations

Load Combination	Max. Deflection in X dir	Distance	Max. Deflection in Y dir	Distance
D Only	0.0000 in	0.000 ft	0.000 in	0.000 ft
+D+L	0.0000 in	0.000 ft	0.000 in	0.000 ft
+D+0.750L	0.0000 in	0.000 ft	0.000 in	0.000 ft
+D+0.420W	0.0000 in	0.000 ft	0.271 in	9.060 ft
+D+0.750L+0.3150W	0.0000 in	0.000 ft	0.203 in	9.060 ft
+0.60D+0.420W	0.0000 in	0.000 ft	0.271 in	9.060 ft
+0.60D	0.0000 in	0.000 ft	0.000 in	0.000 ft

Steel Section Properties : HSS8x6x1/4

Depth	=	8.000 in	I xx	=	56.60 in^4	J	=	70.300 in^4
Design Thick	=	0.233 in	S xx	=	14.20 in^3	Cw	=	20.80 in^6
Width	=	6.000 in	R xx	=	3.030 in			
Wall Thick	=	0.250 in	Zx	=	16.900 in^3			
Area	=	6.170 in^2	I yy	=	36.400 in^4	C	=	20.800 in^3
Weight	=	22.420 plf	S yy	=	12.100 in^3			
			R yy	=	2.430 in			
			Zy	=	13.900 in^3			
Ycg	=	0.000 in						

Steel Column

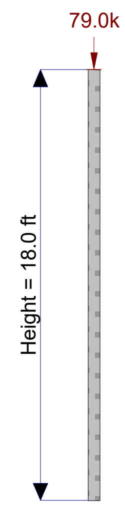
Project File: Steel Column.ec6

LIC# : KW-06000215, Build:20.25.11.24 Licensed ENERCALC User

DESCRIPTION: Steel Column Calculation

Sketches

My Loads - Looking along Y-Y Axis



My Loads - Looking along X-X Axis