Hand Calculation

Problem Statement:
Determine if W12 x 19 steel beam is safe and meet all the required demands

Beam size: W12 x 19	
Span	$L := 18\ ft$
Tributary width	$S := 9\ ft$
Dead load (including self-weight)	$D_L := 40\ psf$
Live load	$LL := 100\ psf$
Total load deflection limit	L/240
Live load deflection limit	L/360
Compression flange bracing	$L_u := 5\ ft$ OC
Steel Yield Strength	$F_y := 50\ ksi$
Steel Modulus Strength	$E := 29000\ ksi$

Assume $C_b := 1.0$
Use AISC 360-22 for properties of W12 x 19
Design Method: ASD

Solution:

Step 1: Calculate Linear Load

$W_{DL} := D_L \cdot S = 360\ plf$ $\qquad W_{DL} = 0.36\ klf$

$W_{LL} := LL \cdot S = 900\ plf$ $\qquad W_{LL} = 0.9\ klf$

Step 2: Calculate Applied Moment

$$M_{DL} := \frac{W_{DL} \cdot L^2}{8} = 14580\ lbf \cdot ft \qquad M_{DL} = 14.58\ kip \cdot ft$$

$$M_{LL} := \frac{W_{LL} \cdot L^2}{8} = 36450\ lbf \cdot ft \qquad M_{LL} = 36.45\ kip \cdot ft$$

Total applied moment is

$$M_a := M_{DL} + M_{LL} = 51030\ lbf \cdot ft \qquad M_a = 51.03\ kip \cdot ft$$

Step 3: Calculate Applied Shear Force

$$V_{DL} := \frac{W_{DL} \cdot L}{2} = 3240\ lbf \qquad V_{DL} = 3.24\ kip$$

$V_{LL} := \dfrac{W_{LL} \cdot L}{2} = 8100 \ lbf$ $\qquad V_{LL} = 8.1 \ kip$

Total applied shear force is

$V_a := V_{DL} + V_{LL} = 11340 \ lbf$ $\qquad V_a = 11.34 \ kip$

Step 4: Check member for slenderness (AISC-SPEC Table B4.1b)

- Check Flange:

W12 x 19 Beam's flange Width, $b := 4.01 \ in$
W12 x 19 Beam's flange thickness, $t_f := 0.35 \ in$

Width to thickness ratio for flange, λ_f

$$\lambda_f := \frac{\frac{b}{2}}{t_f} = 5.729$$

Limiting slenderness for a compact flange, λ_{pf}

$\lambda_{pf} := 0.38 \sqrt{\dfrac{E}{F_y}} = 9.152$ > 5.729, λ_f

Therefore, flange is compact

- Check Web:

W12 x 19 Beam's web height, $h := 10.85 \ in$
W12 x 19 Beam's web thickness, $t_w := 0.235 \ in$

Height to thickness ratio for web, λ_w

$$\lambda_w := \frac{h}{t_w} = 46.17$$

Limiting slenderness for a compact web, λ_{pw}

$\lambda_{pw} := 3.76 \sqrt{\dfrac{E}{F_y}} = 90.553$ > 46.17, λ_w

Therefore, web is compact

Step 5: Calculate nominal flexural strength capacity

- Yielding limit state:

Plastic section modulus, $Z_x := 24.7 \ in^3$

$M_{n\_yield} := Z_x \cdot F_y = 1235 \ kip \cdot in$ (spec Eq. F2-1)

- Lateral Torsional Buckling (LTB) limit state:

$L_u = 60\ in$

W12 x 19 Beam's radius of gyration, $r_y := 0.822\ in$

$$L_p := 1.76 \cdot r_y \cdot \sqrt{\frac{E}{F_y}} = 34.84\ in$$ (spec Eq. F2-5)

For doubly symmetric shapes, $c := 1.0$

Effective radius of gyration for lateral torsional buckling, $r_{ts} := 1.02\ in$

Elastic section modulus about x-axis, $S_x := 21.3\ in^3$

Torsional constant, $J := 0.18\ in^4$

Distance between flange centroids, $h_o := 11.9\ in$

$$L_r := 1.95 \cdot r_{ts} \cdot \frac{E}{0.7 \cdot F_y} \cdot \sqrt{\frac{J \cdot c}{S_x \cdot h_o} + \sqrt{\left(\frac{J \cdot c}{S_x \cdot h_o}\right)^2 + 6.67 \cdot \left(\frac{0.7 \cdot F_y}{E}\right)^2}} = 103.01\ in$$ (spec Eq. F2-6)

$L_u = 60\ in$ $L_p = 34.842\ in$ $L_r = 103.01\ in$

$L_p < L_u < L_r$

Hence, inelastic LTB Controls

$$M_{n\_LTB} := C_b \cdot \left(Z_x \cdot F_y - \left(\left(Z_x \cdot F_y - 0.7 \cdot F_y \cdot S_x\right) \cdot \left(\frac{L_u - L_p}{L_r - L_p}\right)\right)\right) = 1054.35\ (kip \cdot in)$$ (spec Eq. F2-2)

Nominal flexure strength is:

$M_{nx} := min\left(M_{n\_yield}, M_{n\_LTB}\right) = 1054.35\ kip \cdot in$

Allowable flexural capacity is:

Safety factor for flexure, $\Omega_f := 1.67$

$$M_{x\_all} := \frac{M_{nx}}{\Omega_f} = 631.35\ kip \cdot in$$

$M_{x\_all} = 52.61\ kip \cdot ft$

Step 6: Calculate shear capacity

- Determine Cv factor:

From step 4, height to thickness ratio for web, $\lambda_w = 46.17$

$$2.24 \cdot \sqrt{\frac{E}{F_y}} = 53.95$$

$\lambda_w < 2.24 \cdot \sqrt{\frac{E}{F_y}}$, Therefore $C_v := 1$ (spec Eq. G2-2)

W12 x 19 Beam total depth, $d := 12.2\ in$
W12 x 19 Beam's web thickness, $t_w = 0.235\ in$
W12 x 19 Beam's web area, $A_w := d \cdot t_w = 2.867\ in^2$

Nominal shear strength is:
$V_n := 0.6 \cdot F_y \cdot A_w \cdot C_v = 86.01\ kip$ (spec Eq. G2-1)

Allowable shear capacity is:
Safety factor for shear, $\Omega_v := 1.5$ (spec Eq. G2.1(a))

$$V_{x\_all} := \frac{V_n}{\Omega_v} = 57.34\ kip$$

Step 7: Demand to Capacity Ratio (DCR) Check

- Flexural check:

Calculated from step 2 and 5
Total applied moment, $M_a = 51.03\ kip \cdot ft$
Allowable moment capacity, $M_{x\_all} = 52.61\ kip \cdot ft$
Moment demand to capacity is:

$$DCR_{moment} := \frac{M_a}{M_{x\_all}} = 0.97$$ < 1 **PASS** ✔

- Shear check:

Calculated from step 3 and 6
Nominal shear strength, $V_a = 11.34\ kip$
Allowable shear capacity, $V_{x\_all} = 57.34\ kip$
Shear demand to capacity is:

$$DCR_{shear} := \frac{V_a}{V_{x\_all}} = 0.198$$ < 1 **PASS** ✔

- Deflection check:

Calculated from step 1
Linear live load, $W_{LL} = 0.9\ klf$
Linear dead load, $W_{DL} = 0.36\ klf$
Total linear load, $W_{TL} := W_{LL} + W_{DL} = 1.26\ klf$

Total load deflection limit is $\frac{L}{240} = 0.9\ in$

W12 x 19 Beam's Moment of Inertia, $I := 130\ in^4$

Actual total load deflection is:

$$\Delta_{TL} := \frac{5\ W_{TL} \cdot L^4}{384 \cdot E \cdot I} = 0.79\ in$$ < 0.9 in **PASS** ✔

Live load deflection limit is $\frac{L}{360} = 0.6\ in$

Actual live load deflection is:

$$\Delta_{LL} := \frac{5 \cdot W_{LL} \cdot L^4}{384 \cdot E \cdot I} = 0.56\ in$$ < 0.6 in **PASS** ✔

See the following ENERCALC printed calc report for comparison

Steel Beam

Project File: Steel Beam.ec6

DESCRIPTION: Steel Beam Calculation

Code References

Governing Code : IBC 2024
Referenced Design Standard(s) : AISC 360-22
Load Combination Set : ASCE 7-22 / IBC 2024

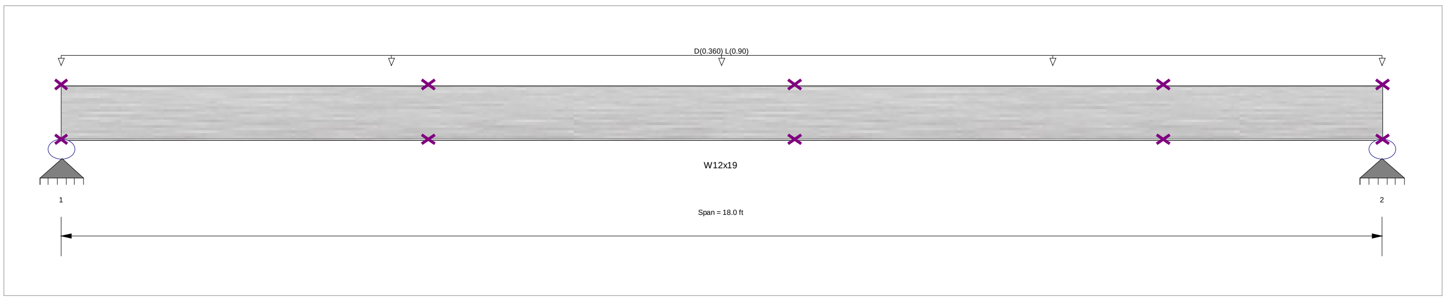
Material Properties

Analysis Method :Allowable Strength Design
Beam Bracing : Beam bracing is defined as a set spacing over all spans
Bending Axis : Major Axis Bending

Fy : Steel Yield : 50.0 ksi
E: Modulus : 29,000.0 ksi

Unbraced Lengths

First Brace starts at ft from Left-Most support
Regular spacing of lateral supports on length of beam = 5.0 ft



Applied Loads

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

Beam self weight NOT internally calculated and added
Uniform Load : D = 0.040, L = 0.10 ksf, Tributary Width = 9.0 ft, (Floor Loads)

DESIGN SUMMARY

Design OK

Maximum Bending Stress Ratio =	**0.968** : 1	Maximum Shear Stress Ratio =	**0.198** : 1
Section used for this span	**W12x19**	Section used for this span	**W12x19**
Ma : Applied	51.030 k-ft	Va : Applied	11.340 k
Mn / Omega : Allowable	52.713 k-ft	Vn/Omega : Allowable	57.340 k
Load Combination	+D+L	Load Combination	+D+L
		Location of maximum on span	0.000 ft
Span # where maximum occurs	Span # 1	Span # where maximum occurs	Span # 1

Maximum Deflection

Max Downward Transient Deflection	0.566 in	Ratio =	381 >=360	Span: 1 : L Only
Max Upward Transient Deflection	0 in	Ratio =	0 <360	n/a
Max Downward Total Deflection	0.793 in	Ratio =	272 >=240.	Span: 1 : +D+L
Max Upward Total Deflection	0 in	Ratio =	0 <240.0	n/a

Maximum Forces & Stresses for Load Combinations

Load Combination / Segment Length	Span #	Max Stress Ratios M	Max Stress Ratios V	Mmax +	Mmax -	Ma Max	Mnx	Mnx/Omega	Cb	Rm	Va Max	Vnx	Vnx/Omega
D Only													
Dsgn. L = 4.99 ft	1	0.222	0.057	11.68		11.68	88.03	52.71	1.00	1.00	3.24	86.01	57.34
Dsgn. L = 4.99 ft	1	0.277	0.025	14.58	11.68	14.58	88.03	52.71	1.00	1.00	1.44	86.01	57.34
Dsgn. L = 4.99 ft	1	0.273	0.037	14.41	8.17	14.41	88.03	52.71	1.00	1.00	2.15	86.01	57.34
Dsgn. L = 3.03 ft	1	0.134	0.057	8.17		8.17	101.98	61.07	1.00	1.00	3.24	86.01	57.34
+D+L													
Dsgn. L = 4.99 ft	1	0.776	0.198	40.89		40.89	88.03	52.71	1.00	1.00	11.34	86.01	57.34
Dsgn. L = 4.99 ft	1	0.968	0.088	51.03	40.89	51.03	88.03	52.71	1.00	1.00	5.05	86.01	57.34
Dsgn. L = 4.99 ft	1	0.957	0.131	50.43	28.61	50.43	88.03	52.71	1.00	1.00	7.52	86.01	57.34
Dsgn. L = 3.03 ft	1	0.468	0.198	28.61		28.61	101.98	61.07	1.00	1.00	11.34	86.01	57.34
+D+0.750L													
Dsgn. L = 4.99 ft	1	0.637	0.162	33.59		33.59	88.03	52.71	1.00	1.00	9.32	86.01	57.34
Dsgn. L = 4.99 ft	1	0.795	0.072	41.92	33.59	41.92	88.03	52.71	1.00	1.00	4.15	86.01	57.34
Dsgn. L = 4.99 ft	1	0.786	0.108	41.42	23.50	41.42	88.03	52.71	1.00	1.00	6.17	86.01	57.34
Dsgn. L = 3.03 ft	1	0.385	0.162	23.50		23.50	101.98	61.07	1.00	1.00	9.31	86.01	57.34
+0.60D													
Dsgn. L = 4.99 ft	1	0.133	0.034	7.01		7.01	88.03	52.71	1.00	1.00	1.94	86.01	57.34
Dsgn. L = 4.99 ft	1	0.166	0.015	8.75	7.01	8.75	88.03	52.71	1.00	1.00	0.87	86.01	57.34

Steel Beam

Project File: Steel Beam.ec6

DESCRIPTION: Steel Beam Calculation

Maximum Forces & Stresses for Load Combinations

Load Combination		Max Stress Ratios		Summary of Moment Values							Summary of Shear Values		
Segment Length	Span #	M	V	Mmax +	Mmax -	Ma Max	Mnx	Mnx/Omega	Cb	Rm	Va Max	Vnx	Vnx/Omega
Dsgn. L = 4.99 ft	1	0.164	0.022	8.64	4.90	8.64	88.03	52.71	1.00	1.00	1.29	86.01	57.34
Dsgn. L = 3.03 ft	1	0.080	0.034	4.90		4.90	101.98	61.07	1.00	1.00	1.94	86.01	57.34

Overall Maximum Deflections

Span	Load Combination	Max. "-" Defl	Location in Span	Load Combination	Max. "+" Defl	Location in Span
1	+D+L	0.7930	9.051		0.0000	0.000

Maximum Deflections for Load Combinations

Load Combination	Span	Max. Downward Defl	Location in Span	Span	Max. Upward Defl	Location in Span
D Only	1	0.2266	9.051		0.0000	0.000
+D+L	1	0.7930	9.051		0.0000	0.000
+D+0.750L	1	0.6514	9.051		0.0000	0.000
+0.60D	1	0.1359	9.051		0.0000	0.000
L Only	1	0.5664	9.051		0.0000	0.000

Vertical Reactions

Support notation : Far left is #1 Values in KIPS

Load Combination	Support 1	Support 2
Max Upward from all Load Conditions	11.340	11.340
Max Upward from Load Combinations	11.340	11.340
Max Upward from Load Cases	8.100	8.100
D Only	3.240	3.240
+D+L	11.340	11.340
+D+0.750L	9.315	9.315
+0.60D	1.944	1.944
L Only	8.100	8.100

Steel Section Properties : W12x19

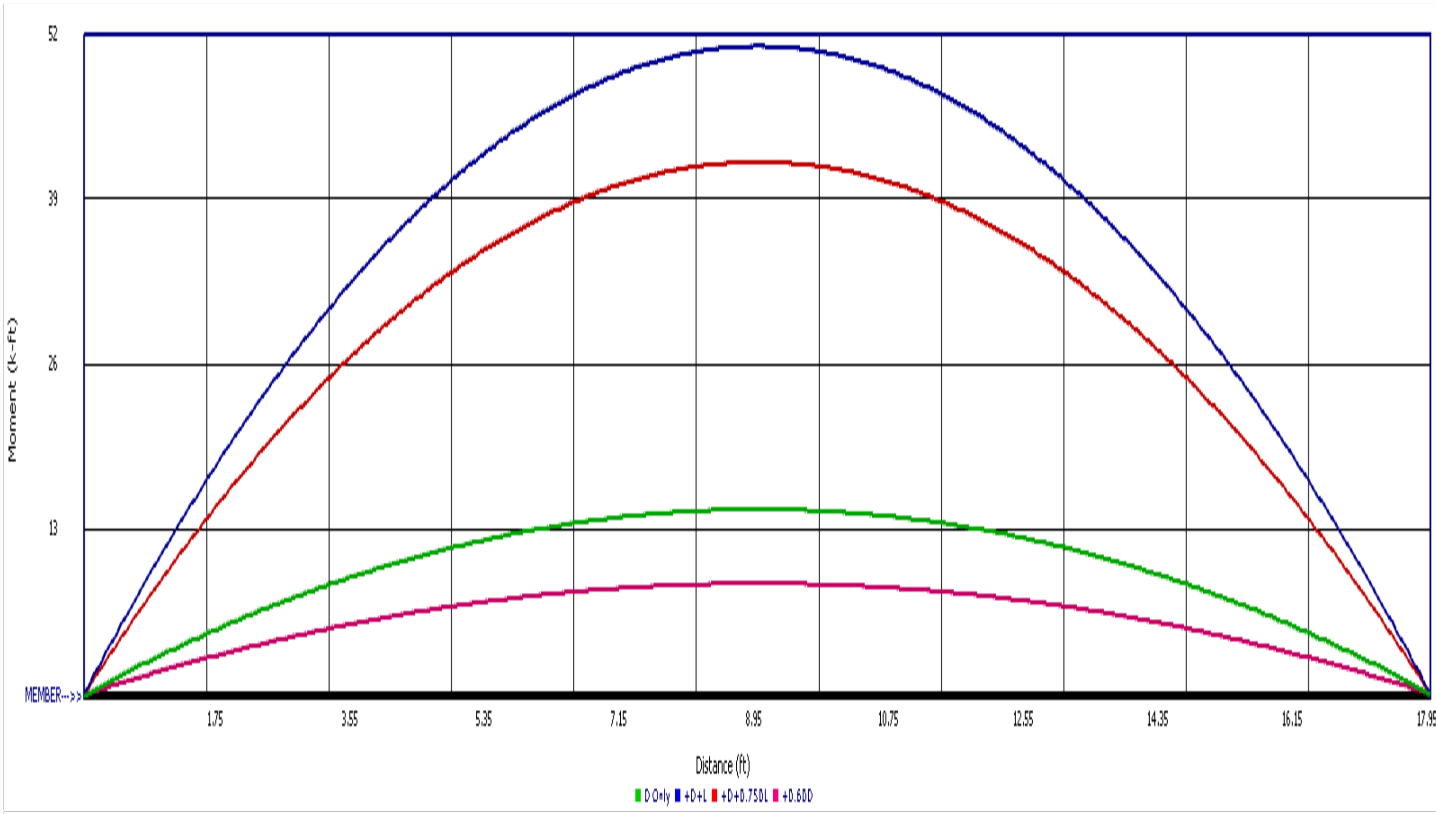
Depth	=	12.200 in	I xx	=	130.00 in^4	J	=	0.180 in^4
Web Thick	=	0.235 in	S xx	=	21.30 in^3	Cw	=	131.00 in^6
Flange Width	=	4.010 in	R xx	=	4.820 in			
Flange Thick	=	0.350 in	Zx	=	24.700 in^3			
Area	=	5.570 in^2	I yy	=	3.760 in^4			
Weight	=	19.000 plf	S yy	=	1.880 in^3	Wno	=	11.900 in^2
Kdesign	=	0.650 in	R yy	=	0.822 in	Sw	=	4.170 in^4
K1	=	0.563 in	Zy	=	2.980 in^3	Qf	=	3.910 in^3
rts	=	1.020 in				Qw	=	12.200 in^3
Ycg	=	6.100 in						

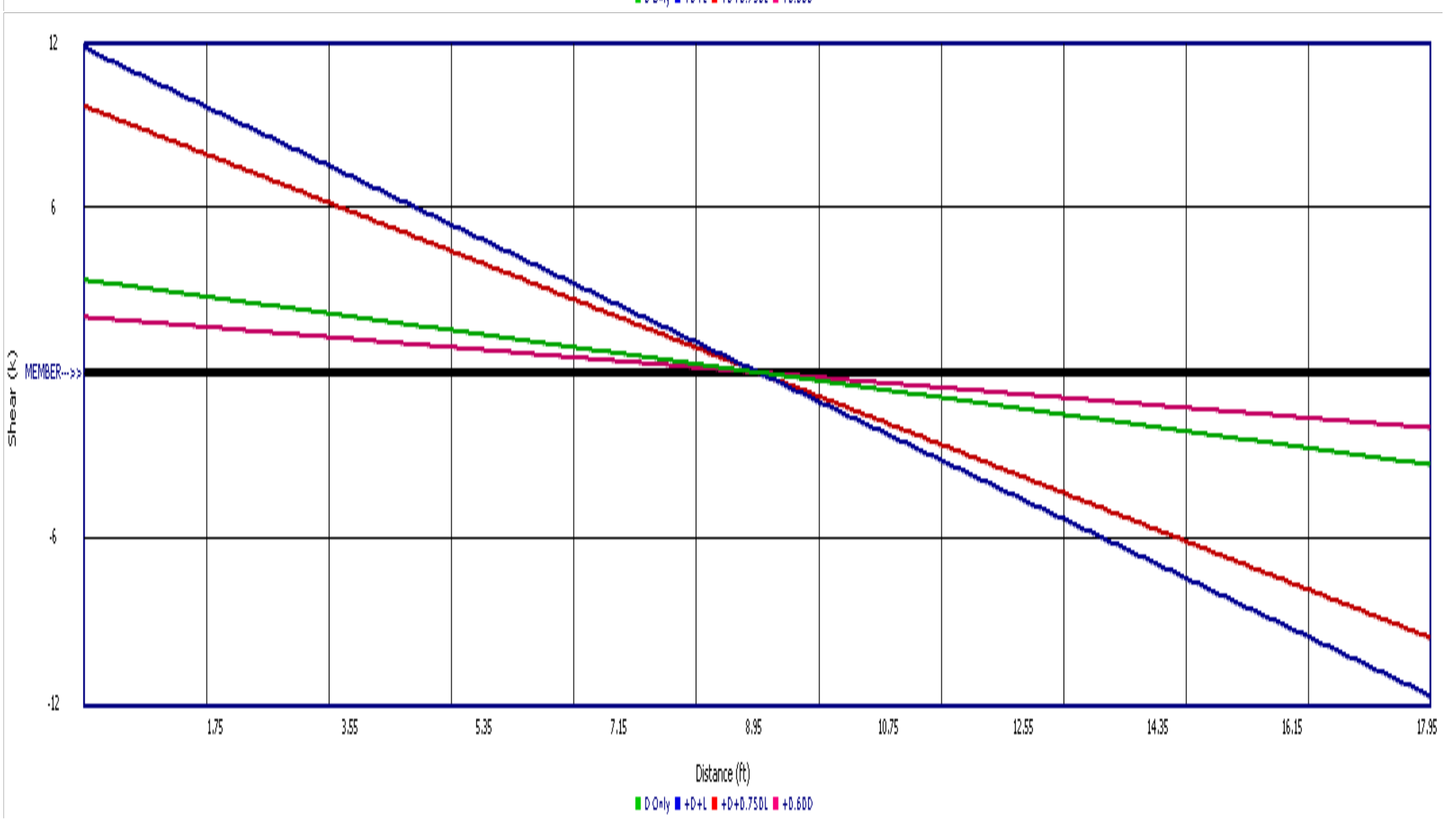
Steel Beam

Project File: Steel Beam.ec6

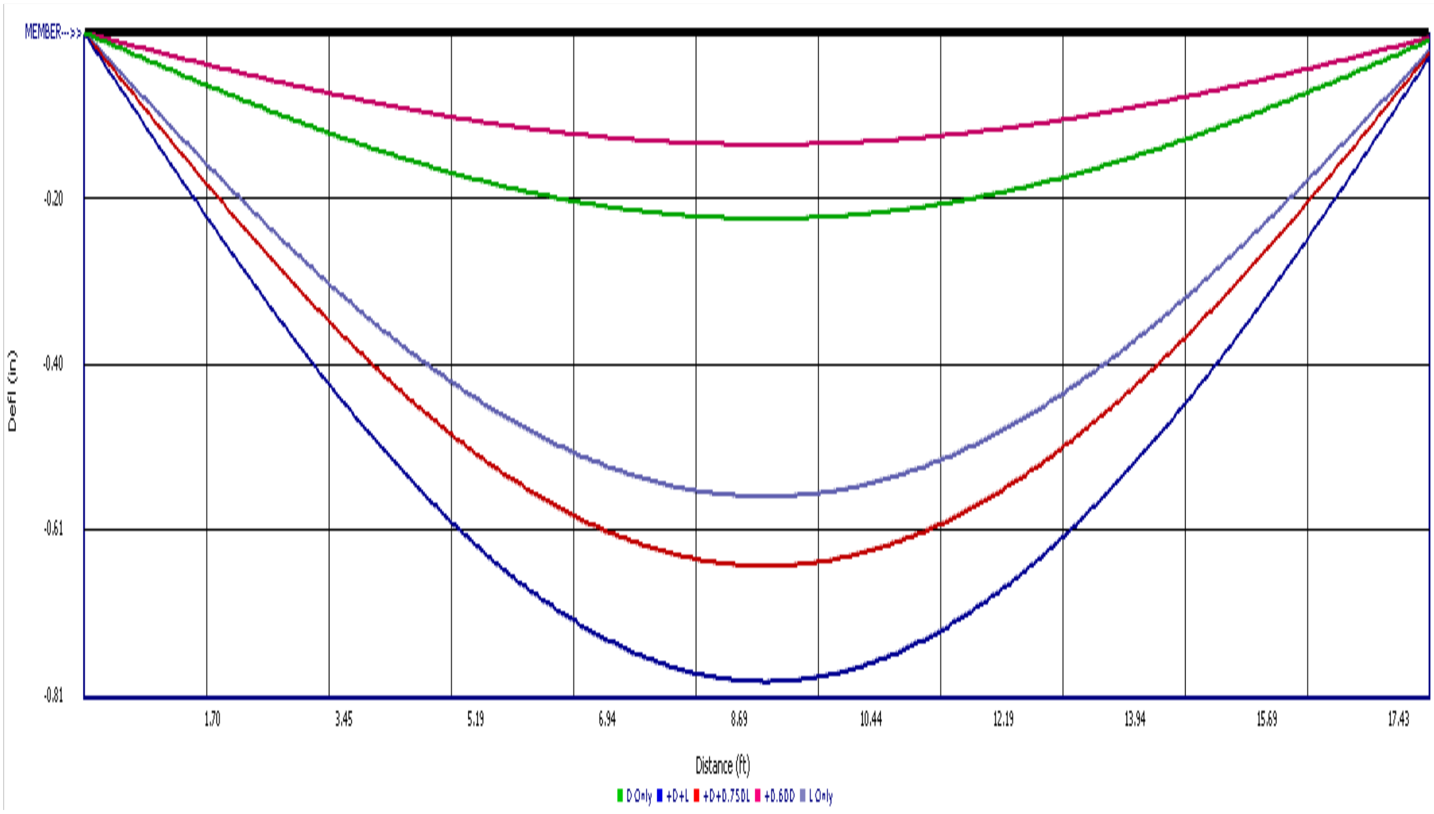
LIC# : KW-06000215, Build:20.25.07.09 Licensed ENERCALC User

DESCRIPTION: Steel Beam Calculation





DESCRIPTION: Steel Beam Calculation



Beam Span Moments & Shears at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Shear (k)	Moment (ft-k)
D Only	0.00	Span 1	3.240	0.000
D Only	1.80	Span 1	2.592	5.249
D Only	3.60	Span 1	1.944	9.331
D Only	5.40	Span 1	1.296	12.247
D Only	7.20	Span 1	0.648	13.997
D Only	9.00	Span 1	0.000	14.580
D Only	10.80	Span 1	-0.648	13.997
D Only	12.60	Span 1	-1.296	12.247
D Only	14.40	Span 1	-1.944	9.331
D Only	16.20	Span 1	-2.592	5.249
D Only	18.00	Span 1	-3.240	0.000
+D+L	0.00	Span 1	11.340	0.000
+D+L	1.80	Span 1	9.072	18.371
+D+L	3.60	Span 1	6.804	32.659
+D+L	5.40	Span 1	4.536	42.865
+D+L	7.20	Span 1	2.268	48.989
+D+L	9.00	Span 1	0.000	51.030
+D+L	10.80	Span 1	-2.268	48.989
+D+L	12.60	Span 1	-4.536	42.865
+D+L	14.40	Span 1	-6.804	32.659
+D+L	16.20	Span 1	-9.072	18.371
+D+L	18.00	Span 1	-11.340	0.000
+D+0.750L	0.00	Span 1	9.315	0.000
+D+0.750L	1.80	Span 1	7.452	15.090
+D+0.750L	3.60	Span 1	5.589	26.827
+D+0.750L	5.40	Span 1	3.726	35.211
+D+0.750L	7.20	Span 1	1.863	40.241
+D+0.750L	9.00	Span 1	0.000	41.918
+D+0.750L	10.80	Span 1	-1.863	40.241
+D+0.750L	12.60	Span 1	-3.726	35.211
+D+0.750L	14.40	Span 1	-5.589	26.827

Steel Beam

DESCRIPTION: Steel Beam Calculation

Beam Span Moments & Shears at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Shear (k)	Moment (ft-k)
+D+0.750L	16.20	Span 1	-7.452	15.090
+D+0.750L	18.00	Span 1	-9.315	0.000
+0.60D	0.00	Span 1	1.944	0.000
+0.60D	1.80	Span 1	1.555	3.149
+0.60D	3.60	Span 1	1.166	5.599
+0.60D	5.40	Span 1	0.778	7.348
+0.60D	7.20	Span 1	0.389	8.398
+0.60D	9.00	Span 1	0.000	8.748
+0.60D	10.80	Span 1	-0.389	8.398
+0.60D	12.60	Span 1	-0.778	7.348
+0.60D	14.40	Span 1	-1.166	5.599
+0.60D	16.20	Span 1	-1.555	3.149
+0.60D	18.00	Span 1	-1.944	0.000

Beam Span Deflections at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Deflection (in)
Overall MAXimum Envelope	0.00	Span 1	0.000
Overall MAXimum Envelope	1.85	Span 1	0.255
Overall MAXimum Envelope	3.70	Span 1	0.481
Overall MAXimum Envelope	5.55	Span 1	0.656
Overall MAXimum Envelope	7.41	Span 1	0.762
Overall MAXimum Envelope	9.26	Span 1	0.792
Overall MAXimum Envelope	11.11	Span 1	0.743
Overall MAXimum Envelope	12.96	Span 1	0.618
Overall MAXimum Envelope	14.81	Span 1	0.429
Overall MAXimum Envelope	16.66	Span 1	0.193
Overall MAXimum Envelope	18.00	Span 1	0.007
D Only	0.00	Span 1	0.000
D Only	1.85	Span 1	0.073
D Only	3.70	Span 1	0.137
D Only	5.55	Span 1	0.187
D Only	7.41	Span 1	0.218
D Only	9.26	Span 1	0.226
D Only	11.11	Span 1	0.212
D Only	12.96	Span 1	0.177
D Only	14.81	Span 1	0.122
D Only	16.66	Span 1	0.055
D Only	18.00	Span 1	0.002
+D+L	0.00	Span 1	0.000
+D+L	1.85	Span 1	0.255
+D+L	3.70	Span 1	0.481
+D+L	5.55	Span 1	0.656
+D+L	7.41	Span 1	0.762
+D+L	9.26	Span 1	0.792
+D+L	11.11	Span 1	0.743
+D+L	12.96	Span 1	0.618
+D+L	14.81	Span 1	0.429
+D+L	16.66	Span 1	0.193
+D+L	18.00	Span 1	0.007
+D+0.750L	0.00	Span 1	0.000
+D+0.750L	1.85	Span 1	0.209
+D+0.750L	3.70	Span 1	0.395
+D+0.750L	5.55	Span 1	0.539
+D+0.750L	7.41	Span 1	0.626
+D+0.750L	9.26	Span 1	0.651
+D+0.750L	11.11	Span 1	0.610
+D+0.750L	12.96	Span 1	0.507
+D+0.750L	14.81	Span 1	0.352
+D+0.750L	16.66	Span 1	0.158
+D+0.750L	18.00	Span 1	0.006
+0.60D	0.00	Span 1	0.000
+0.60D	1.85	Span 1	0.044
+0.60D	3.70	Span 1	0.082
+0.60D	5.55	Span 1	0.112

Steel Beam

DESCRIPTION: Steel Beam Calculation

Beam Span Deflections at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Deflection (in)
+0.60D	7.41	Span 1	0.131
+0.60D	9.26	Span 1	0.136
+0.60D	11.11	Span 1	0.127
+0.60D	12.96	Span 1	0.106
+0.60D	14.81	Span 1	0.073
+0.60D	16.66	Span 1	0.033
+0.60D	18.00	Span 1	0.001
L Only	0.00	Span 1	0.000
L Only	1.85	Span 1	0.182
L Only	3.70	Span 1	0.344
L Only	5.55	Span 1	0.468
L Only	7.41	Span 1	0.545
L Only	9.26	Span 1	0.566
L Only	11.11	Span 1	0.531
L Only	12.96	Span 1	0.441
L Only	14.81	Span 1	0.306
L Only	16.66	Span 1	0.138
L Only	18.00	Span 1	0.005