Beam Design

1. Beam Data

Load Type:	Uniform Dist. Load
Support:	Simple Beam
Beam Type:	Sawn Lumber
Species:	Douglas Fir-Larch
Grade:	DF No.1 & Btr
Size:	4 x 16
Design Span (L):	13.25 ft.
Clear Span:	13.00 ft.
Total Span:	13.50 ft.
Bearing (l_b):	3 in.
Quantity (N):	1

2. Design Loads

Live Load:	320	plf
Dead Load:	120	plf
Selfweight:	171.3	lbs
Dist. Selfweight:	12.93	plf
Total Weight:	174.6	lbs

3. Design Options

Lateral Support:	Undefined
Defl. Limits:	360|240
Load Duration:	1.15
Exposure:	wet
Temperature:	T <= 100°F
Orientation:	Vertical
Incised Lumber:	Yes
Rep. Members:	No

4. Design Assumptions and Notes

Code Standard: IBC 2015, NDS 2015

Bending Stress: Parallel to Grain

Notes:

5. Adjustment Factors

Factor	Description	F_b	F_t	F_v	F_c	$F_{c\perp}$	E/E_{min}
C_D	Load Duration Factor	1.15	1.15	1.15	1.15	-	-
C_M	Wet Service Factor	0.85[b]	1	0.97	0.8[c]	0.67	0.9
C_t	Temperature Factor	1	1	1	1	1	1
C_L	Beam Stability Factor	0.995	-	-	-	-	-
C_F	Size Factor	1	0.9	-	0.9	-	-
C_{fu}	Flat Use Factor	1.1[d]	-	-	-	-	-
C_i	Incising Factor	0.8	0.8	0.8	0.8	1	0.95
C_r	Repetitive Member Factor	1	-	-	-	-	-

a) Adjustment factors per AWC NDS 2015 and NDS 2015 Supplement.

b) When $(F_b)(C_F) \leq 1{,}150$ psi, $C_M = 1.0$.

c) When $(F_c)(C_F) \leq 750$ psi, $C_M = 1.0$.

d) Only applies when sawn lumber or glulam beams are loaded in bending about the y-y axis.

6. Beam Calculations

Determine reference design values, sectional properties and self weight of beam:

A = b x d

$$S_x = \frac{bd^2}{6},\ S_y = \frac{b^2 d}{6}$$

$$I_x = \frac{bd^3}{12},\ I_y = \frac{b^3 d}{12}$$

where:

b = Breadth of rectangular beam in bending (in.)
d = Depth of rectangular beam in bending (in.)
A = Cross sectional area of beam (in.^{2})
S_x = Section modulus about the X-X axis (in.^{3})
S_y = Section modulus about the Y-Y axis (in.^{3})
I_x = Moment of inertia about the X-X axis (in.^{4})
I_y = Moment of inertia about the Y-Y axis (in.^{4})

b = 3.500 in.
d = 15.000 in.
A = 3.500 x 15.000 = 52.50 in.^{2}
S_x = (3.500)(15.000)^2/6 = 131.25 in.^{3}
S_y = (3.500)^2(15.000)/6 = 30.63 in.^{3}
I_x = (3.500)(15.000)^3/12 = 984.38 in.^{4}
I_y = (3.500)^3(15.000)/12 = 53.59 in.^{4}

Reference Design Values from Table 4A NDS Supplement (Reference Design Values for Visually Graded Dimension Lumber, 2" - 4" thick).

Species & Grade	F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G
DF No.1 & Btr	1200	800	180	625	1550	1800000	660000	0.5

The following formula shall be used to determine the density of wood (lbs/ft^3. *(NDS Supplement Sec. 3.1.3)*

$$\rho_w = 62.4\left[\frac{G}{1 + G(0.009)(m.c)}\right]\left[1 + \frac{m.c.}{100}\right]$$

where:

ρ_w = Density of wood (lbs/ft^3
G = Specific gravity of wood (dimensionless)
m.c. = Moisture content of wood (percentile)

G = 0.5
m.c. = 28 % (Estimated moisture content at wet service conditions)

$$\rho_w = 62.4\left[\frac{0.5}{1+0.5(0.009)(28)}\right]\left[1+\frac{28}{100}\right] = 35.47 \text{ lbs/ft}^3$$

$\text{Volume}_{total} = N[A \times (L + l_b)] = 1 \times [52.50 \times (159.00 + 3)] \times (12 \text{ in./ft.})^3 = 4.92 \text{ ft}^3$

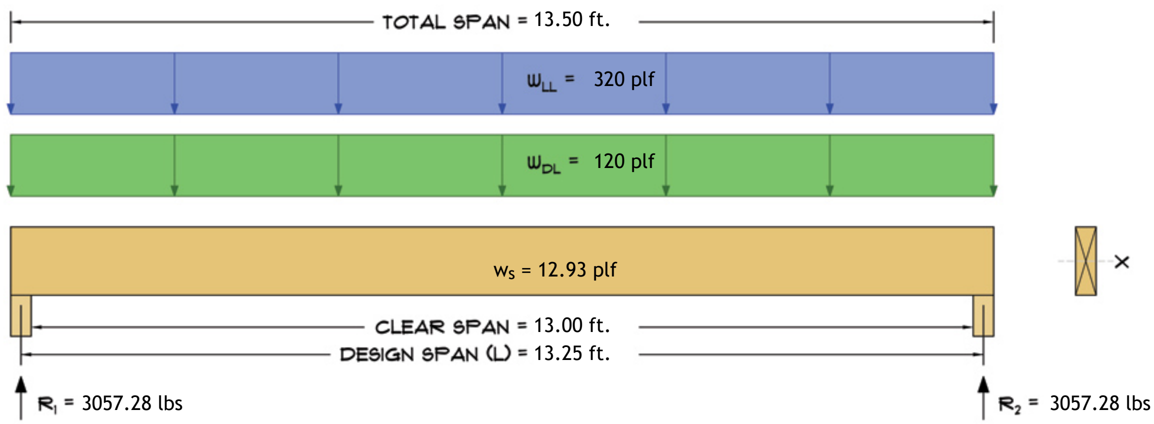
$\text{Volume}_{span} = N[A \times L] = 1 \times [52.50 \times 159.00] \times (12 \text{ in./ft.})^3 = 4.83 \text{ ft}^3$

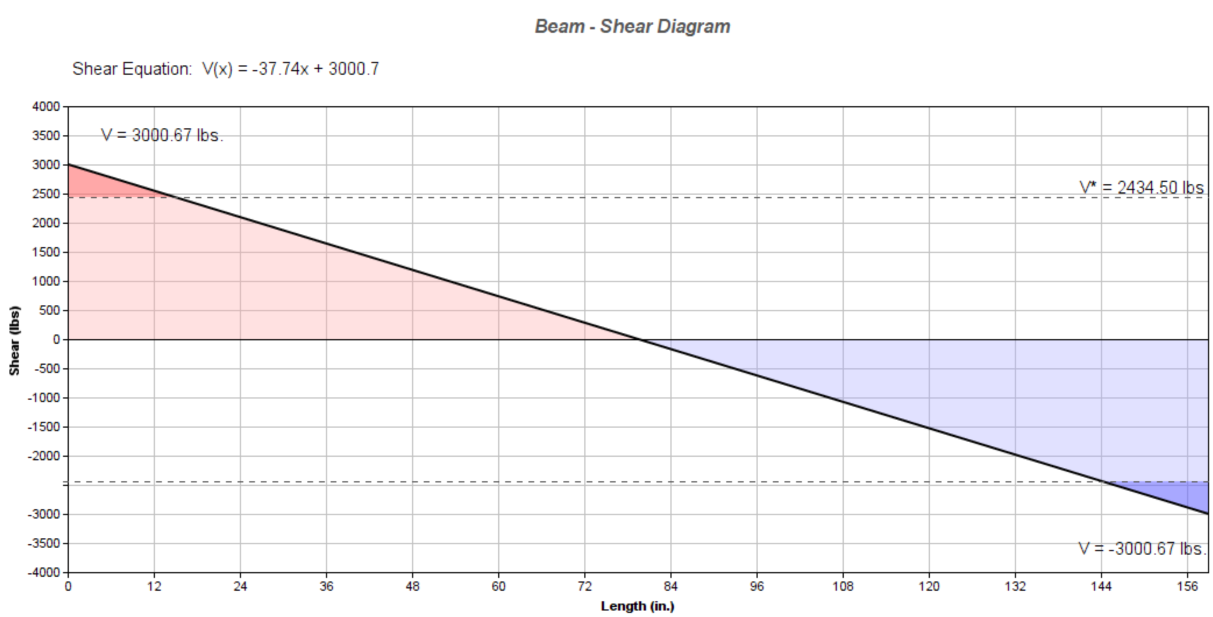
Total Weight (W_T) = $\rho_W \times \text{Volume}_{total} = 35.47 \times 4.92 = 174.6$ lbs

Self Weight (W_S) = $\rho_W \times \text{Volume}_{span} = 35.47 \times 4.83 = 171.3$ lbs

Distributed Self Weight (w_S) = $\dfrac{W_S}{L} = \dfrac{171.3}{13.25} = 12.93$ plf

Load, Shear and Moment Diagrams:





Subject	Customer	Location	Job No.
Beam Design			2024A255

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Date: 6/25/2024

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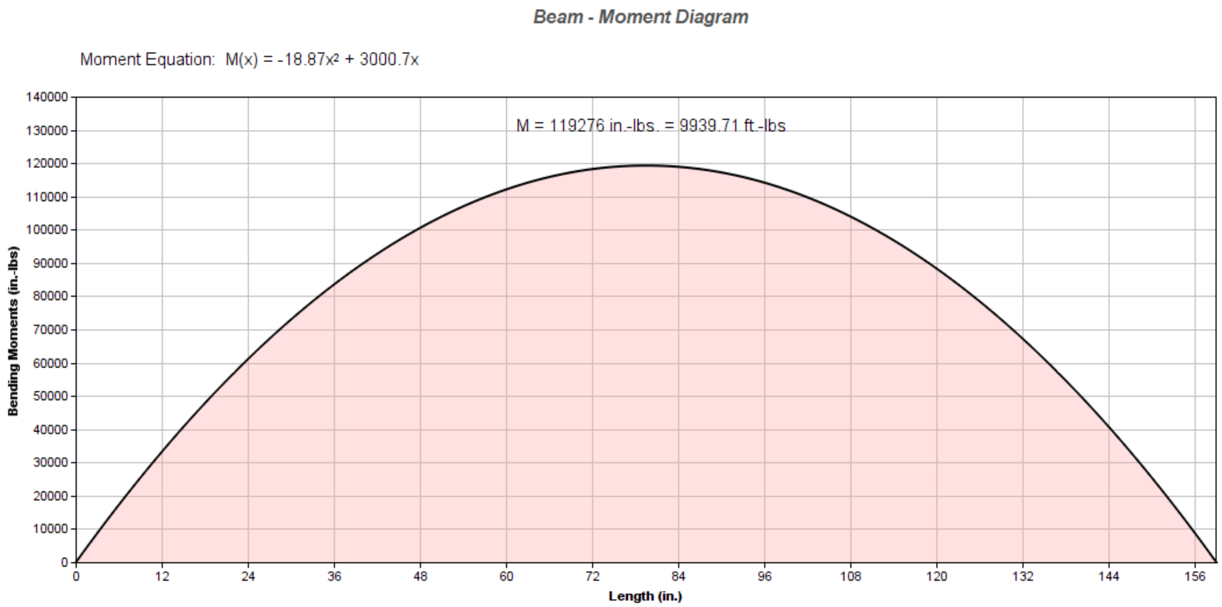
Rev.: -



1.) Bending:

Members subject to bending stresses shall be proportioned so that the actual bending stress or moment shall not exceed the adjusted bending design value:

$f_b \leq F_b'$ *(NDS Sec. 3.3.1)*

where:

$f_b = M / S$
$F_b' = F_b(C_D)(C_M)(C_t)(C_L)(C_F)(C_i)(C_r)$

Beam is unbraced along its compression edge, lateral stability is considered below:

Slenderness Ratio for bending member R_B:

l_u = Unbraced Length = 2 ft.

$$l_u/d = \frac{24}{15} = 1.60$$

$l_e = 2.06 l_u = 2.06(24.0) = 49.44$ in. $= 4.12$ ft. *(NDS Table 3.3.3)*

$$R_b = \sqrt{\frac{l_e d}{b^2}} = \sqrt{\frac{49.44(15)}{(1 \times 3.5)^2}} = 7.78$$

$R_b = 7.78 < 50$? **OK**

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Euler-based ASD critical buckling value for bending members:

$E_{miny}' = E_{miny}(C_M)(C_t)(C_i) = 660000(0.9)(1)(0.95) = 564300$ psi

$$F_{bE} = \frac{1.2E'_{miny}}{(R_b)^2} = \frac{1.2(564300)}{(7.78)^2} = 11185.56 \text{ psi}$$

$F_{bx}^* = F_{bx}(C_D)(C_M)(C_t)(C_F)(C_i)(C_r) = (1200)(1.15)(0.85)(1)(1)(0.8)(1) = 938.40$ psi

Beam stability factor:

$$C_L = \frac{1+F_{be}/F_{bx}^*}{1.9} - \sqrt{\left(\frac{1+F_{be}/F_{bx}^*}{1.9}\right)^2 - \frac{F_{be}/F_{bx}^*}{0.95}} = \frac{1+11185.56/938.40}{1.9} - \sqrt{\left(\frac{1+11185.56/938.40}{1.9}\right)^2 - \frac{11185.56/938.40}{0.95}} = 0.995$$

$F_{bx}' = (1200)(1.15)(0.85)(1)(0.995)(1)(0.8)(1) = 934.1$ psi

$$f_b = \frac{M}{N \times S_x} = \frac{119276}{1 \times 131.25} = 908.8 \text{ psi}$$

$f_b = 908.8$ psi < $F_{bx}' = 934.1$ psi (CSI = 0.97) ? **OK**

2.) <u>Shear</u>:

Members subject to shear stresses shall be proportioned so that the actual shear stress parallel to grain or shear force at any cross section of the bending member shall not exceed the adjusted shear design value:

$f_v \leq F_v'$ *(NDS Sec. 3.4.1)*

where:

$$f_v = \frac{3V}{2A}$$

$F_v' = F_v(C_D)(C_M)(C_t)(C_i)$

$F_{vx}' = (180)(1.15)(0.97)(1)(0.8) = 160.63$ psi

Shear Reduction: Uniformly distributed loads within a distance, d, from supports equal to the depth of the bending member shall be pemitted to be ignored. Concentrated loads within a distance equal to the depth of the bending member from supports shall be permitted to be multiplied by x/d where x is the distance from the beam support face to the load. See NDS 2015, Figure 3C.

$$f_v^* = \frac{3V^*}{2(N \times A)} = \frac{3(2434.50)}{2(1 \times 52.50)} = 69.56 \text{ psi}$$

$f_v^* = 69.56$ psi < $F_{vx}' = 160.63$ psi (CSI = 0.43) ? **OK**

No Reduction in Shear (conservative):

$$f_v = \frac{3V}{2(N \times A)} = \frac{3(3000.67)}{2(1 \times 52.50)} = 85.73 \text{ psi}$$

$f_v = 85.73$ psi < $F_{vx}' = 160.63$ psi (CSI = 0.53) ? **OK**

3.) Deflection:

Bending deflections calculated per standard method of engineering mechanics for live load and total load:

LL Allowable: L/360
TL Allowable: L/240

$E_x' = E_x(C_M)(C_t)(C_i) = 1800000(0.9)(1)(0.95) = 1539000$ psi

$$\Delta_{LL} = \frac{5 w_{LL} L^4}{384 E_x' (N \times I_x)} = \frac{5(320)(13.250)^4}{384(1539000)(1 \times 984.38)} \times \left(12 \frac{in.}{ft.}\right)^3 = 0.15 \text{ in.}$$

$(L/d)_{LL} = 159.00 / 0.15 = 1085$

$\Delta_{LL} = 0.15$ in = L/1085 < L/360 ? **OK**

$$\Delta_{TL} = \frac{5(w_{TL} + w_s) L^4}{384 E_x' (N \times I_x)} = \frac{5(440 + 12.93)(13.250)^4}{384(1539000)(1 \times 984.38)} \times \left(12 \frac{in.}{ft.}\right)^3 = 0.21 \text{ in.}$$

$(L/d)_{TL} = 159.00 / 0.21 = 767$

$\Delta_{TL} = 0.21$ in = L/767 < L/240 ? **OK**

4.) Bearing:

Members subject to bearing stresses perpendicular to the grain shall be proportioned so that the actual compressive stress perpendicular to grain shall be based on the net bearing area and shall not exceed the adjusted compression design value perpendicular to grain:

$f_{c\perp} \leq F_{c\perp}'$ *(NDS Sec. 3.10.2)*

where:

$$f_{c\perp} = \frac{R}{A_b}$$

$F_{c\perp}' = F_{c\perp}(C_M)(C_t)(C_i)$

$F_{c\perp x}' = (625)(0.67)(1)(1) = 418.75$ psi

$A_b = b \times l_b = 3.5 \times 3 = 10.50 \text{ in}^2$

$$f_{c\perp} = \frac{R}{N \times A_b} = \frac{3057.28}{1 \times 10.50} = 291.2 \text{ psi}$$

$f_{c\perp} = 291.2$ psi < $F_{c\perp x}' = 418.75$ psi (CSI = 0.70) ? **OK**

*Disclaimer: The calculations produced herein are for initial design and estimating purposes only. The calculations and drawings presented do not constitute a fully engineered design. All of the potential load cases required to fully design an actual structure may not be provided by this calculator. For the design of an actual structure, a registered and licensed professional should be consulted as per IRC 2012 Sec. R802.10.2 and designed according to the minimum requirements of ASCE 7-10. The beam calculations provided by this online tool are for educational and illustrative purposes only. Medeek Design assumes no liability or loss for any designs presented and does not guarantee fitness for use.