



# Beam Design

## 1. Beam Data

Load Type: Uniform Dist. Load  
 Support: Simple Beam  
 Beam Type: Glulam  
 Species: Southern Pine  
 Grade: 24F-V3 1.8E SP/SP  
 Size: 3.5 x 15.125  
 Design Span (L): 22.25 ft.  
 Clear Span: 22.00 ft.  
 Total Span: 22.50 ft.  
 Bearing (lb): 3 in.  
 Quantity (N): 1

## 2. Design Loads

Live Load: 120 plf  
 Dead Load: 180 plf  
 Selfweight: 301.7 lbs  
 Dist. Selfweight: 13.56 plf  
 Total Weight: 305.1 lbs

## 3. Design Options

Lateral Support: Undefined  
 Defl. Limits: 360|240  
 Load Duration: 1.00  
 Exposure: dry  
 Temperature:  $T \leq 100^{\circ}\text{F}$   
 Orientation: Vertical

## 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	1.00	1.00	1.00	1.00	-	-
$C_M$	Wet Service Factor	1	1	1	1	1	1
$C_t$	Temperature Factor	1	1	1	1	1	1
$C_L$	Beam Stability Factor	0.992	-	-	-	-	-
$C_V$	Volume Factor	$1.0^b$	-	-	-	-	-
$C_{fu}$	Flat Use Factor	$N/A^c$	-	-	-	-	-

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

b) The volume factor,  $C_V$ , shall not apply simultaneously with the beam stability factor,  $C_L$ . The lesser factor shall apply.

c) Only applies when glulam beam is loaded in bending about the y-y axis.

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## 6. Beam Calculations

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

$$A = b \times d$$

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

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

where:

b = Breadth of rectangular beam in bending (in.)

d = Depth of rectangular beam in bending (in.)

A = Cross sectional area of beam (in.<sup>2</sup>)

S<sub>x</sub> = Section modulus about the X-X axis (in.<sup>3</sup>)

S<sub>y</sub> = Section modulus about the Y-Y axis (in.<sup>3</sup>)

I<sub>x</sub> = Moment of inertia about the X-X axis (in.<sup>4</sup>)

I<sub>y</sub> = Moment of inertia about the Y-Y axis (in.<sup>4</sup>)

$$b = 3.500 \text{ in.}$$

$$d = 15.125 \text{ in.}$$

$$A = 3.500 \times 15.125 = 52.94 \text{ in.}^2$$

$$S_x = (3.500)(15.125)^2/6 = 133.45 \text{ in.}^3$$

$$S_y = (3.500)^2(15.125)/6 = 30.88 \text{ in.}^3$$

$$I_x = (3.500)(15.125)^3/12 = 1009.19 \text{ in.}^4$$

$$I_y = (3.500)^3(15.125)/12 = 54.04 \text{ in.}^4$$

Reference Design Values from Table 5A NDS Supplement (Reference Design Values for Structural Glue Laminated Softwood Timber Combinations).

Species & Grade	F <sub>bx+</sub>	F <sub>bx-</sub>	F <sub>c⊥x</sub>	F <sub>vx</sub>	E <sub>x</sub>	E <sub>minx</sub>	F <sub>by</sub>	F <sub>c⊥y</sub>	F <sub>vy</sub>	E <sub>y</sub>	E <sub>miny</sub>	F <sub>t</sub>	F <sub>c</sub>	G
24F-V3 1.8E SP/SP	2400	2000	740	300	1800000	950000	1700	650	260	1600000	850000	1150	1650	0.55

The following formula shall be used to determine the density of wood (lbs/ft<sup>3</sup>). (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:

$\rho_w$  = Density of wood (lbs/ft<sup>3</sup>)

G = Specific gravity of wood (dimensionless)

m.c. = Moisture content of wood (percentile)

$$G = 0.55$$

m.c. = 16 % (Max. moisture content at dry service conditions)

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$$\rho_w = 62.4 \left[ \frac{0.55}{1 + 0.55(0.009)(16)} \right] \left[ 1 + \frac{16}{100} \right] = 36.89 \text{ lbs/ft}^3$$

$$\text{Volume}_{\text{total}} = N[A \times (L + l_b)] = 1 \times [52.94 \times (267.00 + 3)] \times (12 \text{ in./ft.})^3 = 8.27 \text{ ft}^3$$

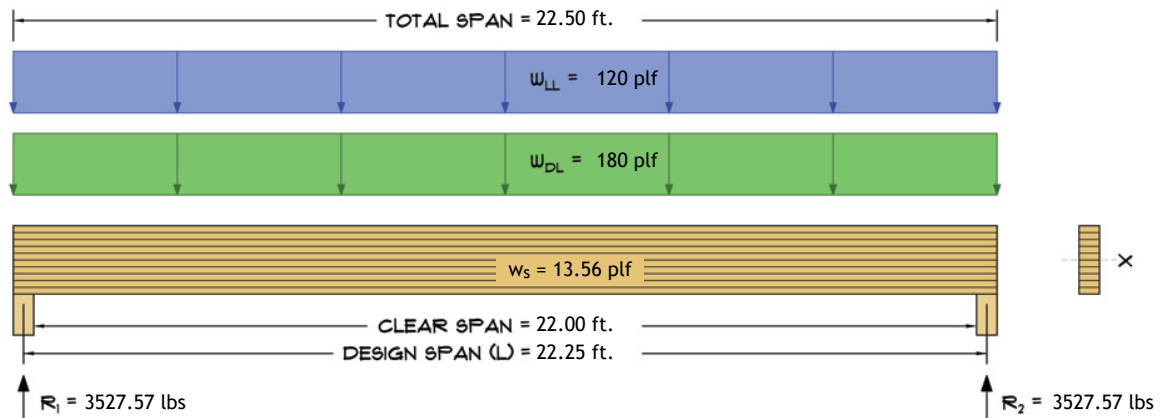
$$\text{Volume}_{\text{span}} = N[A \times L] = 1 \times [52.94 \times 267.00] \times (12 \text{ in./ft.})^3 = 8.18 \text{ ft}^3$$

$$\text{Total Weight } (W_T) = \rho_w \times \text{Volume}_{\text{total}} = 36.89 \times 8.27 = 305.1 \text{ lbs}$$

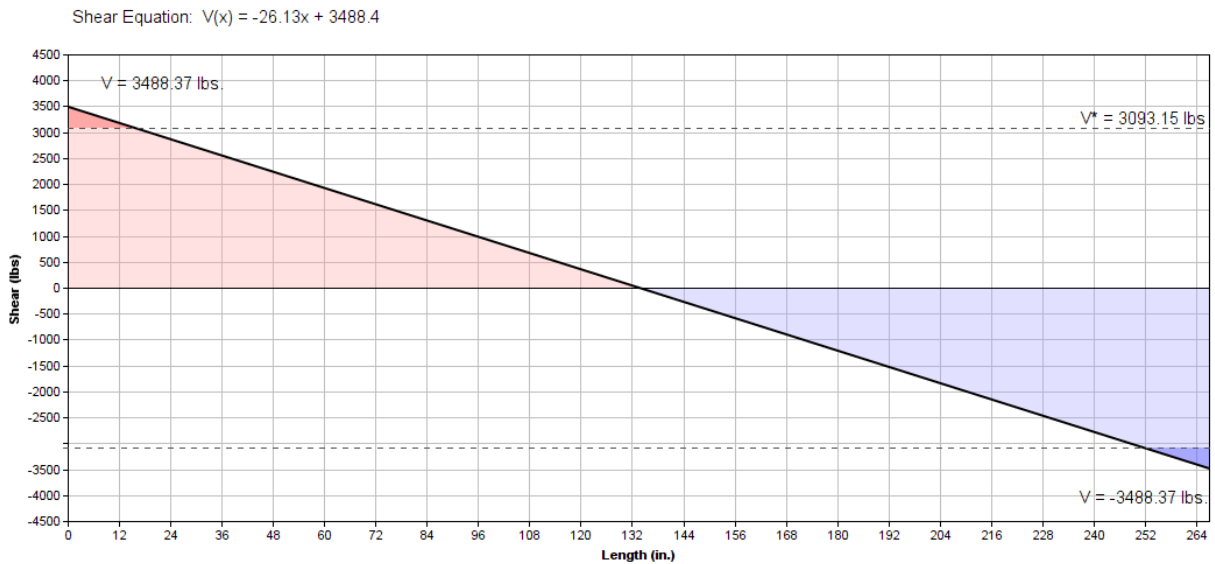
$$\text{Self Weight } (W_S) = \rho_w \times \text{Volume}_{\text{span}} = 36.89 \times 8.18 = 301.7 \text{ lbs}$$

$$\text{Distributed Self Weight } (w_s) = \frac{W_S}{L} = \frac{301.7}{22.25} = 13.56 \text{ plf}$$

Load, Shear and Moment Diagrams:



Beam - Shear Diagram



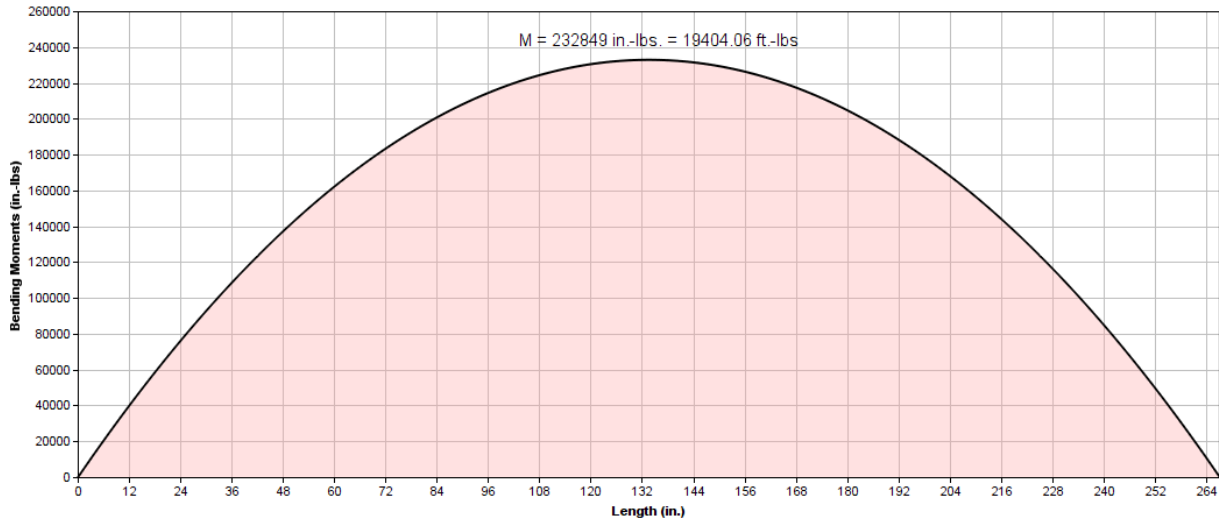
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**Beam - Moment Diagram**

Moment Equation:  $M(x) = -13.07x^2 + 3488.4x$



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:

$$f_b \leq F_b' \quad (NDS \text{ Sec. } 3.3.1)$$

where:

$$f_b = M / S$$

$$F_{bx}' = F_{bx}(C_D)(C_M)(C_t)(C_V) \quad \text{or} \quad F_{bx}' = F_{bx}(C_D)(C_M)(C_t)(C_L)$$

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

Slenderness Ratio for bending member RB:

$l_u$  = Unbraced Length = 2 ft.

$$l_u/d = \frac{24}{15.125} = 1.59$$

$$l_e = 2.06l_u = 2.06(24.0) = 49.44 \text{ in.} = 4.12 \text{ ft.} \quad (NDS \text{ Table } 3.3.3)$$

$$R_b = \sqrt{\frac{l_e d}{b^2}} = \sqrt{\frac{49.44(15.125)}{(1 \times 3.5)^2}} = 7.81$$

$$R_b = 7.81 < 50 \quad ? \quad \mathbf{OK}$$

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Euler-based ASD critical buckling value for bending members:

$$E_{\min y}' = E_{\min y}(C_M)(C_t) = 850000(1)(1) = 850000 \text{ psi}$$

$$F_{bE} = \frac{1.2E'_{\min y}}{(R_b)^2} = \frac{1.2(850000)}{(7.81)^2} = 16709.46 \text{ psi}$$

$$F_{bx}^* = F_{bx}(C_D)(C_M)(C_t) = (2400)(1.00)(1)(1) = 2400.00 \text{ psi}$$

Beam stability factor:

$$C_L = \frac{1 + F_{bc}/F_{bx}^*}{1.9} - \sqrt{\left(\frac{1 + F_{bc}/F_{bx}^*}{1.9}\right)^2 - \frac{F_{bc}/F_{bx}^*}{0.95}} = \frac{1 + 16709.46/2400.00}{1.9} - \sqrt{\left(\frac{1 + 16709.46/2400.00}{1.9}\right)^2 - \frac{16709.46/2400.00}{0.95}} = 0.992$$

$$C_V = \left(\frac{21}{L}\right)^{0.05} \left(\frac{12}{d}\right)^{0.05} \left(\frac{5.125}{b}\right)^{0.05} = \left(\frac{21}{22.250}\right)^{0.05} \left(\frac{12}{15.125}\right)^{0.05} \left(\frac{5.125}{3.5}\right)^{0.05} = 1.0$$

Lateral stability governs over volume effect:

$$C_L = 0.992 < C_V = 1.0$$

$$F_{bx}' = (2400)(1.00)(1)(0.992) = 2380.2 \text{ psi}$$

$$f_b = \frac{M}{N \times S_x} = \frac{232849}{1 \times 133.45} = 1744.9 \text{ psi}$$

$$f_b = 1744.9 \text{ psi} < F_{bx}' = 2380.2 \text{ psi} \quad (\text{CSI} = 0.73) \quad ? \quad \mathbf{OK}$$

## 2.) Shear:

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:

$$f_v \leq F_v' \quad (\text{NDS Sec. 3.4.1})$$

where:

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

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

$$F_{vx}' = (300)(1.00)(1)(1) = 300.00 \text{ psi}$$

Shear Reduction: Uniformly distributed loads within a distance, d, from supports equal to the depth of the bending member shall be permitted 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.

$$f_v^* = \frac{3V^*}{2(N \times A)} = \frac{3(3093.15)}{2(1 \times 52.94)} = 87.65 \text{ psi}$$

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$$f_v^* = 87.65 \text{ psi} < F_{vx}' = 300.00 \text{ psi} \quad (\text{CSI} = 0.29) \quad ? \quad \mathbf{OK}$$

No Reduction in Shear (conservative):

$$f_v = \frac{3V}{2(N \times A)} = \frac{3(3488.37)}{2(1 \times 52.94)} = 98.84 \text{ psi}$$

$$f_v = 98.84 \text{ psi} < F_{vx}' = 300.00 \text{ psi} \quad (\text{CSI} = 0.33) \quad ? \quad \mathbf{OK}$$

### 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

$$E_x' = E_x(C_M)(C_t) = 1800000(1)(1) = 1800000 \text{ psi}$$

$$\Delta_{LL} = \frac{5w_{LL}L^4}{384E_x'(N \times I_x)} = \frac{5(120)(22.250)^4}{384(1800000)(1 \times 1009.19)} \times \left(12 \frac{\text{in.}}{\text{ft.}}\right)^3 = 0.36 \text{ in.}$$

$$(L/d)_{LL} = 267.00 / 0.36 = 733$$

$$\Delta_{LL} = 0.36 \text{ in} = L/733 < L/360 \quad ? \quad \mathbf{OK}$$

$$\Delta_{TL} = \frac{5(w_{TL} + w_s)L^4}{384E_x'(N \times I_x)} = \frac{5(300 + 13.56)(22.250)^4}{384(1800000)(1 \times 1009.19)} \times \left(12 \frac{\text{in.}}{\text{ft.}}\right)^3 = 0.95 \text{ in.}$$

$$(L/d)_{TL} = 267.00 / 0.95 = 280$$

$$\Delta_{TL} = 0.95 \text{ in} = L/280 < L/240 \quad ? \quad \mathbf{OK}$$

### 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:

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

where:

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

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

$$F_{c \perp x}' = (740)(1)(1) = 740.00 \text{ psi}$$

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

$$f_{c\perp} = \frac{R}{N \times A_b} = \frac{3527.57}{1 \times 10.50} = 336.0 \text{ psi}$$

$$f_{c\perp} = 336.0 \text{ psi} < F_{c\perp}' = 740.00 \text{ psi} \quad (\text{CSI} = 0.45) \quad ? \quad \mathbf{OK}$$

\*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.

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