



# Beam Design

## 1. Beam Data

Load Type: Uniform Dist. Load  
 Support: Simple Beam  
 Beam Type: Sawn Lumber  
 Species: Southern Pine  
 Grade: SP No.2  
 Size: 2 x 12  
 Design Span (L): 19.75 ft.  
 Clear Span: 19.50 ft.  
 Total Span: 20.00 ft.  
 Bearing (lb): 3 in.  
 Quantity (N): 1

## 2. Design Loads

Live Load: 100 plf  
 Dead Load: 75 plf  
 Selfweight: 86.4 lbs  
 Dist. Selfweight: 4.37 plf  
 Total Weight: 87.5 lbs

## 3. Design Options

Lateral Support: unbraced  
 Defl. Limits: 360|240  
 Load Duration: 1.15  
 Exposure: dry  
 Temperature:  $T \leq 100^{\circ}\text{F}$   
 Orientation: Vertical  
 Incised Lumber: No  
 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	$1^b$	1	1	$1^c$	1	1
$C_t$	Temperature Factor	1	1	1	1	1	1
$C_L$	Beam Stability Factor	0.330	-	-	-	-	-
$C_F$	Size Factor	1	1	-	1	-	-
$C_{fu}$	Flat Use Factor	$1.2^d$	-	-	-	-	-
$C_i$	Incising Factor	1	1	1	1	1	1
$C_r$	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.

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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>)

$$b = 1.500 \text{ in.}$$

$$d = 11.250 \text{ in.}$$

$$A = 1.500 \times 11.250 = 16.88 \text{ in.}^2$$

$$S_x = (1.500)(11.250)^2/6 = 31.64 \text{ in.}^3$$

$$S_y = (1.500)^2(11.250)/6 = 4.22 \text{ in.}^3$$

$$I_x = (1.500)(11.250)^3/12 = 177.98 \text{ in.}^4$$

$$I_y = (1.500)^3(11.250)/12 = 3.16 \text{ in.}^4$$

Reference Design Values from Table 4B NDS Supplement (Reference Design Values for Visually Graded Southern Pine Dimension Lumber, 2" - 4" thick). Values per March 2013 Addendum

Species & Grade	F <sub>b</sub>	F <sub>t</sub>	F <sub>v</sub>	F <sub>c⊥</sub>	F <sub>c</sub>	E	E <sub>min</sub>	G
SP No.2	750	450	175	565	1250	1400000	510000	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:

ρ<sub>w</sub> = Density of wood (lbs/ft<sup>3</sup>)

G = Specific gravity of wood (dimensionless)

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

$$G = 0.55$$

$$m.c. = 19 \% \text{ (Max. moisture content at dry service conditions)}$$

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$$\rho_w = 62.4 \left[ \frac{0.55}{1 + 0.55(0.009)(19)} \right] \left[ 1 + \frac{19}{100} \right] = 37.33 \text{ lbs/ft}^3$$

$$\text{Volume}_{\text{total}} = N[A \times (L + l_b)] = 1 \times [16.88 \times (237.00 + 3)] \times (12 \text{ in./ft.})^3 = 2.34 \text{ ft}^3$$

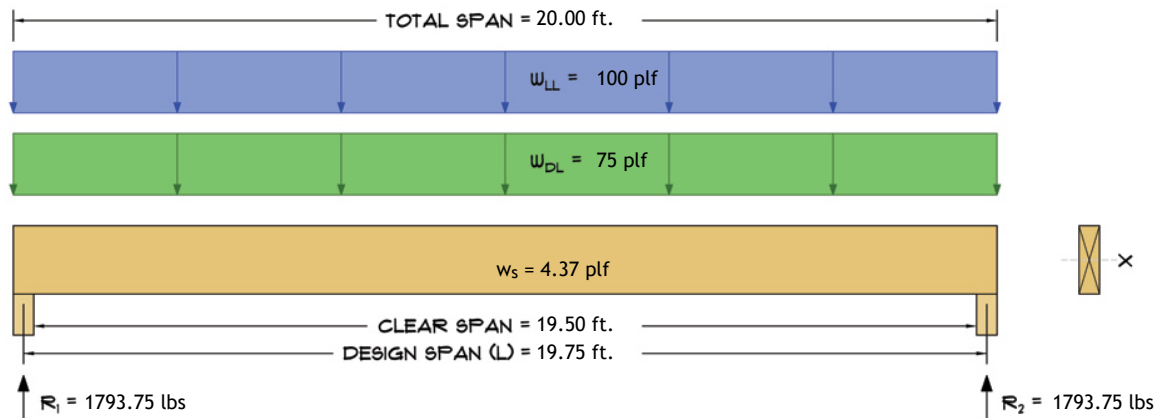
$$\text{Volume}_{\text{span}} = N[A \times L] = 1 \times [16.88 \times 237.00] \times (12 \text{ in./ft.})^3 = 2.31 \text{ ft}^3$$

$$\text{Total Weight (} W_T) = \rho_w \times \text{Volume}_{\text{total}} = 37.33 \times 2.34 = 87.5 \text{ lbs}$$

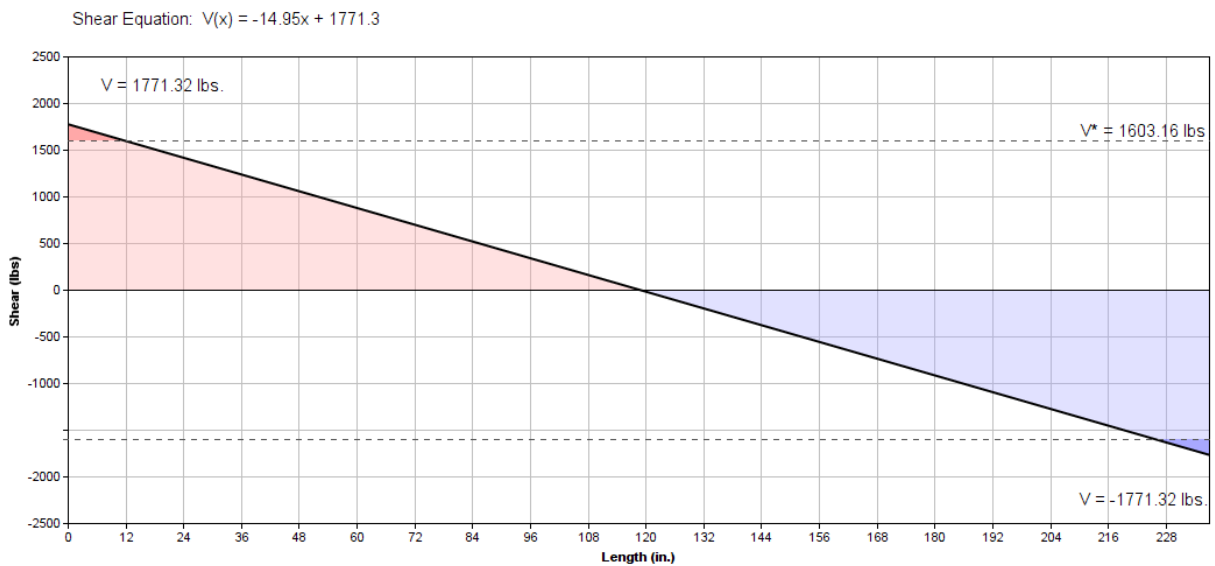
$$\text{Self Weight (} W_S) = \rho_w \times \text{Volume}_{\text{span}} = 37.33 \times 2.31 = 86.4 \text{ lbs}$$

$$\text{Distributed Self Weight (} w_s) = \frac{W_S}{L} = \frac{86.4}{19.75} = 4.37 \text{ plf}$$

Load, Shear and Moment Diagrams:



Beam - Shear Diagram



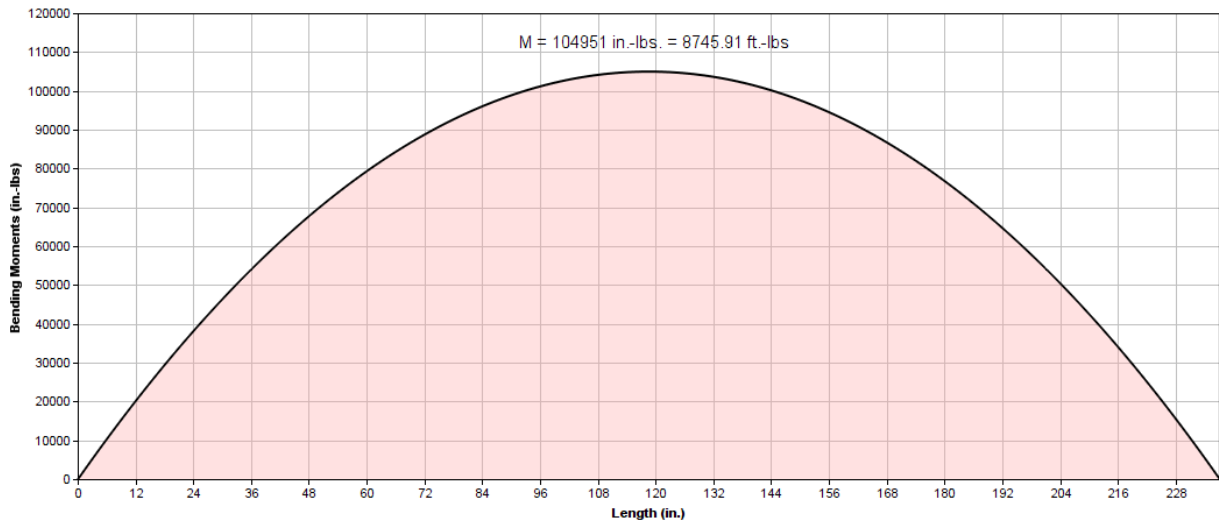
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**Beam - Moment Diagram**

Moment Equation:  $M(x) = -7.47x^2 + 1771.3x$



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:

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

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 RB:

$$l_u = \text{Unbraced Length} = 19.750 \text{ ft.}$$

$$l_u/d = \frac{237}{11.25} = 21.07$$

$$l_e = 1.63l_u + 3d = 1.63(237.0) + 3(11.25) = 420.06 \text{ in.} = 35.00 \text{ ft. (NDS Table 3.3.3)}$$

$$R_b = \sqrt{\frac{l_e d}{b^2}} = \sqrt{\frac{420.06(11.25)}{(1 \times 1.5)^2}} = 45.83$$

$$R_b = 45.83 < 50 \text{ ? OK}$$

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Euler-based ASD critical buckling value for bending members:

$$E_{\min y'} = E_{\min y}(C_M)(C_t)(C_i) = 510000(1)(1)(1) = 510000 \text{ psi}$$

$$F_{bE} = \frac{1.2E'_{\min y}}{(R_b)^2} = \frac{1.2(510000)}{(45.83)^2} = 291.39 \text{ psi}$$

$$F_{bx}^* = F_{bx}(C_D)(C_M)(C_t)(C_F)(C_i)(C_r) = (750)(1.15)(1)(1)(1)(1)(1) = 862.50 \text{ psi}$$

Beam stability factor:

$$C_L = \frac{1 + F_{be}/F_{bx}^*}{1.9} - \sqrt{\left(\frac{1 + F_{be}/F_{bx}^*}{1.9}\right)^2 - \frac{F_{be}/F_{bx}^*}{0.95}} = \frac{1 + 291.39/862.50}{1.9} - \sqrt{\left(\frac{1 + 291.39/862.50}{1.9}\right)^2 - \frac{291.39/862.50}{0.95}} = 0.330$$

$$F_{bx}' = (750)(1.15)(1)(1)(0.330)(1)(1)(1) = 284.4 \text{ psi}$$

$$f_b = \frac{M}{N \times S_x} = \frac{104951}{1 \times 31.64} = 3317.0 \text{ psi}$$

$$f_b = 3317.0 \text{ psi} > F_{bx}' = 284.4 \text{ psi} \quad (\text{CSI} = 11.66) \quad ? \quad \mathbf{NG}$$

## 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:

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

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

$$F_{vx}' = (175)(1.15)(1)(1)(1) = 201.25 \text{ psi}$$

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.

$$f_v^* = \frac{3V^*}{2(N \times A)} = \frac{3(1603.16)}{2(1 \times 16.88)} = 142.50 \text{ psi}$$

$$f_v^* = 142.50 \text{ psi} < F_{vx}' = 201.25 \text{ psi} \quad (\text{CSI} = 0.71) \quad ? \quad \mathbf{OK}$$

No Reduction in Shear (conservative):

$$f_v = \frac{3V}{2(N \times A)} = \frac{3(1771.32)}{2(1 \times 16.88)} = 157.45 \text{ psi}$$

$$f_v = 157.45 \text{ psi} < F_{vx}' = 201.25 \text{ psi} \quad (\text{CSI} = 0.78) \quad ? \quad \mathbf{OK}$$

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### 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

$$E_x' = E_x(C_M)(C_t)(C_i) = 1400000(1)(1)(1) = 1400000 \text{ psi}$$

$$\Delta_{LL} = \frac{5w_{LL}L^4}{384E_x'(N \times I_x)} = \frac{5(100)(19.750)^4}{384(1400000)(1 \times 177.98)} \times \left(12 \frac{\text{in.}}{\text{ft.}}\right)^3 = 1.37 \text{ in.}$$

$$(L/d)_{LL} = 237.00 / 1.37 = 173$$

$$\Delta_{LL} = 1.37 \text{ in} = L/173 > L/360 \quad ? \quad \mathbf{NG}$$

$$\Delta_{TL} = \frac{5(w_{TL} + w_s)L^4}{384E_x'(N \times I_x)} = \frac{5(175 + 4.37)(19.750)^4}{384(1400000)(1 \times 177.98)} \times \left(12 \frac{\text{in.}}{\text{ft.}}\right)^3 = 2.46 \text{ in.}$$

$$(L/d)_{TL} = 237.00 / 2.46 = 96$$

$$\Delta_{TL} = 2.46 \text{ in} = L/96 > L/240 \quad ? \quad \mathbf{NG}$$

### 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:

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

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

$$F_{c \perp x}' = (565)(1)(1)(1) = 565.00 \text{ psi}$$

$$A_b = b \times l_b = 1.5 \times 3 = 4.50 \text{ in}^2$$

$$f_{c \perp} = \frac{R}{N \times A_b} = \frac{1793.75}{1 \times 4.50} = 398.6 \text{ psi}$$

$$f_{c \perp} = 398.6 \text{ psi} < F_{c \perp x}' = 565.00 \text{ psi} \quad (\text{CSI} = 0.71) \quad ? \quad \mathbf{OK}$$

\*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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