# 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 10 |
| Design Span (L): | 20.75 ft. |
| Clear Span: | 20.50 ft. |
| Total Span: | 21.00 ft. |
| Bearing ($l_b$): | 3 in. |
| Quantity (N): | 1 |

## 2. Design Loads

| | |
|---|---|
| Live Load: | 100 plf |
| Dead Load: | 75 plf |
| Selfweight: | 74.6 lbs |
| Dist. Selfweight: | 3.60 plf |
| Total Weight: | 75.5 lbs |

## 3. Design Options

| | |
|---|---|
| Lateral Support: | Undefined |
| Defl. Limits: | 360\|240 |
| Load Duration: | 1.00 |
| Exposure: | dry |
| Temperature: | T <= 100°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 | 1.00 | 1.00 | 1.00 | 1.00 | - | - |
| $C_M$ | 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 | 0.983 | - | - | - | - | - |
| $C_F$ | 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 $(F_b)(C_F) \le 1{,}150$ psi, $C_M = 1.0$.

c) When $(F_c)(C_F) \le 750$ 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 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 = 1.500 in.
d = 9.250 in.
A = 1.500 x 9.250 = 13.88 in.$^2$
$S_x = (1.500)(9.250)^2/6 = 21.39$ in.$^3$
$S_y = (1.500)^2(9.250)/6 = 3.47$ in.$^3$
$I_x = (1.500)(9.250)^3/12 = 98.93$ in.$^4$
$I_y = (1.500)^3(9.250)/12 = 2.60$ 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 | $F_b$ | $F_t$ | $F_v$ | $F_{c\perp}$ | $F_c$ | E | $E_{min}$ | G |
|---|---|---|---|---|---|---|---|---|
| SP No.2 | 800 | 475 | 175 | 565 | 1300 | 1400000 | 510000 | 0.55 |

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:

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

G = 0.55
m.c. = 19 % (Max. moisture content at dry service conditions)



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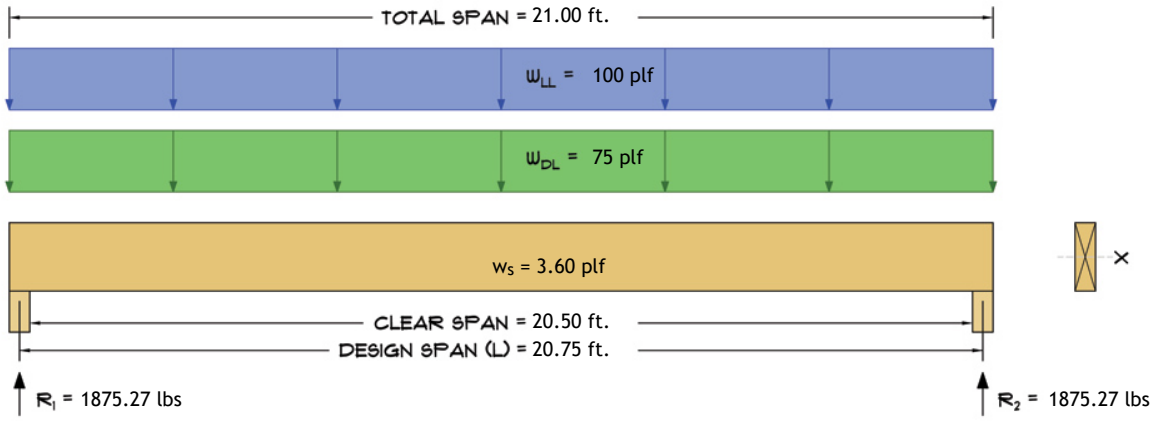
$$\rho_w = 62.4\left[\frac{0.55}{1+0.55(0.009)(19)}\right]\left[1+\frac{19}{100}\right] = 37.33 \text{ lbs/ft}^3$$

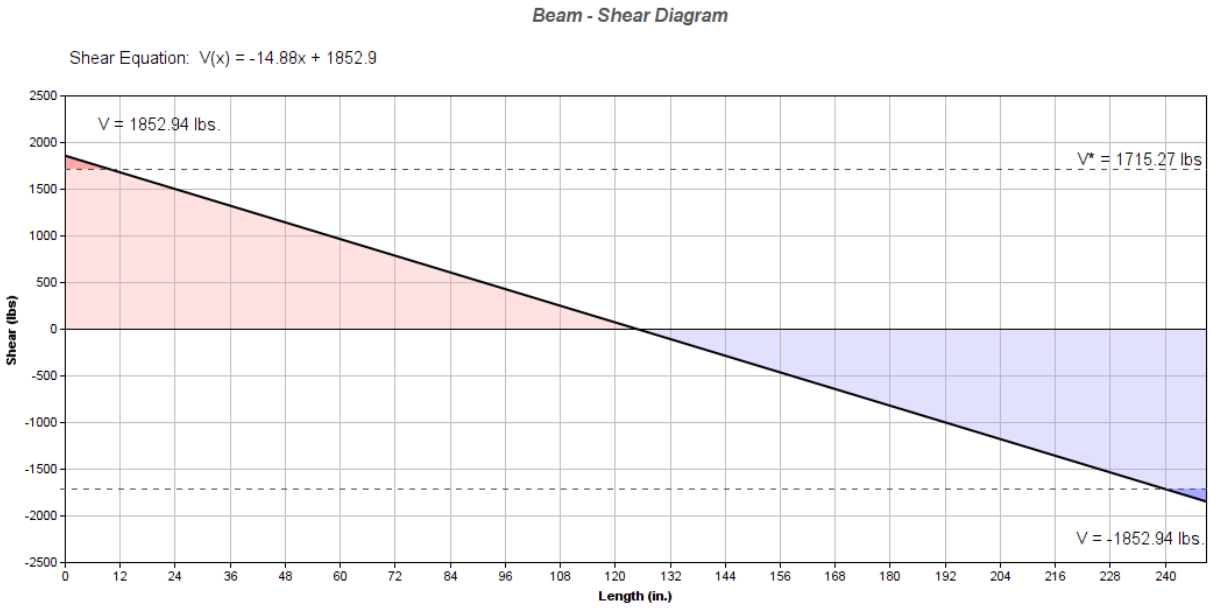
$\text{Volume}_{total}$ = N[A x (L + $l_b$)] = 1 x [13.88 x (249.00 + 3)] x (12 in./ft.)$^3$ = 2.02 ft$^3$
$\text{Volume}_{span}$ = N[A x L] = 1 x [13.88 x 249.00] x (12 in./ft.)$^3$ = 2.00 ft$^3$

Total Weight ($W_T$) = $\rho_w$ x $\text{Volume}_{total}$ = 37.33 x 2.02 = 75.5 lbs
Self Weight ($W_S$) = $\rho_w$ x $\text{Volume}_{span}$ = 37.33 x 2.00 = 74.6 lbs

Distributed Self Weight ($w_s$) = $\frac{W_S}{L} = \frac{74.6}{20.75}$ = 3.60 plf

Load, Shear and Moment Diagrams:

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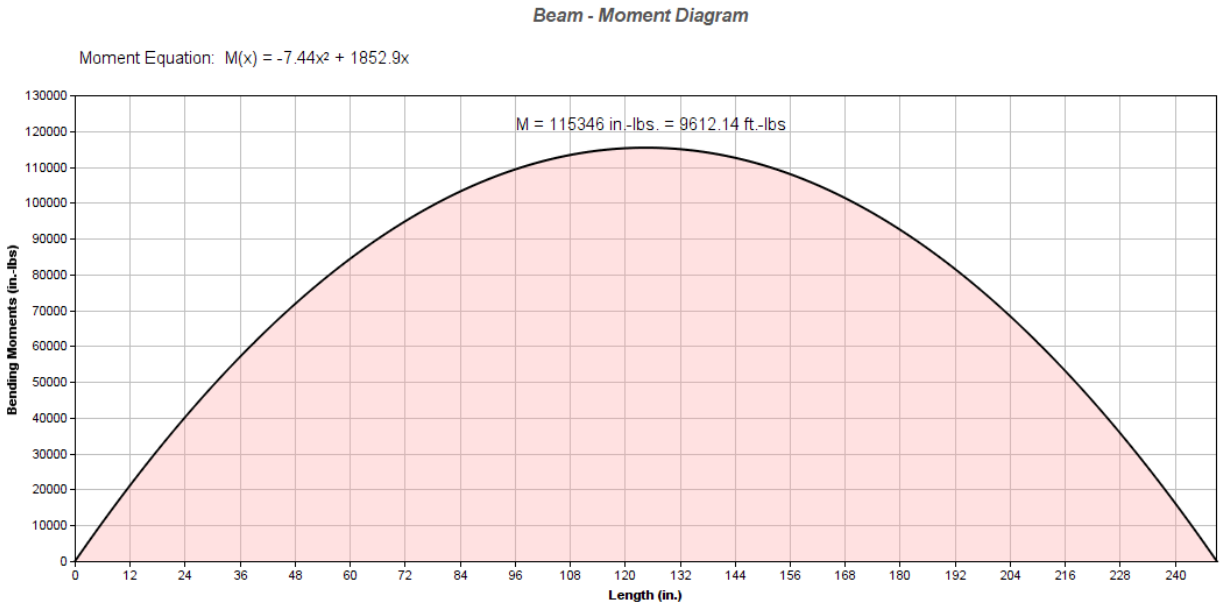


## 1.) Bending:

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.

$$l_u/d = \frac{24}{9.25} = 2.59$$

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

$$R_b = \sqrt{\frac{l_e d}{b^2}} = \sqrt{\frac{49.44(9.25)}{(1 \times 1.5)^2}} = 14.26$$

$R_b = 14.26 < 50$ ? **OK**

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Euler-based ASD critical buckling value for bending members:

$E_{miny}' = E_{miny}(C_M)(C_t)(C_i) = 510000(1)(1)(1) = 510000$ psi

$$F_{bE} = \frac{1.2E'_{miny}}{(R_b)^2} = \frac{1.2(510000)}{(14.26)^2} = 3011.02 \text{ psi}$$

$F_{bx}^* = F_{bx}(C_D)(C_M)(C_t)(C_F)(C_i)(C_r) = (800)(1.00)(1)(1)(1)(1)(1) = 800.00$ psi

Beam stability factor:

$$C_L = \frac{1+F_{be}/F^*_{bx}}{1.9} - \sqrt{\left(\frac{1+F_{be}/F^*_{bx}}{1.9}\right)^2 - \frac{F_{be}/F^*_{bx}}{0.95}} = \frac{1+3011.02/800.00}{1.9} - \sqrt{\left(\frac{1+3011.02/800.00}{1.9}\right)^2 - \frac{3011.02/800.00}{0.95}} = 0.983$$

$F_{bx}' = (800)(1.00)(1)(1)(0.983)(1)(1)(1) = 786.1$ psi

$$f_b = \frac{M}{N \times S_x} = \frac{115346}{1 \times 21.39} = 5392.3 \text{ psi}$$

$f_b = 5392.3$ psi > $F_{bx}' = 786.1$ psi (CSI = 6.86) ? **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:

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

where:

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

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

$F_{vx}' = (175)(1.00)(1)(1)(1) = 175.00$ 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.

$$f_v^* = \frac{3V^*}{2(N \times A)} = \frac{3(1715.27)}{2(1 \times 13.88)} = 185.44 \text{ psi}$$

$f_v^* = 185.44$ psi > $F_{vx}' = 175.00$ psi (CSI = 1.06) ? **NG**

No Reduction in Shear (conservative):

$$f_v = \frac{3V}{2(N \times A)} = \frac{3(1852.94)}{2(1 \times 13.88)} = 200.32 \text{ psi}$$

$f_v = 200.32$ psi > $F_{vx}' = 175.00$ psi (CSI = 1.14) ? **NG**



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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

$E_x' = E_x(C_M)(C_t)(C_i) = 1400000(1)(1)(1) = 1400000$ psi

$$\Delta_{LL} = \frac{5w_{LL}L^4}{384E_x'(N \times I_x)} = \frac{5(100)(20.750)^4}{384(1400000)(1 \times 98.93)} \times \left(12\frac{in.}{ft.}\right)^3 = 3.01 \text{ in.}$$

$(L/d)_{LL} = 249.00 / 3.01 = 83$

$\Delta_{LL} = 3.01$ in = L/83 > L/360 ? **NG**

$$\Delta_{TL} = \frac{5(w_{TL} + w_s)L^4}{384E_x'(N \times I_x)} = \frac{5(175 + 3.60)(20.750)^4}{384(1400000)(1 \times 98.93)} \times \left(12\frac{in.}{ft.}\right)^3 = 5.38 \text{ in.}$$

$(L/d)_{TL} = 249.00 / 5.38 = 46$

$\Delta_{TL} = 5.38$ in = L/46 > L/240 ? **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:

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

where:

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

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

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

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

$$f_{c\perp} = \frac{R}{N \times A_b} = \frac{1875.27}{1 \times 4.50} = 416.7 \text{ psi}$$

$f_{c\perp} = 416.7$ psi < $F_{c\perp x}' = 565.00$ psi (CSI = 0.74) ? **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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