Beam Design - APB 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:	5.125 x 20.625
Design Span (L):	21.75 ft.
Clear Span:	21.50 ft.
Total Span:	22.00 ft.
Bearing (l_b):	3 in.
Quantity (N):	1

2. Design Loads

Live Load:	600	plf
Dead Load:	350	plf
Selfweight:	589.0	lbs
Dist. Selfweight:	27.08	plf
Total Weight:	595.7	lbs

3. Design Options

Lateral Support:	braced
Defl. Limits:	180|120
Load Duration:	1.15
Exposure:	dry
Temperature:	T <= 100°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	1.15	1.15	1.15	1.15	-	-
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	1	-	-	-	-	-
C_V	Volume Factor	0.972[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 x 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.^{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 = 5.125 in.
d = 20.625 in.
A = 5.125 x 20.625 = 105.70 in.^{2}
$S_x = (5.125)(20.625)^2/6 = 363.35$ in.^{3}
$S_y = (5.125)^2(20.625)/6 = 90.29$ in.^{3}
$I_x = (5.125)(20.625)^3/12 = 3747.09$ in.^{4}
$I_y = (5.125)^3(20.625)/12 = 231.36$ in.^{4}

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

Species & Grade	F_{bx}+	F_{bx}-	$F_{c\perp x}$	F_{vx}	E_x	E_{minx}	F_{by}	$F_{c\perp y}$	F_{vy}	E_y	E_{miny}	F_t	F_c	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^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 = 0.55
m.c. = 16 % (Max. moisture content at dry service conditions)

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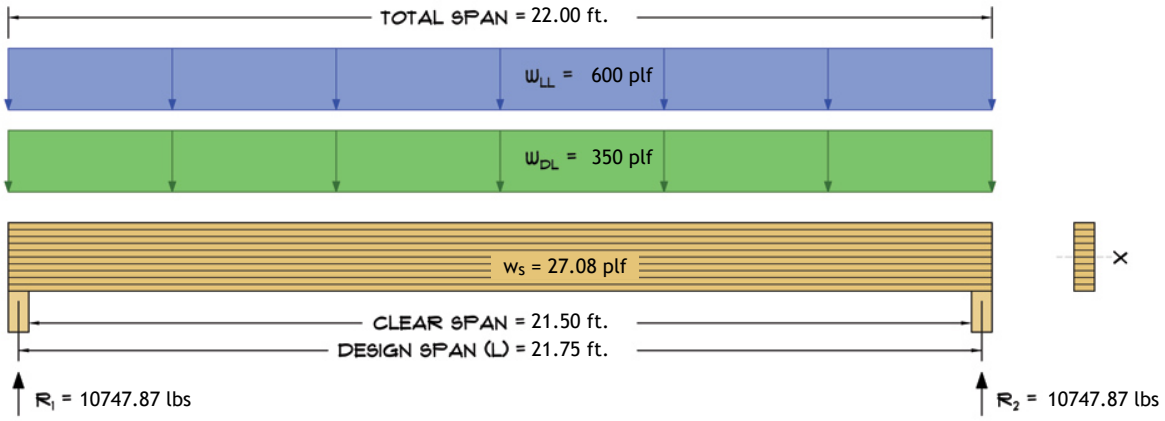
$$\rho_w = 62.4\left[\frac{0.55}{1+0.55(0.009)(16)}\right]\left[1+\frac{16}{100}\right] = 36.89 \text{ lbs/ft}^3$$

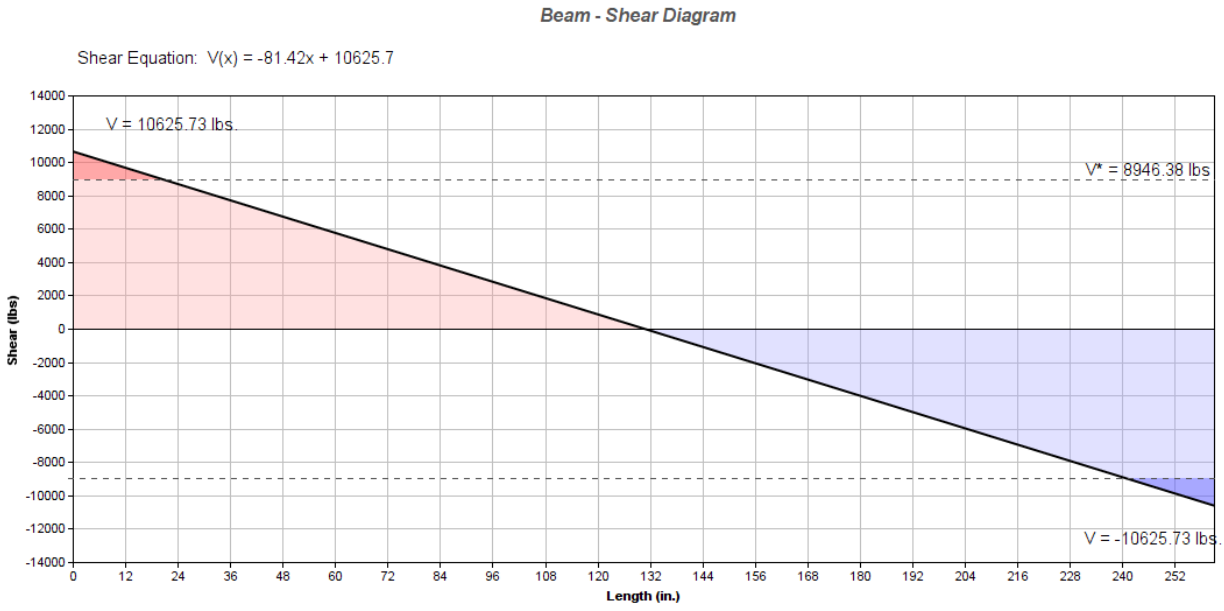
$\text{Volume}_{\text{total}} = N[A \times (L + l_b)] = 1 \times [105.70 \times (261.00 + 3)] \times (12 \text{ in./ft.})^3 = 16.15 \text{ ft}^3$
$\text{Volume}_{\text{span}} = N[A \times L] = 1 \times [105.70 \times 261.00] \times (12 \text{ in./ft.})^3 = 15.97 \text{ ft}^3$

Total Weight (W_T) = ρ_w x $\text{Volume}_{\text{total}}$ = 36.89 x 16.15 = 595.7 lbs
Self Weight (W_S) = ρ_w x $\text{Volume}_{\text{span}}$ = 36.89 x 15.97 = 589.0 lbs

Distributed Self Weight (w_s) = $\frac{W_S}{L} = \frac{589.0}{21.75}$ = 27.08 plf

Load, Shear and Moment Diagrams:





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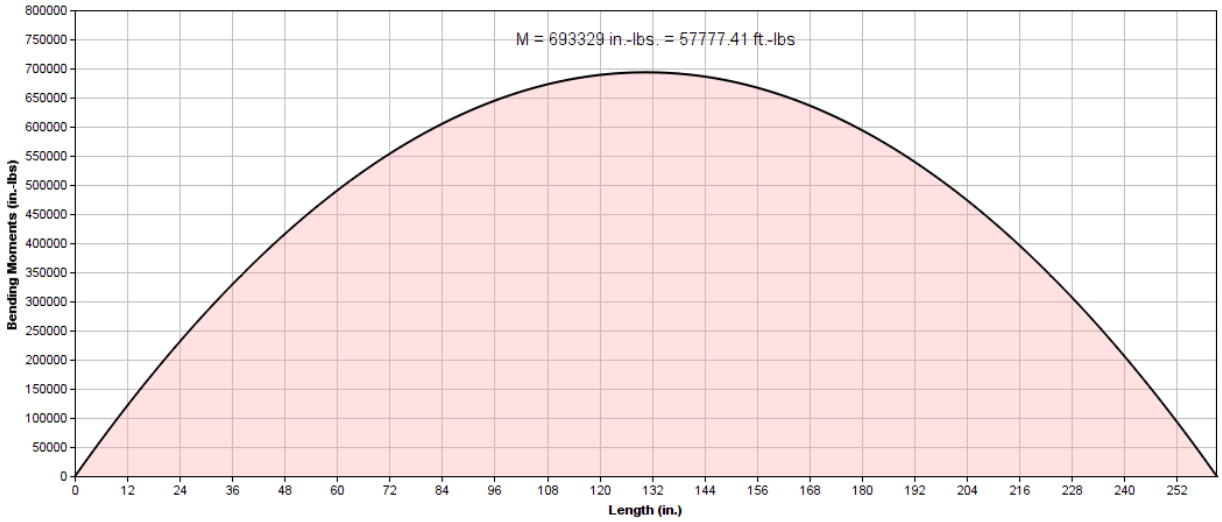
Beam - Moment Diagram

Moment Equation: M(x) = -40.71x² + 10625.7x



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:

$f_b = M / S$

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

Beam is braced laterally along its compression edge. Laterial stability is not a consideration:

C_L = Beam Stability Factor = 1.0

$$C_V = \left(\frac{21}{L}\right)^{0.05}\left(\frac{12}{d}\right)^{0.05}\left(\frac{5.125}{b}\right)^{0.05} = \left(\frac{21}{21.750}\right)^{0.05}\left(\frac{12}{20.625}\right)^{0.05}\left(\frac{5.125}{5.125}\right)^{0.05} = 0.972$$

Volume effect governs over lateral stability:

$C_V = 0.972 < C_L = 1$

$F_{bx}' = (2400)(1.15)(1)(1)(0.972) = 2681.6$ psi

$$f_b = \frac{M}{N \times S_x} = \frac{693329}{1 \times 363.35} = 1908.1 \text{ psi}$$

$f_b = 1908.1$ psi $< F_{bx}' = 2681.6$ psi (CSI = 0.71) ? **OK**

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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:

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

where:

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

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

$F_{vx}' = (300)(1.15)(1)(1) = 345.00$ psi

Shear Reduction: For beams supported by full bearing on one surface and loads applied to the opposite surface, uniformly distributed loads within a distance, d, from supports equal to the depth of the bending member shall be pemitted to be ignored. For beams supported by full bearing on one surface and loads applied to the opposite surface, 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.

$$f_v^* = \frac{3V^*}{2(N \times A)} = \frac{3(8946.38)}{2(1 \times 105.70)} = 126.96 \text{ psi}$$

$f_v^* = 126.96$ psi $< F_{vx}' = 345.00$ psi (CSI = 0.37) ? **OK**

No Reduction in Shear (conservative):

$$f_v = \frac{3V}{2(N \times A)} = \frac{3(10625.73)}{2(1 \times 105.70)} = 150.79 \text{ psi}$$

$f_v = 150.79$ psi $< F_{vx}' = 345.00$ psi (CSI = 0.44) ? **OK**

3.) Deflection:

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

LL Allowable: L/180
TL Allowable: L/120

$E_x' = E_x(C_M)(C_t) = 1800000(1)(1) = 1800000$ psi

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$$\Delta_{LL} = \frac{5w_{LL}L^4}{384E'_x(N \times I_x)} = \frac{5(600)(21.750)^4}{384(1800000)(1 \times 3747.09)} \times \left(12\frac{in.}{ft.}\right)^3 = 0.45 \text{ in.}$$

$(L/d)_{LL}$ = 261.00 / 0.45 = 583

Δ_{LL} = 0.45 in = L/583 < L/180 ? **OK**

$$\Delta_{TL} = \frac{5(w_{TL} + w_s)L^4}{384E'_x(N \times I_x)} = \frac{5(950 + 27.08)(21.750)^4}{384(1800000)(1 \times 3747.09)} \times \left(12\frac{in.}{ft.}\right)^3 = 0.73 \text{ in.}$$

$(L/d)_{TL}$ = 261.00 / 0.73 = 358

Δ_{TL} = 0.73 in = L/358 < L/120 ? **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:

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

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

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

$A_b = b \times l_b = 5.125 \times 3 = 15.38$ in^2

$$f_{c\perp} = \frac{R}{N \times A_b} = \frac{10747.87}{1 \times 15.38} = 699.0 \text{ psi}$$

$f_{c\perp}$ = 699.0 psi < $F_{c\perp x}'$ = 740.00 psi (CSI = 0.94) ? **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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