# Beam Design

## 1. Beam Data

| | |
|---|---|
| Load Type: | Uniform Dist. Load |
| Support: | Simple Beam |
| Beam Type: | Glulam |
| Species: | Western Species |
| Grade: | 24F-V4 1.8E DF/DF |
| Size: | 6.75 x 16.5 |
| Design Span (L): | 18.00 ft. |
| Clear Span: | 17.50 ft. |
| Total Span: | 18.50 ft. |
| Bearing ($l_b$): | 6 in. |
| Quantity (N): | 1 |

## 2. Design Loads

| | |
|---|---|
| Live Load: | 1080 plf |
| Dead Load: | 180 plf |
| Selfweight: | 470.0 lbs |
| Dist. Selfweight: | 26.11 plf |
| Total Weight: | 483.1 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: | Snow Load 90 |

## 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 | 0.957[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.

## 6. Beam Calculations

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

$A = b \times d$

,

,

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 = 6.750 in.
d = 16.500 in.
A = 6.750 x 16.500 = 111.38 in.$^2$
$S_x = (6.750)(16.500)^2/6 = 306.28$ in.$^3$
$S_y = (6.750)^2(16.500)/6 = 125.30$ in.$^3$
$I_x = (6.750)(16.500)^3/12 = 2526.82$ in.$^4$
$I_y = (6.750)^3(16.500)/12 = 422.88$ 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-V4 1.8E DF/DF | 2400 | 1850 | 650 | 265 | 1800000 | 950000 | 1450 | 560 | 230 | 1600000 | 850000 | 1100 | 1650 | 0.5 |

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

where:

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

G = 0.5
m.c. = 16 %   (Max. moisture content at dry service conditions)

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$= 33.76 \text{ lbs/ft}^3$

$\text{Volume}_{total} = N[A \times (L + l_b)] = 1 \times [111.38 \times (216.00 + 6)] \times (12 \text{ in./ft.})^3 = 14.31 \text{ ft}^3$

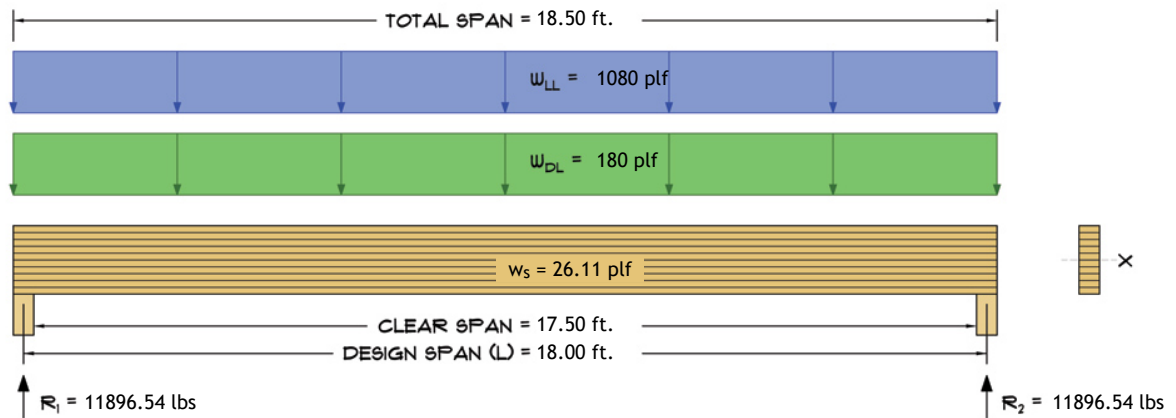$\text{Volume}_{span} = N[A \times L] = 1 \times [111.38 \times 216.00] \times (12 \text{ in./ft.})^3 = 13.92 \text{ ft}^3$

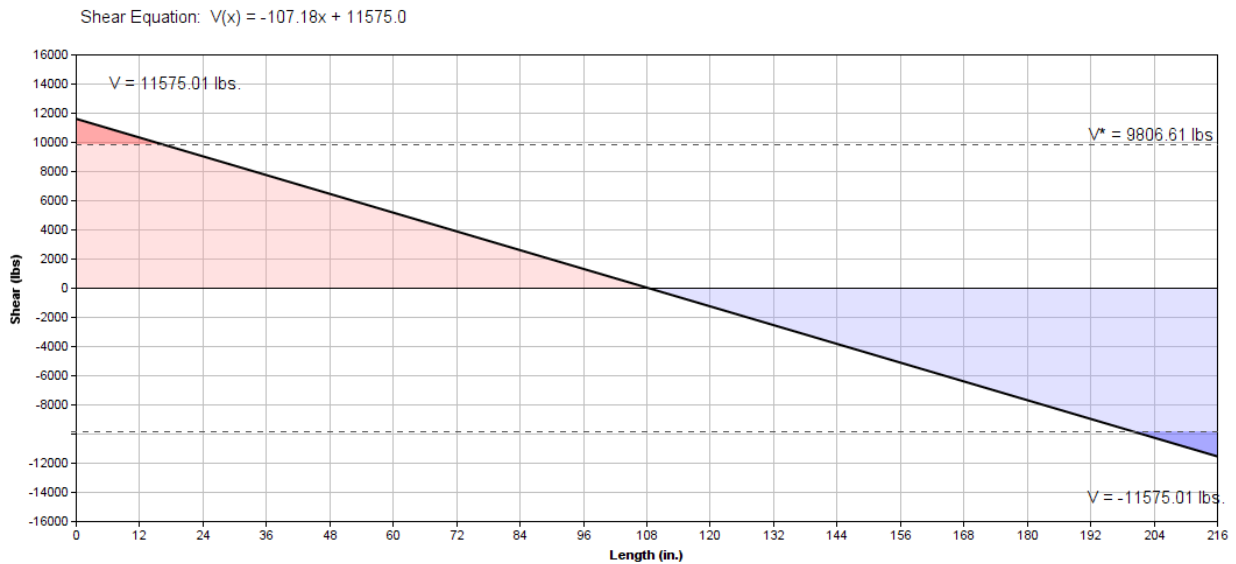Total Weight $(W_T) = \rho_w \times \text{Volume}_{total} = 33.76 \times 14.31 = 483.1 \text{ lbs}$

Self Weight $(W_S) = \rho_w \times \text{Volume}_{span} = 33.76 \times 13.92 = 470.0 \text{ lbs}$

Distributed Self Weight $(w_s) = \; = 26.11 \text{ plf}$
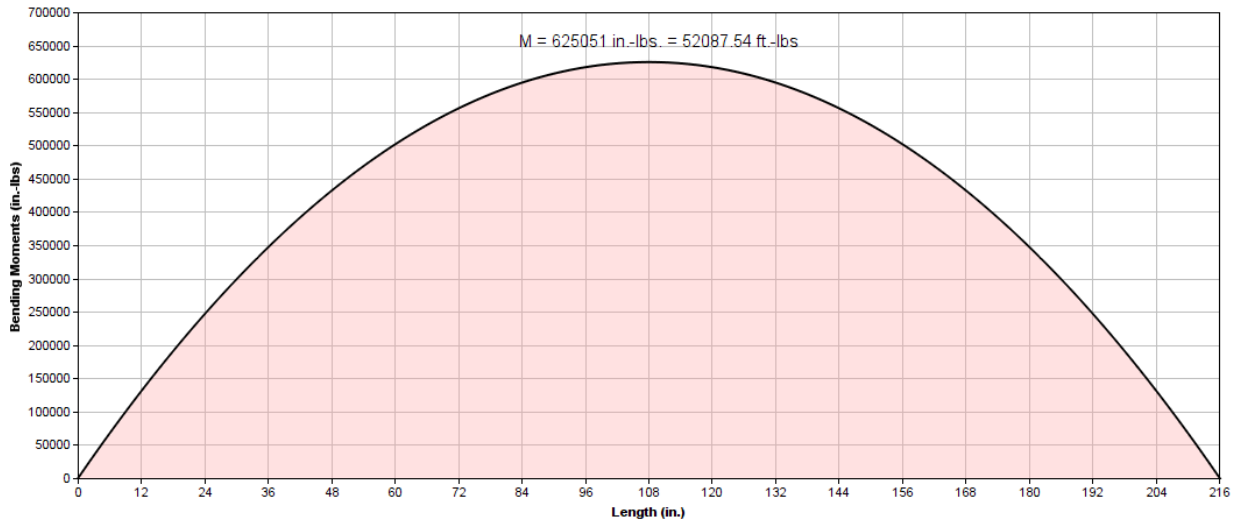
Load, Shear and Moment Diagrams:



**Beam - Shear Diagram**

Shear Equation: $V(x) = -107.18x + 11575.0$

**Beam - Moment Diagram**

Moment Equation: $M(x) = -53.59x^2 + 11575.0x$

$M = 625051$ in.-lbs. $= 52087.54$ ft.-lbs



1.) <u>Bending</u>:

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

$C_V = = 0.957$

Volume effect governs over lateral stability:

$C_V = 0.957 < C_L = 1$

$F_{bx}' = (2400)(1.15)(1)(1)(0.957) = 2641.3$ psi

$f_b = = 2040.8$ psi

$f_b = 2040.8$ psi $< F_{bx}' = 2641.3$ psi (CSI = 0.77) ? **OK**

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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:

$f_v =$

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

$F_{VX}' = (265)(1.15)(1)(1) = 304.75$ 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.

$f_v* = = 132.08$ psi

$f_v* = 132.08$ psi $< F_{VX}' = 304.75$ psi  (CSI = 0.43)  ?  **OK**

No Reduction in Shear (conservative):

$f_v = = 155.89$ psi

$f_v = 155.89$ psi $< F_{VX}' = 304.75$ psi  (CSI = 0.51)  ?  **OK**

3.) <u>Deflection</u>:

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

$\Delta_{LL} = \ = 0.56$ in.

$(L/d)_{LL} = 216.00 / 0.56 = 385$

$\Delta_{LL} = 0.56$ in $= L/385 < L/180$  ?  **OK**


$\Delta_{TL} = \ = 0.67$ in.

$(L/d)_{TL} = 216.00 / 0.67 = 323$

$\Delta_{TL} = 0.67$ in $= L/323 < L/120$  ?  **OK**


4.) <u>Bearing</u>:

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:

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

where:

$f_{c\perp} = $

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

$F_{c\perp x}' = (650)(1)(1) = 650.00$ psi

$A_b = b \times l_b = 6.75 \times 6 = 40.50$ in$^2$

$f_{c\perp} = \ = 293.7$ psi

$f_{c\perp} = 293.7$ psi $< F_{c\perp x}' = 650.00$ psi  (CSI = 0.45)  ?  **OK**