Beam Design

1. Beam Data

Load Type:	Uniform Dist. Load
Support:	Simple Beam
Beam Type:	Sawn Lumber
Species:	Douglas Fir-Larch
Grade:	DF No.2
Size:	2 x 12
Design Span (L):	19.75 ft.
Clear Span:	19.50 ft.
Total Span:	20.00 ft.
Bearing (l_b):	3 in.
Quantity (N):	3

2. Design Loads

Live Load:	80	plf
Dead Load:	65	plf
Selfweight:	237.5	lbs
Dist. Selfweight:	12.02	plf
Total Weight:	240.5	lbs

3. Design Options

Lateral Support:	braced
Defl. Limits:	360|240
Load Duration:	1.15
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	1.15	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	1	-	-	-	-	-
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 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 = 11.250 in.
A = 1.500 x 11.250 = 16.88 in.^{2}
S_x = (1.500)(11.250)^2/6 = 31.64 in.^{3}
S_y = (1.500)^2(11.250)/6 = 4.22 in.^{3}
I_x = (1.500)(11.250)^3/12 = 177.98 in.^{4}
I_y = (1.500)^3(11.250)/12 = 3.16 in.^{4}

Reference Design Values from Table 4A NDS Supplement (Reference Design Values for Visually Graded Dimension Lumber, 2" - 4" thick).

Species & Grade	F_b	F_t	F_v	$F_{c\perp}$	F_c	E	E_{min}	G
DF No.2	900	575	180	625	1350	1600000	580000	0.5

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 = 0.5
m.c. = 19 % (Max. moisture content at dry service conditions)

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$$\rho_w = 62.4\left[\frac{0.5}{1+0.5(0.009)(19)}\right]\left[1+\frac{19}{100}\right] = 34.20\ \text{lbs/ft}^3$$

$\text{Volume}_{total} = N[A \times (L + l_b)] = 3 \times [16.88 \times (237.00 + 3)] \times (12\ \text{in./ft.})^3 = 7.03\ \text{ft}^3$

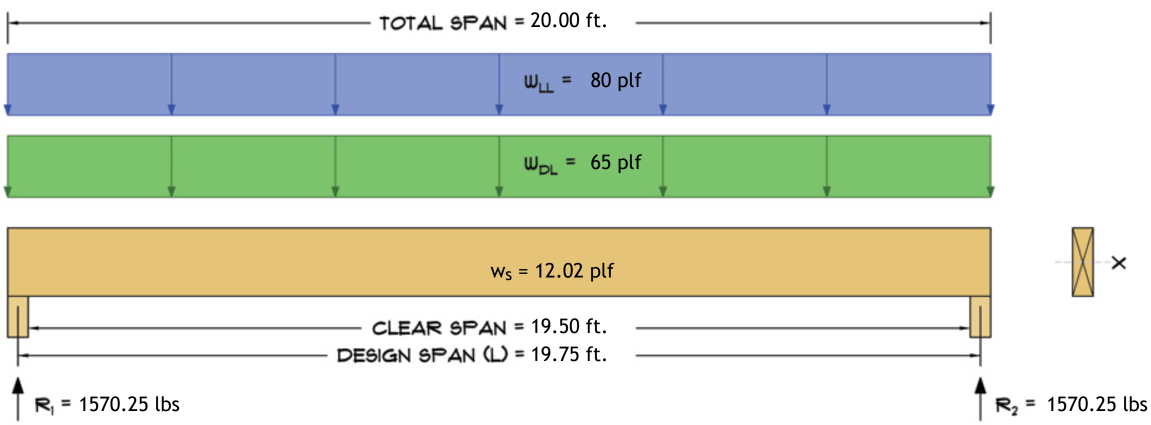
$\text{Volume}_{span} = N[A \times L] = 3 \times [16.88 \times 237.00] \times (12\ \text{in./ft.})^3 = 6.94\ \text{ft}^3$

Total Weight (W_T) = $\rho_W \times \text{Volume}_{total} = 34.20 \times 7.03 = 240.5$ lbs

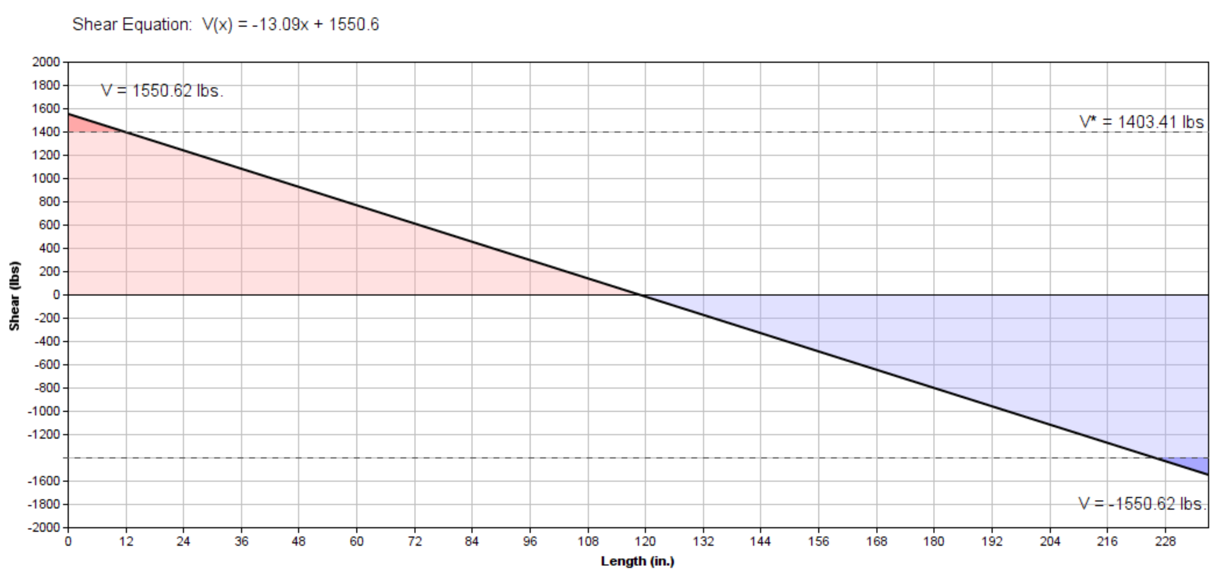
Self Weight (W_S) = $\rho_W \times \text{Volume}_{span} = 34.20 \times 6.94 = 237.5$ lbs

$$\text{Distributed Self Weight } (w_S) = \frac{W_S}{L} = \frac{237.5}{19.75} = 12.02\ \text{plf}$$

Load, Shear and Moment Diagrams:



Beam - Shear Diagram



Subject	Customer	Location	Job No.
Beam Design			2023A152

Engr.: N. Wilkerson

Date: 4/14/2023

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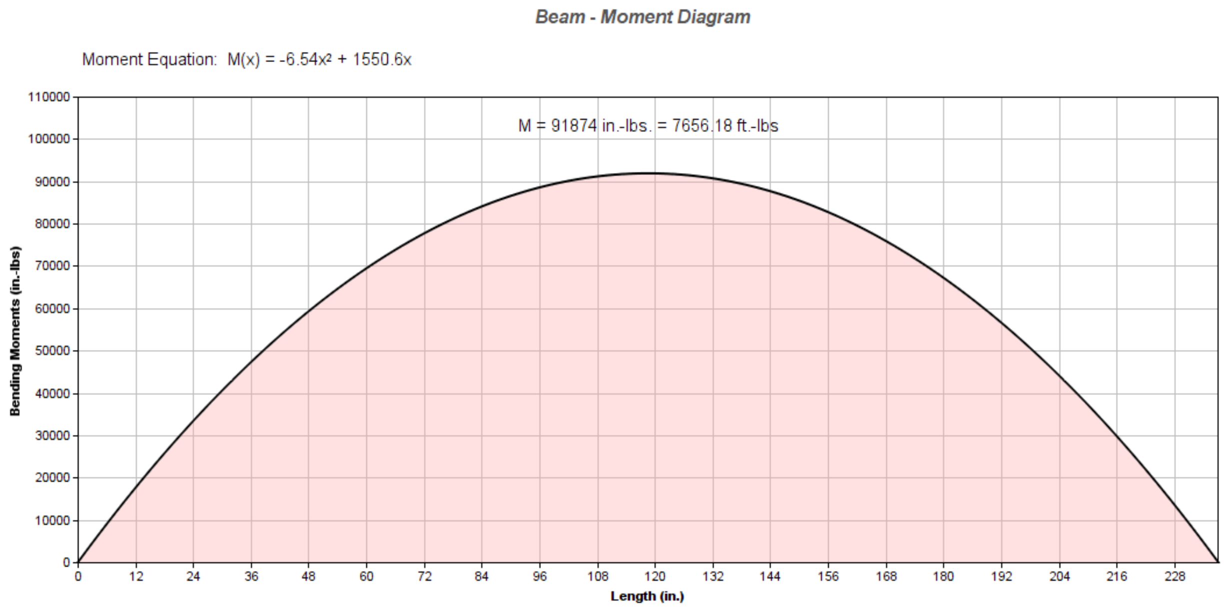

1.) Bending:

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

C_L = Beam Stability Factor = 1.0

$F_{bx}' = (900)(1.15)(1)(1)(1)(1)(1)(1) = 1035.0$ psi

$$f_b = \frac{M}{N \times S_x} = \frac{91874}{3 \times 31.64} = 967.9 \text{ psi}$$

$f_b = 967.9$ psi $< F_{bx}' = 1035.0$ psi (CSI = 0.94) ? **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:

$f_V \leq F_V'$ *(NDS Sec. 3.4.1)*

where:

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

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

$F_{VX}' = (180)(1.15)(1)(1)(1) = 207.00$ 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.

$$f_V^* = \frac{3V^*}{2(N \times A)} = \frac{3(1403.41)}{2(3 \times 16.88)} = 41.58 \text{ psi}$$

$f_V^* = 41.58$ psi $< F_{VX}' = 207.00$ psi (CSI = 0.20) ? **OK**

No Reduction in Shear (conservative):

$$f_V = \frac{3V}{2(N \times A)} = \frac{3(1550.62)}{2(3 \times 16.88)} = 45.94 \text{ psi}$$

$f_V = 45.94$ psi $< F_{VX}' = 207.00$ psi (CSI = 0.22) ? **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

$E_X' = E_X(C_M)(C_t)(C_i) = 1600000(1)(1)(1) = 1600000$ psi

$$\Delta_{LL} = \frac{5w_{LL}L^4}{384E'_x(N \times I_x)} = \frac{5(80)(19.750)^4}{384(1600000)(3 \times 177.98)} \times \left(12\frac{in.}{ft.}\right)^3 = 0.32 \text{ in.}$$

$(L/d)_{LL}$ = 237.00 / 0.32 = 739

Δ_{LL} = 0.32 in = L/739 < L/360 ? **OK**

$$\Delta_{TL} = \frac{5(w_{TL} + w_s)L^4}{384E'_x(N \times I_x)} = \frac{5(145 + 12.02)(19.750)^4}{384(1600000)(3 \times 177.98)} \times \left(12\frac{in.}{ft.}\right)^3 = 0.63 \text{ in.}$$

$(L/d)_{TL}$ = 237.00 / 0.63 = 377

Δ_{TL} = 0.63 in = L/377 < L/240 ? **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:

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

where:

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

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

$F_{c\perp x}'$ = (625)(1)(1)(1) = 625.00 psi

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

$$f_{c\perp} = \frac{R}{N \times A_b} = \frac{1570.25}{3 \times 4.50} = 116.3 \text{ psi}$$

$f_{c\perp}$ = 116.3 psi < $F_{c\perp x}'$ = 625.00 psi (CSI = 0.19) ? **OK**