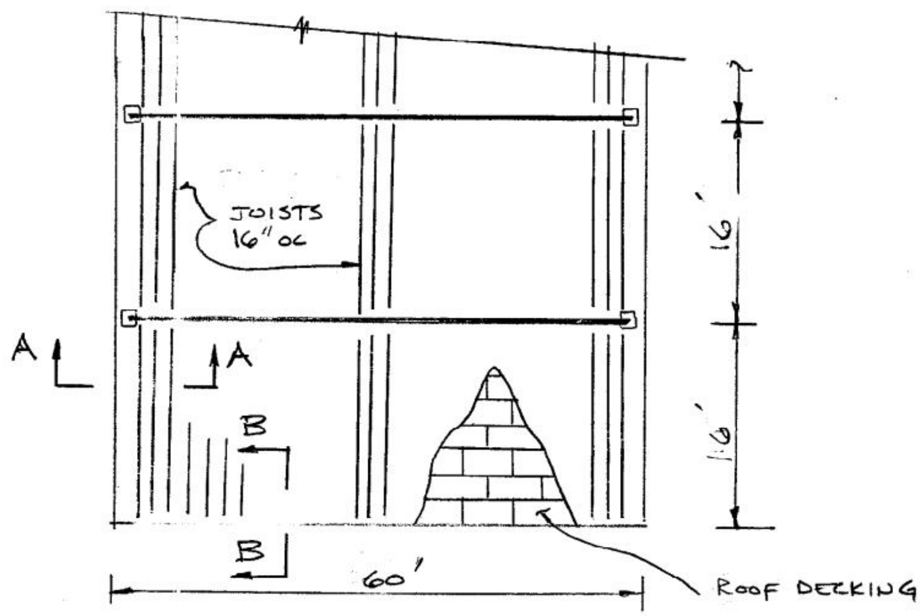
Given:

Roof Framing System:



$l := 60\ ft$

Design Loads:

- Roof Dead Load **(Beam Weight at 73 lbs/ft, for 6.75" X 45.375" Southern Pine Glulam)**:

  Plywood, rigid insulation, felt, gravel (2 in), HVAC, ceiling, joists and beam self weight (73 plf):

  $$D := 3\cdot\frac{5}{8} + 4\cdot.75 + 0.7\cdot5 + 104\cdot\frac{2}{12} + 4 + 2 + 7 = 38.708\ psf$$

- Roof Live Load (A_T = 960 ft^2):

  $A_T := 16\cdot60 = 960\ ft^2$

  $K_{LL} := 2$ 2007 FBC, Table 1607.9.1

  $L_0 := 20\ psf$

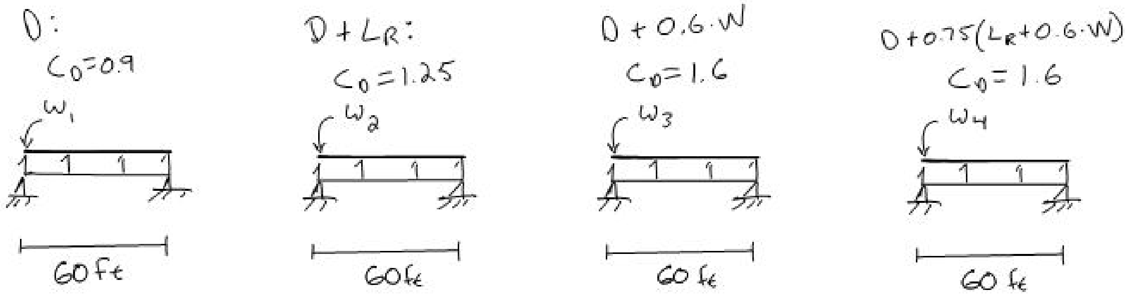
  $$L_R := \begin{cases} L_0\cdot\left(0.25 + \frac{15}{\sqrt{K_{LL}\cdot A_T}}\right) & \text{if } L_0\cdot\left(0.25 + \frac{15}{\sqrt{K_{LL}\cdot A_T}}\right) > 0.6\cdot L_0 \\ 0.6\cdot L_0 & \text{if } L_0\cdot\left(0.25 + \frac{15}{\sqrt{K_{LL}\cdot A_T}}\right) \le 0.6\cdot L_0 \end{cases}$$ 2007 FBC, Section 1607.9.1

  $L_R = 12\ psf$

- Wind Load:

 65.3 psf upward on 6 ft edge strips
 55.1 psf upward on interior
 19.4 psf downward

- <u>Downward Load Conditions (Glulam Beams @ 16' o.c.):</u>



Dead Load Only:

$w_1 := 16 \cdot D + 73 = 692.333$ plf

Dead plus Roof Live:

$w_2 := 16 \cdot \left(D + L_R\right) + 73 = 884.333$ plf

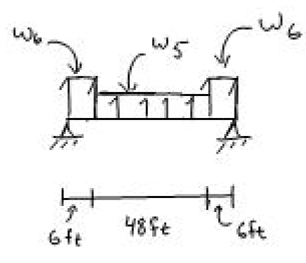
*Dead plus 0.6*Wind:*

$w_3 := 16 \cdot (D + 0.6 \cdot 19.4) + 73 = 878.573$ plf

*Dead plus 3/4 of (Roof Live plus 0.6*Wind):*

$w_4 := 16 \cdot \left[D + 0.75 \cdot \left(L_R + 0.6 \cdot 19.4\right)\right] + 73 = 976.013$ plf

- <u>Upward Load Conditions:</u> 0.6*D+W [W-0.6*D upward] C_D=1.6



Interior:

$w_5 := 16 \cdot (55.1 - 0.6 \cdot D) - 0.6 \cdot 73 = 466.2$ plf

Edge:

$w_6 := 16 \cdot (65.3 - 0.6 \cdot D) - 0.6 \cdot 73 = 629.4$ plf

- Estimate Controlling Downward Load Case:

Downward Load (C_L = 1.0):

Load Case:	Load (plf):	C_D:	Load/C_D:
1. D	692.33	0.9	769.26
2. D + L_R	884.33	1.25	707.46
5. D + 0.6*(W)	878.57	1.6	549.11
6a. D + 0.75*(L_R + 0.6*W)	976.01	1.6	610.01

Therefore $w_{down} := 692.33\ \text{plf}$ $C_{Ddown} := 0.9$

$$M_{down} := \frac{w_{down} \cdot l^2}{8} = 3.115 \times 10^5 \quad \text{ft} \cdot \text{lb}$$

Upward Load ($C_L \neq 1.0$):

Results from Visual Analysis:

Member	Result Case Name	Fx K	Vy K	Mz K-ft
BmX001	D	**0.0000**	**-14.9652**	0.0000
BmX001	D	0.0000	-14.2099	-17.5051
BmX001	D	0.0000	-13.4546	-34.1038
BmX001	D	0.0000	-12.6994	-49.7962
BmX001	D	0.0000	-11.9441	-64.5823
BmX001	D	0.0000	-11.1888	-78.462
BmX002	D	0.0000	-8.9510	-126.7976
BmX002	D	0.0000	-4.4755	-191.2451
BmX002	D	0.0000	0.0000	**-212.7276**
BmX002	D	0.0000	4.4755	-191.2451
BmX002	D	0.0000	8.9510	-126.7976
BmX003	D	0.0000	11.1888	-78.462
BmX003	D	0.0000	11.9441	-64.5823
BmX003	D	0.0000	12.6994	-49.7962
BmX003	D	0.0000	13.4546	-34.1038
BmX003	D	0.0000	14.2099	-17.5051
BmX003	D	0.0000	**14.9652**	**0.0000**

$M_{up} := 212728\ \text{ft} \cdot \text{lb}$ $C_{Dup} := 1.6$

- Determine Actual Bending Stresses:

*****6.75" X 45.375" Southern Pine Glulam:** NDS Supplement, Tables 5A & 1D (P.25 and P.60)

$d := 45.375 \text{ in} \quad b := 6.75 \text{ in} \quad S_x := 2316 \text{ in}^3 \quad E_{ymin} := 670000 \text{ psi}$

Downward Loads: $f_{bdown} := \frac{M_{down} \cdot (12)}{S_x} = 1.614 \times 10^3 \text{ psi}$

Upward Loads: $f_{bup} := \frac{M_{up} \cdot (12)}{S_x} = 1.102 \times 10^3 \text{ psi}$

- Check Bending Strength of Member: NDS 2005, Table 5.3.1 (P.34)

*****Use 24F-1.7E:** $SG := 0.55$ Manual for Engineered Wood Construction, Table M5.4-1 (P.32)

$F_{bxpos} := 2400 \text{ psi}$ NDS Supplement 2005, Table 5A (P.60)

$F_{bxneg} := 1450 \text{ psi}$ NDS Supplement 2005, Table 5A (P.60)

$C_{Ddown} := 0.9$ NDS 2005, Table 2.3.2 (P.9)

$C_{Dup} := 1.6$ NDS 2005, Table 2.3.2 (P.9)

$C_M := 1.0$ $EMC \leq 19\%$ NDS Supplement 2005, Table 4B (P.37)

$C_t := 1.0$ NDS 2005, Table 2.3.3 (P.9)

$C_{fu} := 1.0$ Major Axis Bending NDS 2005, Section 5.3.7

$C_c := 1.0$ NDS 2005, Section 5.3.8

Volume Factor (C_V): NDS 2005, Section 5.3.6

$x := 20$ for Southern Pine

$$C_V := \left(\frac{21}{l}\right)^{\frac{1}{x}} \cdot \left(\frac{12}{d}\right)^{\frac{1}{x}} \cdot \left(\frac{5.125}{b}\right)^{\frac{1}{x}} = 0.876$$ Eqn. (5.3-1)

Beam Stability Factor (C_L):

*****Bracing at 1/3 point:**

$l_u := \frac{60}{3} \cdot 12 = 240 \text{ in}$ $\qquad \frac{l_u}{d} = 5.289$

$l_e := 2.06 \cdot l_u = 494.4 \text{ in}$ NDS 2005, Table 3.3.3 (P.14)

$R_B := \sqrt{\frac{l_e \cdot d}{b^2}} = 22.189$ NDS 2005, Section 3.3.3.6

$F_{be} := \frac{1.2 \cdot E_{ymin}}{R_B^{\,2}} = 1.633 \times 10^3$ $\qquad F_{b'} := F_{bxneg} \cdot C_{Dup} = 2.32 \times 10^3$

$$C_{Lup} := \frac{1 + \left(\frac{F_{be}}{F_{b'}}\right)}{1.9} - \sqrt{\left[\frac{1 + \left(\frac{F_{be}}{F_{b'}}\right)}{1.9}\right]^2 - \frac{\frac{F_{be}}{F_{b'}}}{0.95}} = 0.645$$ Eqn. (3.3-6)

*****Downward Load Controls:**

$C_{Ldown} := 1.0$

Use the smaller of the C_L and C_V factors:

$F'_{bdown} := F_{bxpos} \cdot C_{Ddown} \cdot C_M \cdot C_t \cdot C_{fu} \cdot C_V \cdot C_c = 1.891 \times 10^3 \text{ psi} \quad > \quad f_{bdown} = 1.614 \times 10^3 \text{ psi}$

$F'_{bup} := F_{bxneg} \cdot C_{Dup} \cdot C_M \cdot C_t \cdot C_{fu} \cdot C_{Lup} \cdot C_c = 1.497 \times 10^3 \text{ psi} \quad > \quad f_{bup} = 1.102 \times 10^3 \text{ psi}$

*****Therefore, a 6.75" X 45.375" Southern Pine Glulam Beam, with lateral bracing at 1/3 points (240 in), has adequate bending strength for the controlling downward load case and adequate bracing for the upward wind load.**

- <u>Determine Actual Shear Stresses:</u>

*****6.75" X 45.375" Southern Pine Glulam:** NDS Supplement, Tables 5A & 1D (P.25 and P.60)

$d := 45.375\ \text{in}$ $b := 6.75\ \text{in}$ $A := 306.3\ \text{in}^2$ $F_{vx} := 210\ \text{psi}$

Shear from upward wind loads contols:

$$V_{max} := \frac{w_{down} \cdot l}{2} = 2.077 \times 10^4\ \text{lbs}$$

$$f_v := \frac{3}{2} \cdot \frac{V_{max}}{A} = 101.714\ \text{psi}$$

- <u>Check Shear Strength of Member:</u> NDS 2005, Table 5.3.1 (P.34)

$F_{vx} := 210\ \text{psi}$ NDS Supplement 2005, Table 5A (P.60)

$$F'_v := F_{vx} \cdot C_{Ddown} \cdot C_M \cdot C_t$$

$$F'_v = 189\ \text{psi} \quad > \quad f_v = 101.714\ \text{psi}$$

*****Therefore, a 6.75" X 45.375" Southern Pine Glulam Beam has adequate shear strength for the controlling load case.**

- Determine Bearing Length at end of members:

$F_{cper} := 500$ psi NDS Supplement 2005, Table 5A (P.60)

$C_b := 1.0$ Conservative NDS 2005, Table 3.10.4 (P.22)

$F'_{cp} := F_{cper} \cdot C_M \cdot C_t \cdot C_b$ NDS 2005, Table 4.3.1 (P.27)

$$F'_{cp} = 500 \text{ psi}$$

The compression strength parallel to the grain is not computed with the C_D factor.
Therefore, "D + 0.75*(L_R + 0.6*W)" [w_4] controls.

$$R := \frac{w_4 \cdot l}{2} = 2.928 \times 10^4 \text{ lbs}$$

$$A_{reqd} := \frac{R}{F'_{cp}} = 58.561 \text{ in}^2$$

$$l_b := \frac{A_{reqd}}{b} = 8.676 \text{ in}$$

*****Therefore, use a bearing length of at least 8.75".**

- Check Deflection Limits: 2007 FBC, Table 1604.3

Roof members supporting nonplaster ceiling:

D:

$\Delta_D := \frac{l \cdot 12}{240} = 3$ in

W:

$\Delta_W := \frac{l \cdot 12}{240} = 3$ in

D + L_R:

$\Delta_{DLr} := \frac{l \cdot 12}{180} = 4$ in

Check Δ_L:

24F-1.7E:

$E := 1700000$ psi 2005 NDS Supplement, Table 5A (P.60)

$I := 52550$ in^4 2005 NDS Supplement, Table 1D (P.25)

$\Delta_L := \frac{5 \cdot (16 \cdot 12) \cdot l^4}{384 \cdot E \cdot I} \cdot 1728 = 0.627$ in $<$ 3 in Therefore, ok

Wind loads (w_6 controls):

Per FBC Table 1604.3, Note (f), use: (0.7 * Component and Cladding)

therefore:

$\Delta_w := \frac{5 \cdot \left(0.7 w_6\right) \cdot l^4}{384 \cdot E \cdot I} \cdot 1728 = 1.438$ in $<$ 3 in Therefore, ok

Dead plus Roof Live Load (w_2):

$\Delta_{DLr} := \frac{5 \cdot w_2 \cdot l^4}{384 \cdot E \cdot I} \cdot 1728 = 2.887$ in $<$ 3 in Therefore, ok

- <u>Determine Camber for Roof Drainage (1/4" per foot):</u>

Dead Load (w_1):

$$\Delta_D := \frac{5 \cdot w_1 \cdot l^4}{384 \cdot E \cdot I} \cdot 1728 = 2.26 \quad \text{in}$$

Creep:

$$\Delta_{Creep} := \frac{1}{2} \cdot \Delta_D = 1.13 \quad \text{in}$$

Camber:

$$\text{Camber} := \frac{1}{4} \cdot \left(\frac{1}{2} \cdot l \right) + \Delta_D + \Delta_{Creep} = 10.89 \quad \text{in}$$

Summary:

- **Use a 6.75" X 45.375" Southern Pine Glulam Beam @ 16' o.c. with a minimum bearing length of 8.75".**
- **Provide lateral blocking at 1/3 points (240").**
- **Provide an 11" camber.**