



September 16, 2021

BES Project Number: 3119 Timothy Lemons

Power Home Solar, LLC  
919 N Main St.  
Mooresville, NC 28115

**Project Location: Timothy Lemons: 38 Lone Pine Trail, Sanford, NC 27332  
Solar Array Installation**

To Whom It May Concern:

Per your request, BES has reviewed the existing structure at the above referenced location. The purpose of this review was to determine the adequacy of the existing structure to support the proposed installation of solar panels on the roof as shown on the attached panel layout plan.

Based upon our review, we certify that existing roof structure will adequately support with the following: Racking and attachment mounting connection: (1) 5/16" lag screw w/ min. 2.5" embedment into framing at max 48" o/c along rails (2) rails per row of panels, evenly spaced; panel length perpendicular to the rails not to exceed 67 in. Solar module mounting hardware design is by the manufacturer.

Limitations: Installation of the solar panels must be performed in accordance with manufacturer recommendations. All work performed must be in accordance with accepted industry-wide methods and applicable safety standards. The contractor must notify BES should any damage, deterioration or discrepancies between the as-built condition of the structure and the condition described in this letter be found. Connections to existing roof framing must be staggered, except at array ends, so as to not overload any existing structural member. The design of the solar panel racking (mounts, rails, etc.) is the responsibility of the manufacturer. Waterproofing around the roof penetrations is the responsibility of others. BES assumes no responsibility for improper installation of the solar array. Existing structure meets or exceeds standard building practices with current building code with assumed single layer asphalt shingles.

Sincerely,



**Jermey Bowers M.E., P.E.**  
*Principal Engineer*

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BOWERS ENGINEERING SERVICES  
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121 S. MAIN ST  
AUBURN, INDIANA 46706

PHONE (260) 333-0900  
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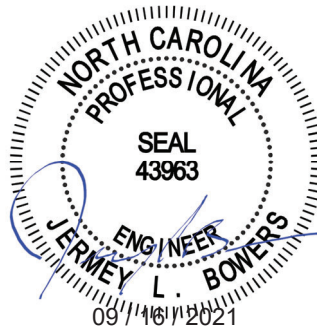
# Structural Analysis

## Location

38 Lone Pine Trail  
Sanford, NC 27332

## Roof Mount Solar

9/16/2021



Project: 3119 Timothy Lemons Rev: -

BES <b>121 South Main ST</b> Auburn, IN		Date:	9/16/2021	Connections
Cust. Name:	Bowers Engineering Services	Subject:	Roof Mount	
Job Number:	3119 Timothy Lemons	Originator:	0	Checker:
<b><u>STRUCTURAL SUMMARY</u></b>				
<b><u>CODE SPEC</u></b>				
WIND				
IBC 2015		Speed:	116	MPH
ASCE 7-10		Exp.:	C	
Risk Cat:	II			

**Wind Load - uplift**

		Max lb
Zone 1	-26.71 psf	-179.49 lb
Zone 2	-32.10 psf	-215.71 lb
Zone 3	-32.10 psf	-215.71 lb
Max trib	11.20 ft2	

**Max loading at connection**

Negative      -215.71 lb/fastener

**Connection (Pull Out)**

Lag screw	5/16 in		
Cd	1.60 Table 2.3.2		
embedment	2.5 in		
Nominal CapacityPrying	205.00 lbs G=0.42		
Max capacity (lbs)	<b>533.00</b>	>	<b>215.71</b> <b>OK</b>

Note:

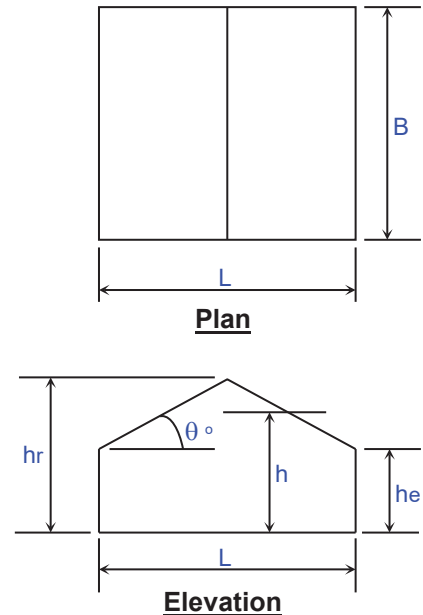
\* Lag screws to be diameter 5/16x2.5inches long.

\* All fasteners need to be placed at roof rafters.

BES 121 South Main ST Auburn, IN		WIND LOADING Per ASCE 7-10	
Cust Name:	Bowers Engineering Services	Subject:	Roof Mount
Job Number:	3119 Timothy Lemons	Originator:	0
		Checker:	

**Input Data:**

Wind Speed, V =	116	mph (Wind Map, Figure 26.5-1A-C)
Bldg. Classification =	II	(Table 1-1 Occupancy Category)
Exposure Category =	C	(Sect. 26.7)
Ridge Height, hr =	24.08	ft. (hr >= he)
Eave Height, he =	20.00	ft. (he <= hr)
Building Width =	14.00	ft. (Normal to Building Ridge)
Building Length =	24.10	ft. (Parallel to Building Ridge)
Roof Type =	Gable	(Gable or Monoslope)
Topo. Factor, Kzt =	1.00	(Sect. 26.8 & Figure 26.8-1)
Direct. Factor, Kd =	0.85	(Table 26.6)
Enclosed? (Y/N)	Y	(Sect. 28.6-1 & Figure 26.11-1)
Hurricane Region?	N	
Component Name =	Decking	(Purlin, Joist, Decking, or Fastener)
Effective Area, Ae =	11.1	ft.^2 (Area Tributary to C&C)
Overhangs? (Y/N)	N	(if used, overhangs on all sides)



**Resulting Parameters and Coefficients:**

Roof Angle, $\theta$ =	30.26	deg.
Mean Roof Ht., h =	22.04	ft. (h = (hr+he)/2, for roof angle >10 deg.)

Roof External Pressure Coefficients, GCp:

GCp Zone 1-3 Pos. =	0.90	(Fig. 30.4-2A, 30.4-2B, and 30.4-2C)
GCp Zone 1 Neg. =	-0.99	(Fig. 30.4-2A, 30.4-2B, and 30.4-2C)
GCp Zone 2 Neg. =	-1.19	(Fig. 30.4-2A, 30.4-2B, and 30.4-2C)
GCp Zone 3 Neg. =	-1.19	(Fig. 30.4-2A, 30.4-2B, and 30.4-2C)

Positive & Negative Internal Pressure Coefficients, GCpi (Figure 26.11-1):

+GCpi Coef. =	0.00	(positive internal pressure)
-GCpi Coef. =	0.00	(negative internal pressure)

If  $z \leq 15$  then:  $Kz = 2.01 \cdot (15/zg)^{2/\alpha}$ , If  $z > 15$  then:  $Kz = 2.01 \cdot (z/zg)^{2/\alpha}$  (Table 30.3-1)

$\alpha$ =	9.50	(Table 26.9-1)
zg =	900	(Table 26.9-1)
Kh =	0.92	(Kh = Kz evaluated at z = h)

Velocity Pressure:  $qz = 0.00256 \cdot Kz \cdot Kzt \cdot Kd \cdot V^2$  (Sect. 30.3.2, Eq. 30.3-1)

qh =	26.95	psf	qh = 0.00256 * Kh * Kzt * Kd * V^2 (qz evaluated at z = h)
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Design Net External Wind Pressures (Sect. 30.4 & 30.6):

For  $h \leq 60$  ft.:  $p = qh \cdot ((GCp) - (+/-GCpi))$  (psf)

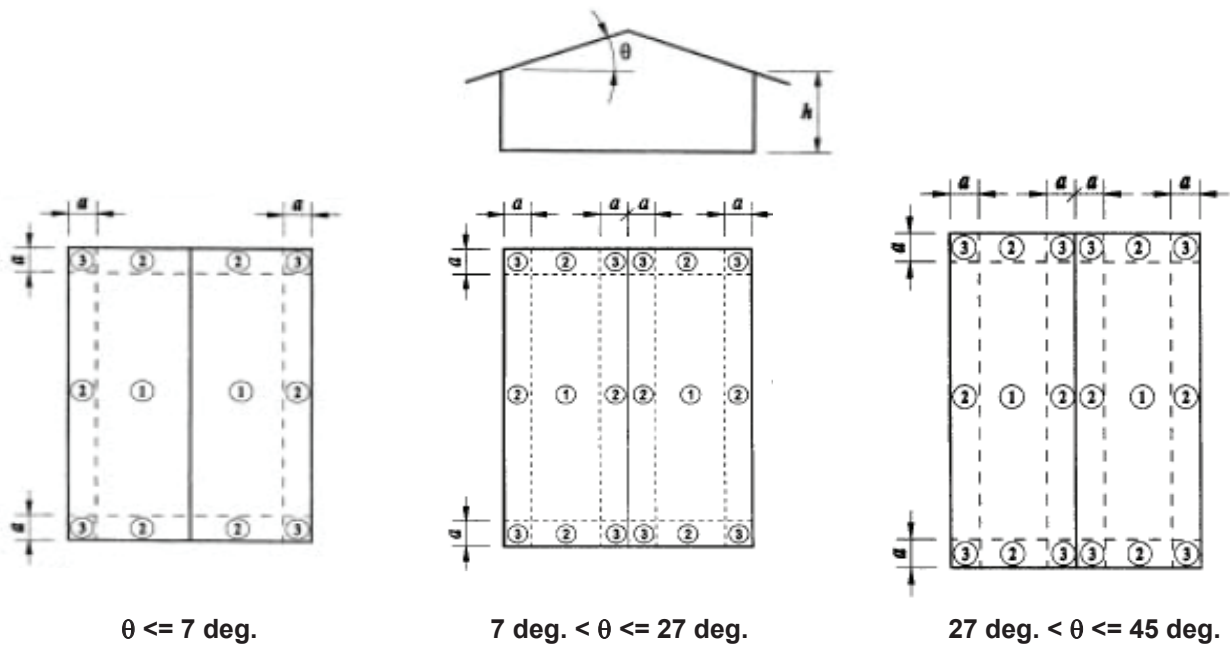
For  $h > 60$  ft.:  $p = q \cdot (GCp) - qi \cdot (+/-GCpi)$  (psf)

where:  $q = qh$  for roof

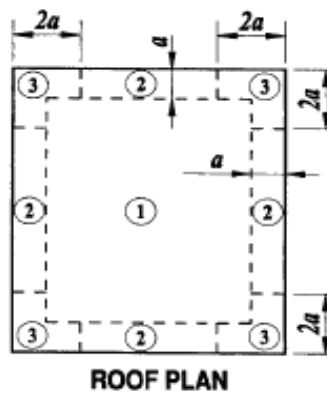
$qi = qh$  for roof (conservatively assumed per Sect. 30.6)



**Roof Components and Cladding:**



**Roof Zones for Buildings with  $h \leq 60$  ft.**  
 (for Gable Roofs  $\leq 45^\circ$  and Monoslope Roofs  $\leq 3^\circ$ )



**Roof Zones for Buildings with  $h > 60$  ft.**  
 (for Gable Roofs  $\leq 10^\circ$  and Monoslope Roofs  $\leq 3^\circ$ )

Frame Design		General Info	
Cust. Name:	Bowers Engineering Services	Subject:	Roof Mount
Job Number:	3119 Timothy Lemons	Originator:	Checker:
Date:	44455	Rev:	-
Address:	38 Lone Pine Trail		
City, State:	Sanford, NC 27332		

**Roof Rafter**

Rafter Size= 2x4 SYP #1  
 Trib. Area= 2 ft  
 Rafter length= 6 ft

**Roof Loads**

Dead Load= 6 psf  
 Live Load= 20 psf  
 Snow Load= 15 psf

**Load Combination**

D+0.75L+0.75S 32.3 psf

w= 64.50 plf

M= 290.25 lb-ft

EI= 8.6E+06 ib-in  
 Sx = 3.0625  
 C<sub>M</sub>= 1.0  
 C<sub>r</sub>= 1.2  
 C<sub>D</sub>= 1.15  
 C<sub>F</sub>= 1.3  
 C<sub>L</sub>= 1.0  
 F<sub>b</sub>= 1500 psi

$$fb = \frac{M * 12}{Sx}$$

$$F'b = Fb * Cd * Cr * Cf * Cm * Cl$$

fb= 1137.31 psi  
 F'b= 2578.88 psi **OK**

$$\frac{5wl^4}{384EI}$$

ΔL= 0.14 in  
 ΔS= 0.10 in  
 ΔD+L= 0.18 in

l/120  
 Δ<sub>allow in</sub>= 0.18 < 0.60 **OK**  
l/180  
 Δ<sub>allow in</sub>= 0.14 < 0.40 **OK**

**2x4 @ 2 o/c OK**

\*Assume rafters are fully braced\*

Bowers Engineering Services  
121 S. Main ST  
Auburn, IN  
(260) 333-0900

# Structural Analysis

## Location

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Sanford, NC 27332

## Roof Mount Solar

9/16/2021

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Project: 3119 Timothy Lemons Rev: -



BES <b>121 South Main ST</b> Auburn, IN		Date:	9/16/2021	Connections
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Job Number:	3119 Timothy Lemons	Originator:	0	Checker:
<b><u>STRUCTURAL SUMMARY</u></b>				
<b><u>CODE SPEC</u></b>				
WIND				
IBC 2015		Speed:	116	MPH
ASCE 7-10		Exp.:	C	
Risk Cat:	II			

**Wind Load - uplift**

		Max lb
Zone 1	-26.86 psf	-180.52 lb
Zone 2	-32.28 psf	-216.95 lb
Zone 3	-32.28 psf	-216.95 lb
Max trib	11.20 ft2	

**Max loading at connection**

Negative      -216.95 lb/fastener

**Connection (Pull Out)**

Lag screw	5/16 in		
Cd	1.60 Table 2.3.2		
embedment	2.5 in		
Nominal CapacityPrying	205.00 lbs G=0.42		
Max capacity (lbs)	<b>533.00</b>	>	<b>216.95</b> <b>OK</b>

Note:

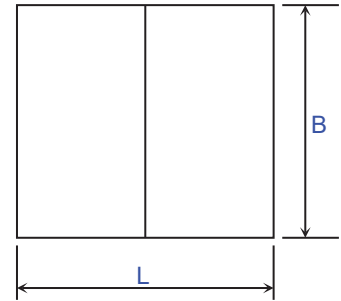
\* Lag screws to be diameter 5/16x2.5inches long.

\* All fasteners need to be placed at roof rafters.

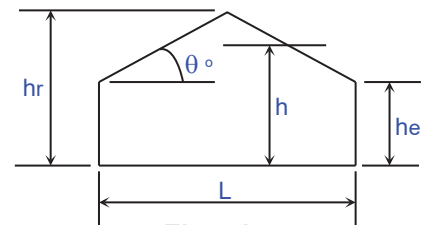
BES 121 South Main ST Auburn, IN		WIND LOADING Per ASCE 7-10	
Cust Name:	Bowers Engineering Services	Subject:	Roof Mount
Job Number:	3119 Timothy Lemons	Originator:	0
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**Input Data:**

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Building Width =	15.90	ft. (Normal to Building Ridge)
Building Length =	33.00	ft. (Parallel to Building Ridge)
Roof Type =	Gable	(Gable or Monoslope)
Topo. Factor, Kzt =	1.00	(Sect. 26.8 & Figure 26.8-1)
Direct. Factor, Kd =	0.85	(Table 26.6)
Enclosed? (Y/N)	Y	(Sect. 28.6-1 & Figure 26.11-1)
Hurricane Region?	N	
Component Name =	Decking	(Purlin, Joist, Decking, or Fastener)
Effective Area, Ae =	11.1	ft.^2 (Area Tributary to C&C)
Overhangs? (Y/N)	N	(if used, overhangs on all sides)



**Plan**



**Elevation**

**Resulting Parameters and Coefficients:**

Roof Angle, $\theta$ =	33.69	deg.
Mean Roof Ht., h =	22.65	ft. (h = (hr+he)/2, for roof angle >10 deg.)

**Roof External Pressure Coefficients, GCp:**

GCp Zone 1-3 Pos. =	0.90	(Fig. 30.4-2A, 30.4-2B, and 30.4-2C)
GCp Zone 1 Neg. =	-0.99	(Fig. 30.4-2A, 30.4-2B, and 30.4-2C)
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**Positive & Negative Internal Pressure Coefficients, GCpi (Figure 26.11-1):**

+GCpi Coef. =	0.00	(positive internal pressure)
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If  $z \leq 15$  then:  $K_z = 2.01 \cdot (15/zg)^{2/\alpha}$ , If  $z > 15$  then:  $K_z = 2.01 \cdot (z/zg)^{2/\alpha}$  (Table 30.3-1)

$\alpha$ =	9.50	(Table 26.9-1)
zg =	900	(Table 26.9-1)
Kh =	0.93	(Kh = Kz evaluated at z = h)

Velocity Pressure:  $q_z = 0.00256 \cdot K_z \cdot K_{zt} \cdot K_d \cdot V^2$  (Sect. 30.3.2, Eq. 30.3-1)

qh =	27.11	psf	qh = 0.00256 * Kh * Kzt * Kd * V^2 (qz evaluated at z = h)
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**Design Net External Wind Pressures (Sect. 30.4 & 30.6):**

For  $h \leq 60$  ft.:  $p = qh \cdot ((GCp) - (+/-GCpi))$  (psf)

For  $h > 60$  ft.:  $p = q \cdot (GCp) - qi \cdot (+/-GCpi)$  (psf)

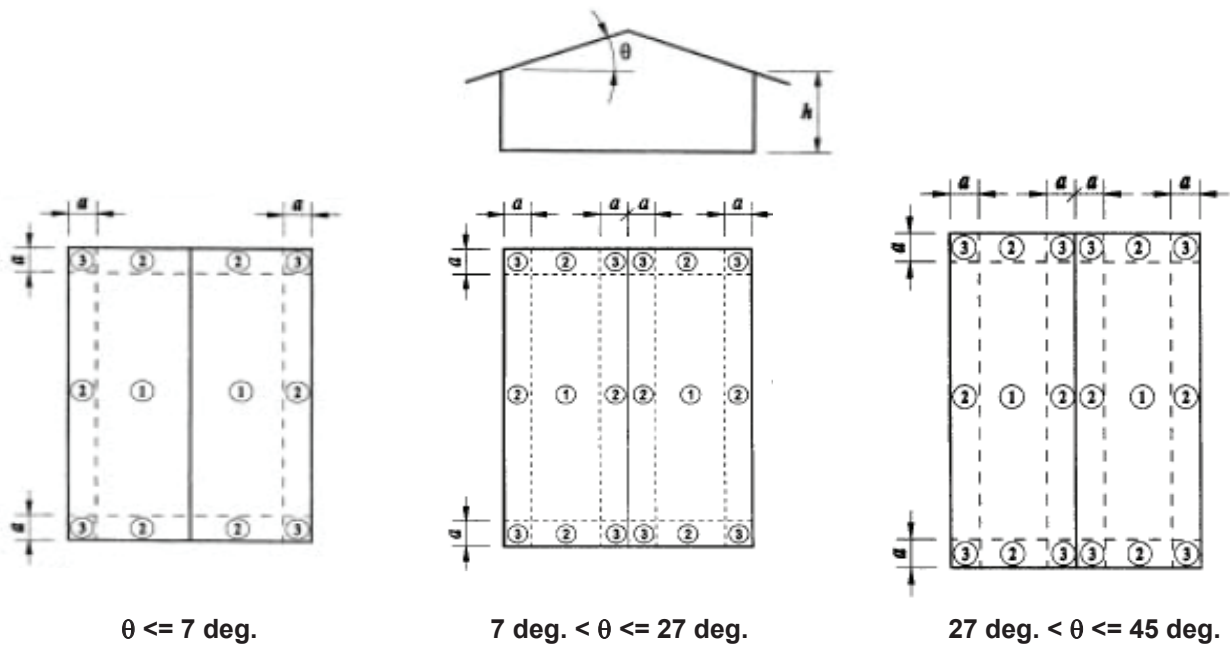
where:  $q = qh$  for roof

$qi = qh$  for roof (conservatively assumed per Sect. 30.6)

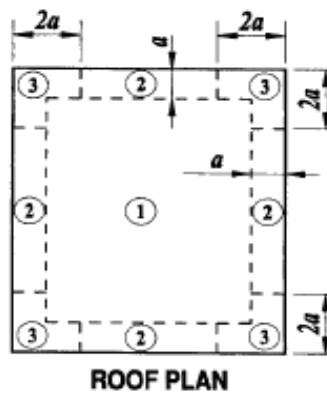
Wind Load Tabulation for Roof Components & Cladding							
Component	z (ft.)	Kh	qh (psf)	p = Net Design Pressures (psf)			
				Zone 1,2,3 (+)	Zone 1 (-)	Zone 2 (-)	Zone 3 (-)
Decking	0	0.93	27.11	24.27	-26.86	-32.28	-32.28
	15.00	0.93	27.11	24.27	-26.86	-32.28	-32.28
	20.00	0.93	27.11	24.27	-26.86	-32.28	-32.28
	25.00	0.93	27.11	24.27	-26.86	-32.28	-32.28
For z = he:	20.00	0.93	27.11	24.27	-26.86	-32.28	-32.28
For z = h:	22.65	0.93	27.11	24.27	-26.86	-32.28	-32.28

- Notes: 1. (+) and (-) signs signify wind pressures acting toward & away from respective surfaces.
2. Width of Zone 2 (edge), 'a' = 3.00 ft.
3. Width of Zone 3 (corner), 'a' = 3.00 ft.
4. For monoslope roofs with  $\theta \leq 3$  degrees, use Fig. 30.4-2A for 'GCp' values with 'qh'.
5. For buildings with  $h > 60'$  and  $\theta > 10$  degrees, use Fig. 30.6-1 for 'GCpi' values with 'qh'.
6. For all buildings with overhangs, use Fig. 30.4-2B for 'GCp' values per Sect. 30.10.
7. If a parapet  $\geq 3'$  in height is provided around perimeter of roof with  $\theta \leq 10$  degrees, Zone 3 shall be treated as Zone 2.
8. Per Code Section 30.2.2, the minimum wind load for C&C shall not be less than 16 psf.
9. References : a. ASCE 7-02, "Minimum Design Loads for Buildings and Other Structures".  
b. "Guide to the Use of the Wind Load Provisions of ASCE 7-02"  
by: Kishor C. Mehta and James M. Delahay (2004).

**Roof Components and Cladding:**



**Roof Zones for Buildings with  $h \leq 60 \text{ ft.}$**   
 (for Gable Roofs  $\leq 45^\circ$  and Monoslope Roofs  $\leq 3^\circ$ )



**Roof Zones for Buildings with  $h > 60 \text{ ft.}$**   
 (for Gable Roofs  $\leq 10^\circ$  and Monoslope Roofs  $\leq 3^\circ$ )

Frame Design		General Info	
Cust. Name:	Bowers Engineering Services	Subject:	Roof Mount
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Address:	38 Lone Pine Trail		
City, State:	Sanford, NC 27332		

**Roof Rafter**

Rafter Size= 2x4 SYP #1  
 Trib. Area= 2 ft  
 Rafter length= 6.5 ft

w= 64.50 plf

M= 340.64 lb-ft

$$fb = \frac{M * 12}{S_x}$$

$$F'b = Fb * Cd * Cr * Cf * Cm * Cl$$

$$\frac{5wl^4}{384EI}$$

$\Delta L = 0.19$  in  
 $\Delta S = 0.14$  in  
 $\Delta D+L = 0.24$  in

$\Delta_{allow\ in} = 0.24 < \frac{L}{120} = 0.65$  **OK**  
 $\Delta_{allow\ in} = 0.19 < \frac{L}{180} = 0.43$  **OK**

**Roof Loads**

Dead Load= 6 psf  
 Live Load= 20 psf  
 Snow Load= 15 psf

**Load Combination**

D+0.75L+0.75S = 32.3 psf

EI= 8.6E+06 ib-in  
 $S_x = 3.0625$   
 $C_M = 1.0$   
 $C_r = 1.2$   
 $C_D = 1.15$   
 $C_F = 1.3$   
 $C_L = 1.0$   
 $F_b = 1500$  psi

fb= 1334.76 psi  
 F'b= 2578.88 psi **OK**

**2x4 @ 2 o/c OK**

\*Assume rafters are fully braced\*