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iRooFA™

Instant Roof Framing Analysis

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STRUCTURAL ANALYSIS

for the

ROOFTOP PV SOLAR INSTALLATION

Project: Vonda Nathan Hamilton, 619 Raiford Road, Erwin, NC 28339

Prepared for:

FREEDOM SOLAR POWER

Freedom Solar, LLC

4801 Freidrich Ln, Ste 100 - Austin, TX 78744

Calculation Report Index

Project Number: 36.114147, Rev. 0

Report Date: 05/07/2024

Report Prepared by:

NORTH CAROLINA PROFESSIONAL 043326 ENGINEER RICHARD PANTEL

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Sealed 05/07/2024

Richard Pantel

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Date: 2024.05.07 20:29:38 -04'00'

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Loading Summary

Exposure and Occupancy Categories		
B		*Exposure Category (ASCE 7-16 Table 26.7.3, Page 274)*
II		*Building Use Occupancy / Risk Category (ASCE 7-16 Table 1.5-1, Page 5)*

Wind Loading:			
v	116	*mph*	*Over-ridden per client request. Original data from Municipality provided wind / snow loadings.*
qz	20.50	*psf*	*Velocity qz, calculated at height z [ASD]*

Snow Loading			
pg	10	*psf*	*Ground Snow Load pg (Over-ridden per client request. Original data from Municipality provided wind / snow loadings.)*
Total Snow Load			
ps	10.00	*psf*	*Effective snow load on roof and modules*

Module Data			
Mission Solar: MSE395SX9R			
Dimensions	*mm*	*ft*	*in*
Length	1,907	6.26	75.08
Width	1,054	3.46	41.50
Area (m^2, ft^2)	2.0	21.64	
Weight	kg	lb	
Module	22.00	48.50	

Roof Panel (Cladding) Loading Summary		Module Loading Summary			
Support Point Loads		*Upward*	*Upward*	*Upward*	*Downward*
Roof Zones		1,2e	2n,2r,3e	3r	All
Net load per module	*lb*	-162	-283	-332	164

Positive values indicate net downward force

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Stanchion Fastener Pull-out and Spacing Calculations					
Framing spacing		*ft*	2.00		
Rails / Module		*ea*	2		
Max proposed stanchion span		*ft*	4.00		
# fasteners per stanchion			5		
Screw thread embedment depth		*in*	0.5		
Safety Factor			1.10		
Pull-out for M5 threaded fasteners		*lb/in*	103		
Factored max fastener uplift capacity		*lb*	235		
Fastener details	*Material* Stainless	*Size*	M5		
Max stanchion uplift capacity		*lb*	400		
Max support point uplift capacity		*lb*	235		

Roof Zones			*1,2e*	*2n,2r,3e*	*3r*
Net lift per module		*lb*	162	283	332
Min tot screw thread embedment depth rq'd		*in*	0.35	0.60	0.71
Net uplift pressure	7. 0.60D - 0.6W	*psf*	-6.49	-11.32	-13.25
Allowable lift area / support point		*sf*	36.24	20.78	17.74
Max rail span per framing spacing		*ft*	4.00	4.00	4.00
Landscape Modules					
Length along rafter		*ft*	3.46		
Lift calc'ed max stanchion EW spacing		*ft*	> 6	> 6	> 6
Max stanchion EW spacing		*ft*	4.00	4.00	4.00
Maximum module area / support point		*sf*	6.92	6.92	6.92
Factored lift per support point		*lb*	-45	-78	-92
Portrait Modules					
Length along rafter		*ft*	6.26		
Lift calc'ed max stanchion EW spacing		*ft*	> 6	6.00	4.00
Max stanchion EW spacing		*ft*	4.00	4.00	4.00
Maximum module area / support point		*sf*	12.51	12.51	12.51
Factored lift per support point		*lb*	-81	-142	-166
Plywood Nailing Calculations					
Nail Size		*Gauge*	*Shank Dia*	*Length*	*W*
8D		10	0.134	2.5	54
10D		9	0.148	3	59
Load Duration Factor - Wind		1.6			
AWC 11.3.1 W'=W*Cd*Cm*Ct*Ceg*LD					
8D withdrawl force @ 2" penetration (lb)		138			
10D withdrawl force @ 2.5" penetration (lb)		189			
			1,2e	*2n,2r,3e*	*3r*
# 8D's Req'd / stanchion in Landscape		*ea*	0.32	0.57	0.66
# 10D's Req'd / stanchion in Landscape		*ea*	0.24	0.41	0.49
# 8D's Req'd / stanchion in Portrait		*ea*	0.59	1.02	1.20
# 10D's Req'd / stanchion in Portrait		*ea*	0.43	0.75	0.88

Stanchion support threaded fastener sizes are indicated in the Module Loading Summary table above. Lift forces were determined from GCp and other coefficients contained in the ASCE nomographs

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Conclusions

We were asked to review the roof of Vonda Nathan Hamilton, located at 619 Raiford Road, Erwin, NC, by Freedom Solar, LLC, to determine its suitability to support a PV solar system installation.

The referenced building's roof structure was field measured by Freedom Solar, LLC on 04/11/2024. The attached framing analyses reflect the results of those field measurements combined with the PV solar module locations shown on the PV solar roof layout design prepared by Freedom Solar, LLC. Loads are calculated to combine the existing building and environmental loads with the proposed new PV array loads.

The Pegasus PSR-B Rail racking and Roof Tech RT Mini II w 5 M5 screws stanchions were selected for this project by Freedom Solar, LLC. The racking and support stanchions shall be placed as shown on their plans, dated 04/26/2024, and shall be fastened to the roof framing using fastener sizes indicated in this report. Rack support spacing shall be no more than that shown above. Note that support points for alternating rows shall share the same rafter. Intermediate rows shall move the support points laterally to the next rafter. The support rail can be cantilevered up to 1/3 of the maximum span between modules. 1/3 maximum span = 16.00 inches.

Google Location Map

Framing Summary

Based upon the attached calculations, the existing roofs' framing systems are capable of supporting the additional loading for the proposed PV solar system along with the existing building and environmental loads. No supplemental roof framing structural supports are required. Minimum required anchorage fastening is described above.

Fastener notes: 1) Install fasteners with head and where required, washer, flush to material surface (no gap). Do not over-torque.

References and Codes:

1) *ASCE 7-16 Minimum Design Loads for Buildings and Other Structures*
2) *2018 IBC*
3) *2018 NC Building Code*
4) *American Wood Council, NDS 2018,Table 12.2A, 12.3.3A.*
5) *American Wood Council, Wood Structural Design, 1992, Figure 6.*

Roof Structural Calculations for PV Solar Installation **Array AR-1**
Location: MP 1
Member: Rafter - Total Length 12.4 ft, Unsupported 5.73 ft

Geometric Data			
Θ	*deg.*	22.02	*Angle of roof plane from horizontal, in degrees*
ω	*deg.*	0.00	*Angle the solar panel makes with the roof surface*
L	*ft.*	73.00	*Length of roof plane, in feet (meters)*
W	*ft.*	12.50	*Plan view width of roof plane, in feet (meters)*
h	*ft.*	18.67	*Average height of roof above grade, in feet (meters)*

Roof Wind Zone Width			
	use, a =	3.00	*ft*

Wind Velocity Pressure, q_z evaluated at the height z						
q_z=	20.50	*psf*	*Vasd* q_z=	12.34	*psf*	Basic wind pressure
V=	116	mph				

Framing Data		
Wood type	US Spruce	
Wood source, moisture content	White 0.12%	
# Framing Members / Support		1
Rafter / Truss OC	*in*	24.00
Member Total Length	*ft*	12.40

2	# Rafters / Rack Support Width
4.00	Rack Support Spacing (ft)
48	Max. Rack Support Spacing (in)
2	Max # of mod's / Rafter

Member Properties		**Member**
Name		(1)1.5x3.5
Repetitive Member Factor (Cr)		1.15
Max Shear perp. to grain	*psi*	530
Max Shear parallel to grain	*psi*	1,100

** Mem properties based upon field measurements*

Rafter

24.00	Collar tie OC spacing, in.

Module Physical Data			
Weight	kg	lb	psf load
Module	22.00	48.50	2.24
4 Stanchions	2.72	6.0	0.28

Existing Dead Loads	*Units*	*Value*	*Description*
Framing Member	*psf*	0.50	
Roof Deck & Surface	*psf*	4.40	*0.50 in. Plywood w/ Standard Asphalt Shingles*

Rack Support Spacing and Loading				
Across rafters	*ft*	4.0		
Along rafter slope	*ft*	6.3		
Area / support point	*sf*	12.5		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	12.40	
Maximum member free span	*ft*	5.73	Rafter above Knee wall
Rafter segment to calc	*ft*	5.73	Free span
Deflection Ratio		180	Use max delta 1/x for deflection

** Knee wall height @ 2.50' AFF max height. Adjust to match lowest adjoining roof's collar tie as needed*

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Eave Overhang Length past Rafter Plate	1.00	*ft*
Uphill Distance from Eave to Lowest Support	1.50	*ft*

ASCE 7-16 **Method for Calculating Uplift on PV Modules**

Notation
Lp = Panel chord length.
p = uplift wind pressure
γa = Solar panel pressure equalization factor, defined in Fig. 29.4-8.
γE = Array edge factor as defined in Section 29.4.4.
θ = Angle of plane of roof from horizontal, in degrees.

29.4.4 Rooftop Solar Panels Parallel to the Roof Surface on Buildings of All Heights and Roof Slopes.
Θ >= 7 deg TRUE

Min.d1: Exposed **FALSE**
Max.d1: Exposed **TRUE** ***Use EXPOSED for uplift calculations***

1.5(Lp) =	5.19
γE =	1.5
γa =	0.67

p = qh(GCp) (γ_E) (γ_a) (lb/ft2) (29.4-7)

Zones	1,2e	2n,2r,3e	3r
GCp	-1.48	-2.13	-2.39
p, Windload (psf)	-18.23	-26.28	-29.51

Downward, Zones All Zones
GCp 0.45

ASCE 7-16 Chapter 2 Combinations of Loads, Table 2.4, Page 8 (in psf)				
Zones	1,2e	2n,2r,3e	3r	All Zones
2.2 SYMBOLS AND NOTATION	*Module Upward*	*Module Upward*	*Module Upward*	*Downward*
D = dead load of PV Module + Stanchion	2.52	2.52	2.52	2.52
S = snow load	10.00	10.00	10.00	10.00
W = wind load	-18.23	-26.28	-29.51	5.58

2.4 Combining Nominal Loads Using Allowable Stress Design (in psf)				
2.4.1 Basic Combinations. Loads listed herein shall be considered to act in the following combinations; whichever produces the most unfavorable effect in the building, foundation, or structural member being considered. Effects of one or more loads not acting shall be considered.				
Combination Formulae	*Upward*	*Upward*	*Upward*	*Downward*
Use this loading combination for DOWNWARD for Proposed PV Dead Load				
6. D + 0.75L - 0.75(0.60W) + 0.75(Lr or S or R)	12.52	12.52	12.52	15.03
Module Support point load (lb)	157	157	157	188
Cr Factored Module Support point load (lb)	136	136	136	164

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.60D - 0.6W	-6.49	-11.32	-13.25	7.42
Module Support point load (lb)	-81	-142	-166	93

DOWNWARD

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Presume loading directly over member.

Combined Dead and Wind Pressure Downward Loading					
	Rafter above Knee wall				
PV Module Row	Point load loc's from Left support		Module Support Point Load	Comment	Module Orientation
	ft from left		*lb*		
1	0.50			Support outside of max stressed section	Portrait
1	6.76		164		Portrait
2	6.84		164		Portrait
2	13.10			Support outside of max stressed section	Portrait

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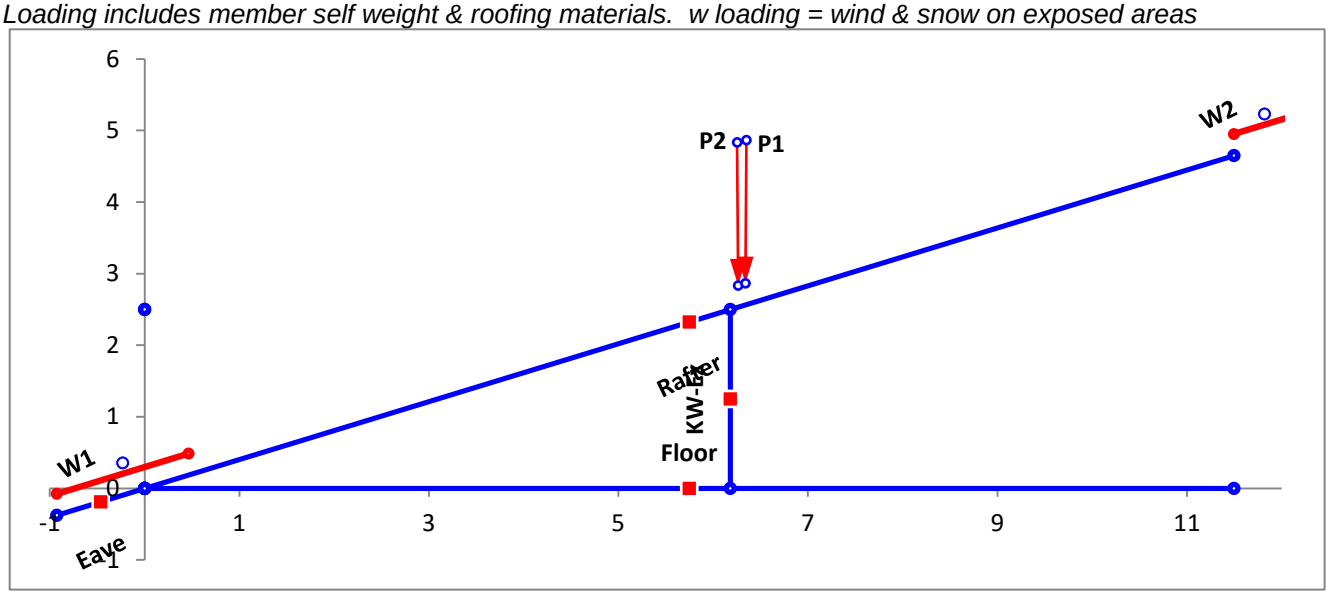
Analysis for PV impacted areas

5. Simple Beam - Exposed Roof Snow Load - Above and Below PV				
Parameter	*Units*	*Total*	*Allowed*	*Check*
Delta @ mid span	*in*	0.00	0.38	***OK***
M at mid span	*lb-ft*	4	1,667	***OK***

Sum Downward Loading Conditions: PV; Beam DL; Exposed Roof Environmental Load				
Parameter	*Units*	*Total*	*Allowed*	*Check*
Delta	*in*	0.04	0.38	***OK***
Percent Max Delta	*%*	10%	100%	***OK***
Moment	*lb-ft*	940	1,667	***OK***
fs	*psi*	3,683	6,533	***OK***

** Loading includes member self weight & roofing materials. w loading = wind & snow on exposed areas*



Framing section with max stress: Rafter above Knee wall

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Roof Structural Calculations for PV Solar Installation **Array AR-2**
Location: MP 2
Member: Rafter - Total Length 12.49 ft, Unsupported 8.32 ft

Geometric Data			
Θ	*deg.*	23.00	*Angle of roof plane from horizontal, in degrees*
ω	*deg.*	0.00	*Angle the solar panel makes with the roof surface*
L	*ft.*	73.00	*Length of roof plane, in feet (meters)*
W	*ft.*	12.50	*Plan view width of roof plane, in feet (meters)*
h	*ft.*	18.67	*Average height of roof above grade, in feet (meters)*

Roof Wind Zone Width			
	use, a =	3.00	*ft*

Wind Velocity Pressure, q_z evaluated at the height z						
q_z=	20.50	*psf*	*Vasd* q_z=	12.34	*psf*	Basic wind pressure
V=	116	mph				

Framing Data		
Wood type	US Spruce	
Wood source, moisture content	White 0.12%	
# Framing Members / Support		1
Rafter / Truss OC	*in*	24.00
Member Total Length	*ft*	12.49

2	# Rafters / Rack Support Width
4.00	Rack Support Spacing (ft)
48	Max. Rack Support Spacing (in)
2	Max # of mod's / Rafter

Member Properties		**Member**
Name		(1)1.5x3.5
Repetitive Member Factor (Cr)		1.15
Max Shear perp. to grain	*psi*	530
Max Shear parallel to grain	*psi*	1,100

** Mem properties based upon field measurements*

Rafter

24.00	Collar tie OC spacing, in.

Module Physical Data			
Weight	kg	lb	psf load
Module	22.00	48.50	2.24
4 Stanchions	2.72	6.0	0.28

Existing Dead Loads	*Units*	*Value*	*Description*
Framing Member	*psf*	0.50	
Roof Deck & Surface	*psf*	4.40	*0.50 in. Plywood w/ Standard Asphalt Shingles*

Rack Support Spacing and Loading				
Across rafters	*ft*	4.0		
Along rafter slope	*ft*	6.3		
Area / support point	*sf*	12.5		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	12.49	
Maximum member free span	*ft*	8.32	Rafter below Knee wall
Rafter segment to calc	*ft*	8.32	Free span
Deflection Ratio		180	Use max delta 1/x for deflection

** Knee wall height @ 3.25' AFF max height. Adjust to match lowest adjoining roof's collar tie as needed*

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Eave Overhang Length past Rafter Plate	1.00	*ft*
Uphill Distance from Eave to Lowest Support	1.50	*ft*

ASCE 7-16 **Method for Calculating Uplift on PV Modules**

Notation
Lp = Panel chord length.
p = uplift wind pressure
γa = Solar panel pressure equalization factor, defined in Fig. 29.4-8.
γE = Array edge factor as defined in Section 29.4.4.
θ = Angle of plane of roof from horizontal, in degrees.

29.4.4 Rooftop Solar Panels Parallel to the Roof Surface on Buildings of All Heights and Roof Slopes.
Θ >= 7 deg TRUE

Min.d1: Exposed **FALSE**
Max.d1: Exposed **TRUE** ***Use EXPOSED for uplift calculations***

1.5(Lp) =	5.19
γE =	1.5
γa =	0.67

p = qh(GCp) (γ_E) (γ_a) (lb/ft2) (29.4-7)

Zones	1,2e	2n,2r,3e	3r
GCp	-1.48	-2.13	-2.39
p, Windload (psf)	-18.23	-26.28	-29.51

Downward, Zones All Zones
GCp 0.45

ASCE 7-16 Chapter 2 Combinations of Loads, Table 2.4, Page 8 (in psf)				
Zones	1,2e	2n,2r,3e	3r	All Zones
2.2 SYMBOLS AND NOTATION	*Module Upward*	*Module Upward*	*Module Upward*	*Downward*
D = dead load of PV Module + Stanchion	2.52	2.52	2.52	2.52
S = snow load	10.00	10.00	10.00	10.00
W = wind load	-18.23	-26.28	-29.51	5.58

2.4 Combining Nominal Loads Using Allowable Stress Design (in psf)				
2.4.1 Basic Combinations. Loads listed herein shall be considered to act in the following combinations; whichever produces the most unfavorable effect in the building, foundation, or structural member being considered. Effects of one or more loads not acting shall be considered.				
Combination Formulae	*Upward*	*Upward*	*Upward*	*Downward*
Use this loading combination for DOWNWARD for Proposed PV Dead Load				
6. D + 0.75L - 0.75(0.60W) + 0.75(Lr or S or R)	12.52	12.52	12.52	15.03
Module Support point load (lb)	157	157	157	188
Cr Factored Module Support point load (lb)	136	136	136	164

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.60D - 0.6W	-6.49	-11.32	-13.25	7.42
Module Support point load (lb)	-81	-142	-166	93

DOWNWARD

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Presume loading directly over member.

Combined Dead and Wind Pressure Downward Loading					
	Rafter below Knee wall				
PV Module Row	Point load loc's from Left support		Module Support Point Load	Comment	Module Orientation
	ft from left		*lb*		
1	0.50			Support placed on adjoining rafter	Portrait
1	6.76		164		Portrait
2	6.84		164		Portrait
2	13.10			Support outside of max stressed section	Portrait

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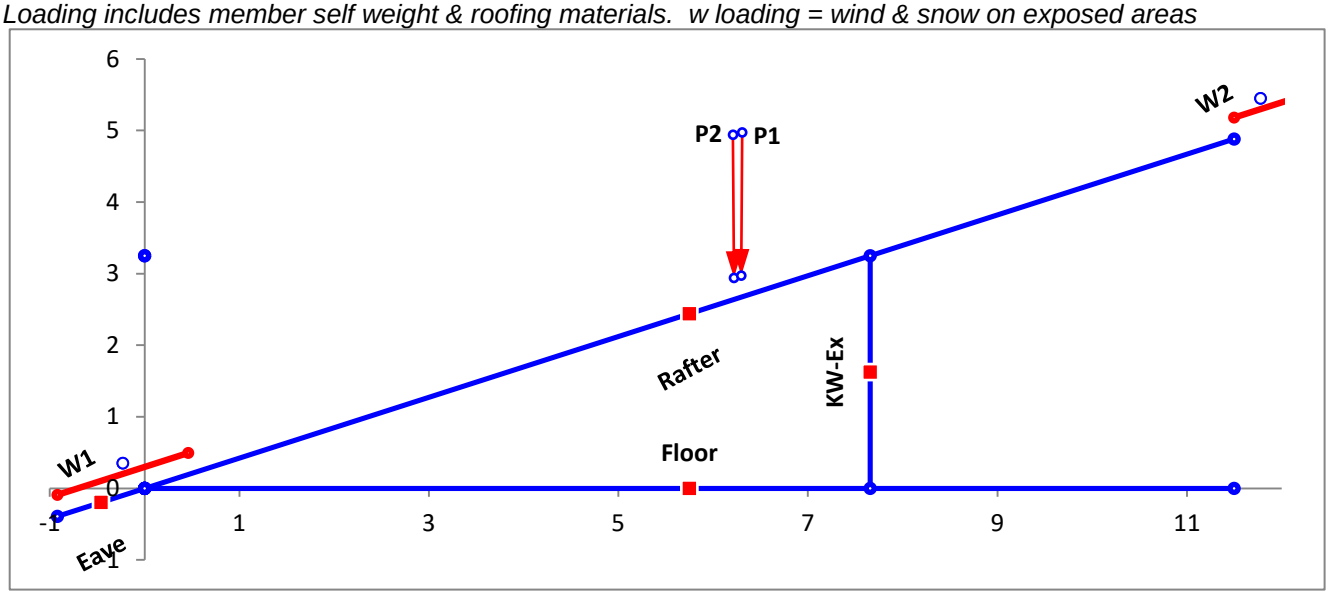
Analysis for PV impacted areas

5. Simple Beam - Exposed Roof Snow Load - Above and Below PV				
Parameter	*Units*	*Total*	*Allowed*	*Check*
Delta @ mid span	*in*	0.01	0.55	***OK***
M at mid span	*lb-ft*	3	1,667	***OK***

Sum Downward Loading Conditions: PV; Beam DL; Exposed Roof Environmental Load				
Parameter	*Units*	*Total*	*Allowed*	*Check*
Delta	*in*	0.51	0.55	***OK***
Percent Max Delta	*%*	92%	100%	***OK***
Moment	*lb-ft*	294	1,667	***OK***
fs	*psi*	1,152	6,533	***OK***

** Loading includes member self weight & roofing materials. w loading = wind & snow on exposed areas*



Framing section with max stress: Rafter below Knee wall

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Snow Loading Analysis

where:

		Fully Exposed	Exposure category
Ce	=	0.9	Exposure Factor, Ce (ASCE 7-16 Table 7.3-1, Page 61)
Ct	=	1.0	Thermal Factor, Ct (ASCE 7-16 Table 7.3-2, Page 61)
Is	=	1.0	Snow Importance Factor, Is (ASCE 7-16 Table 1.5-2, Page 5)
p_g	=	10	Ground Snow Load pg (Over-ridden per client request. Original data from Municipality
p_f	=	**0.7CeCtIsPg**	Flat Roof Snow Load, pf (ASCE 7-16 Table 7.3-1, Page 61)
p_f	=	**6.3**	psf
			but where Pf is not less than the following:
			Minimum Snow Load pm (ASCE 7-16 Table 7.3.4, Page 62)
p_m	=	**10**	When Pg <=20 psf, then use Pf = Pg x Is
p_f	=	**10**	psf. Resultant Snow pressure to be used with Roof slope factor below
p_s	=	$C_s p_f$	Sloped Roof Snow Load ps (ASCE 7-16 Table 7.4, Page 61)

Roof Type Warm Roofs

Roof slope factor Cs for Warm Roofs, where Ct = 1.0

Roof surface condition = Slippery Roof

C_s	=	1.00	Roof Slope Factor, Cs (ASCE 7-16 Table 7.4-1a, Page 62)

Total Snow Load

p_s	=	**10.00**	**psf**	Roof snow load

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