iRooFA™

Instant Roof Framing Analysis

www.iroofa.solar

tel: 540.313.5317 - email: info@iRooFA.solar

STRUCTURAL ANALYSIS

for the

ROOFTOP PV SOLAR INSTALLATION

Project: Frederick J Bushey, 271 Horse Whisperer Lane, Lillington, NC 27546

Prepared for:

FREEDOM SOLAR POWER

Freedom Solar, LLC

4801 Freidrich Ln, Ste 100 - Austin, TX 78744

Calculation Report Index

Project Number: 36.113163, Rev. 0

Report Date: 11/21/2023

Report Prepared by:

NORTH CAROLINA PROFESSIONAL SEAL 043326 ENGINEER RICHARD PANTEL

Richard Pantel, P.E.
NC License No. 43326
Sealed 11/21/2023

Richard Pantel

Digitally signed by Richard Pantel
DN: c=US, o=TECTONICORP PC, dnQualifier=A01410D00000178D0DC BFCA00007095, cn=Richard Pantel
Date: 2023.11.21 16:29:53 -05'00'

Loading Summary

Exposure and Occupancy Categories		
B		*Exposure Category (ASCE 7-16 Table 26.7.3, Page 266)*
II		*Building Use Occupancy / Risk Category (ASCE 7-16 Table 1.5-1, Page 4)*

Wind Loading:			
v	117	*mph*	*ASCE 7-16, Figure 26.5-1 A, B or C, pp 249-251. [(117 mph, 50 year wind MRI)]*
qz	21.00	*psf*	*Velocity qz, calculated at height z [ASD]*

Snow Loading			
pg	10	*psf*	*Ground Snow Load pg (ASCE 7-16 Table 7.2-1, Page 52-53)*
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,2r	2n,3r	3e	All
Net load per module	*lb*	-164	-216	-293	182

Positive values indicate net downward force

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		1	
Bolt thread embedment depth	*in*	2.5	
Safety Factor		1.10	
Pull-out for 5/16 threaded fasteners	*lb/in*	220	
Factored max fastener uplift capacity	*lb*	499	
Fastener details *Material* Stainless	*Size*	5/16	*Predrill hole 0.16" dia or use self tapping*
Max stanchion uplift capacity	*lb*	618	
Max support point uplift capacity	*lb*	499	

Roof Zones		*1,2e,2r*	*2n,3r*	*3e*
Net lift per module	*lb*	164	216	293
Min tot bolt thread embedment depth rq'd	*in*	0.82	1.08	1.47
Net uplift pressure 7. 0.60D - 0.6W	*psf*	-6.53	-8.63	-11.72
Allowable lift area / support point	*sf*	76.38	57.84	42.56
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	-60	-81
Portrait Modules				
Length along rafter	*ft*	6.26		
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*	12.51	12.51	12.51
Factored lift per support point	*lb*	-82	-108	-147

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

Conclusions

Princeton Engineering was asked to review the roof of Frederick J Bushey, located at 271 Horse Whisperer Lane, Lillington, 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 11/17/2023. 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.

Freedom Solar, LLC selected the Pegasus Max Rail racking with Pegasus Solar InstaFlash PIF-RBDT stanchions for this project. The racking and support stanchions shall be placed as shown on their plans, dated 11/20/2023, 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 truss. Intermediate rows shall move the support points laterally to the next truss. 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 roof's framing system is 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.

Wood fastener notes: 1) Fastener threads must be embedded in the side grain of a roof support structural member or other structural member integrated into the building's structure. 2) Fastener must be located in the middle third of the structural member. 3) 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) *IBC 2018*
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.*

Geometric Data			
Θ	*deg.*	34.00	*Angle of roof plane from horizontal, in degrees*
ω	*deg.*	0.00	*Angle the solar panel makes with the roof surface*
L	*ft.*	43.33	*Length of roof plane, in feet (meters)*
W	*ft.*	19.58	*Plan view width of roof plane, in feet (meters)*
h	*ft.*	24.33	*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=	21.00	*psf*	*Vasd* q_z=	12.61	*psf*	Basic wind pressure
V=	117	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*	24.00

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

Member Properties		**Member**
Name		(1) 2x4
Repetitive Member Factor (Cr)		1.15

** Mem properties based upon field measurements*

Top truss chord

Module Physical Data			
Weight	kg	lb	psf load
Module	22.00	48.50	2.24
4 Stanchions	1.36	3.0	0.14

Existing Dead Loads	*Units*	*Value*	*Description*
Roof Deck & Surface	*psf*	4.40	*Truss members' self weight added to FEA analysis*

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*	24.00	
Maximum member free span	*ft*	24.00	Top truss chord span

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**
1.5(Lp) =	5.19
γE =	1.5
γa =	0.67

Use EXPOSED for uplift calculations

$p = qh(GCp)\ (\gamma_E)\ (\gamma_a)$ (lb/ft2) (29.4-7)

Zones	1,2e,2r	2n,3r	3e
p, Windload (psf)	-18.46	-21.95	-27.11

ASCE 7-16 Chapter 2 Combinations of Loads, Table 2.4, Page 8 (in psf)				
Zones	1,2e,2r	2n,3r	3e	All Zones
2.2 SYMBOLS AND NOTATION	*Module Upward*	*Module Upward*	*Module Upward*	*Downward*
D = dead load of PV Module + Stanchion	2.38	2.38	2.38	2.38
S = snow load	10.00	10.00	10.00	10.00
W = wind load	-18.46	-21.95	-27.11	9.66

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)	12.38	12.38	12.38	16.73
Module Support point load (lb)	155	155	155	209
Cr Factored Module Support point load (lb)	135	135	135	182

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.60D - 0.6W	-6.53	-8.63	-11.72	7.57
Module Support point load (lb)	-82	-108	-147	95

DOWNWARD

Presume loading directly over member.

Combined Dead and Wind Pressure Downward Loading		
	Top truss chord span	

PV Module Row	Point load loc's from Left support	Point Load #'s	Module Support Point Load	Comment	Module Orientation
	ft from left		*lb*		
1	2.92		182		Portrait
1	9.18			Support placed on adjoining truss	Portrait
2	9.26			Support placed on adjoining truss	Portrait
2	15.52		182		Portrait
3	15.60		182		Portrait
3	21.86			Support placed on adjoining truss	Portrait

Truss Data and Loading for MP 1

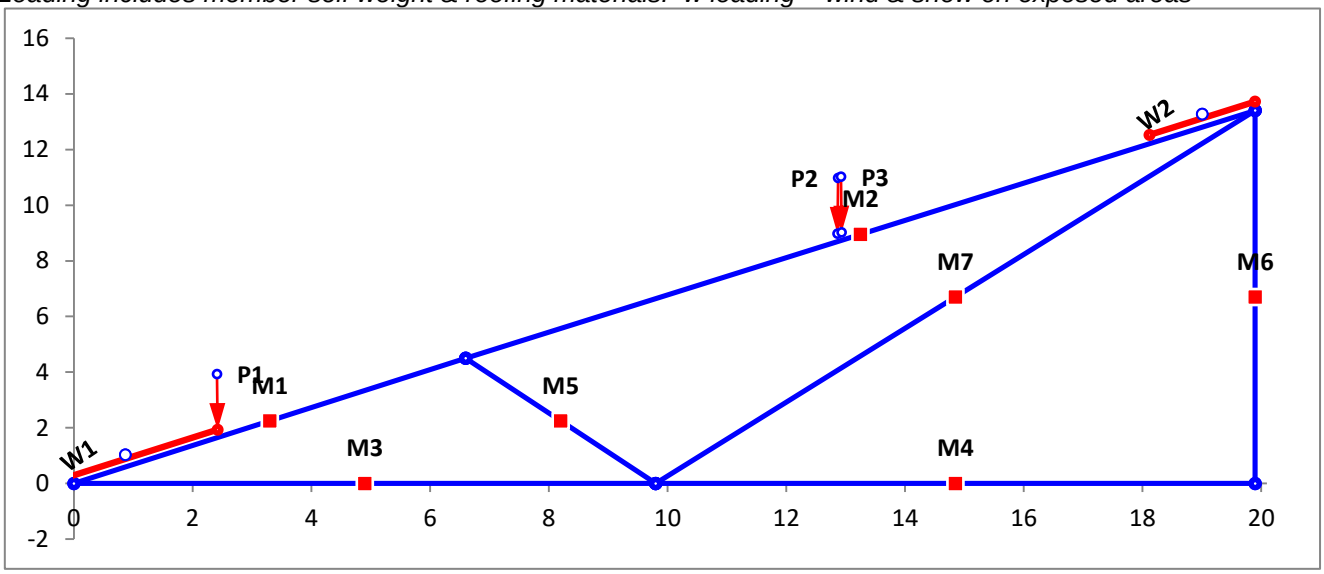
Roof slope (degrees)	34.00
Top ridge height above floor plane	13.42

	Length of roof plane	24.00
	Length of floor plane	19.58

Truss Segments

Roof Plane		*Floor Plane*		*Diagonals*		*Diagonals*	
Mem #	*Mem Type*	Mem #	*Mem Type*	Mem #	*Mem Type*	Mem #	*Mem Type*
1	2x4	3	2x4	5	2x4	7	2x4
2	2x4	4	2x4	6	2x4		

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



Snow Loading Analysis

where:

		Fully Exposed	Exposure category
Ce	=	0.9	Exposure Factor, Ce (ASCE 7-16 Table 7.3-1, Page 58)
Ct	=	1.0	Thermal Factor, Ct (ASCE 7-16 Table 7.3-2, Page 58)
Is	=	1.0	Snow Importance Factor, Is (ASCE 7-16 Table 1.5-2, Page 5)
p_g	=	10	Ground Snow Load pg (ASCE 7-16 Table 7.2-1, Page 52-53)
p_f	=	**0.7CeCtIsPg**	Flat Roof Snow Load, pf (ASCE 7-16 Table 7.3-1, Page 58)
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 53)
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 54)

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 7-2a, Page 36)

Total Snow Load

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

FEA Calculation Results for Roof Plane MP 1 for Freedom Solar, LLC Client FREDERICK J BUSHEY

IDSPL - 2D Frame Analysis of a 2D frame subject to distributed loads, point loads and moments

Equilibrium check	FX	FY
Total applied forces	0.00	2605
Total output reactions	0.00	-2605
Output error	-1.56E-13	-4.55E-13

2.1E-05

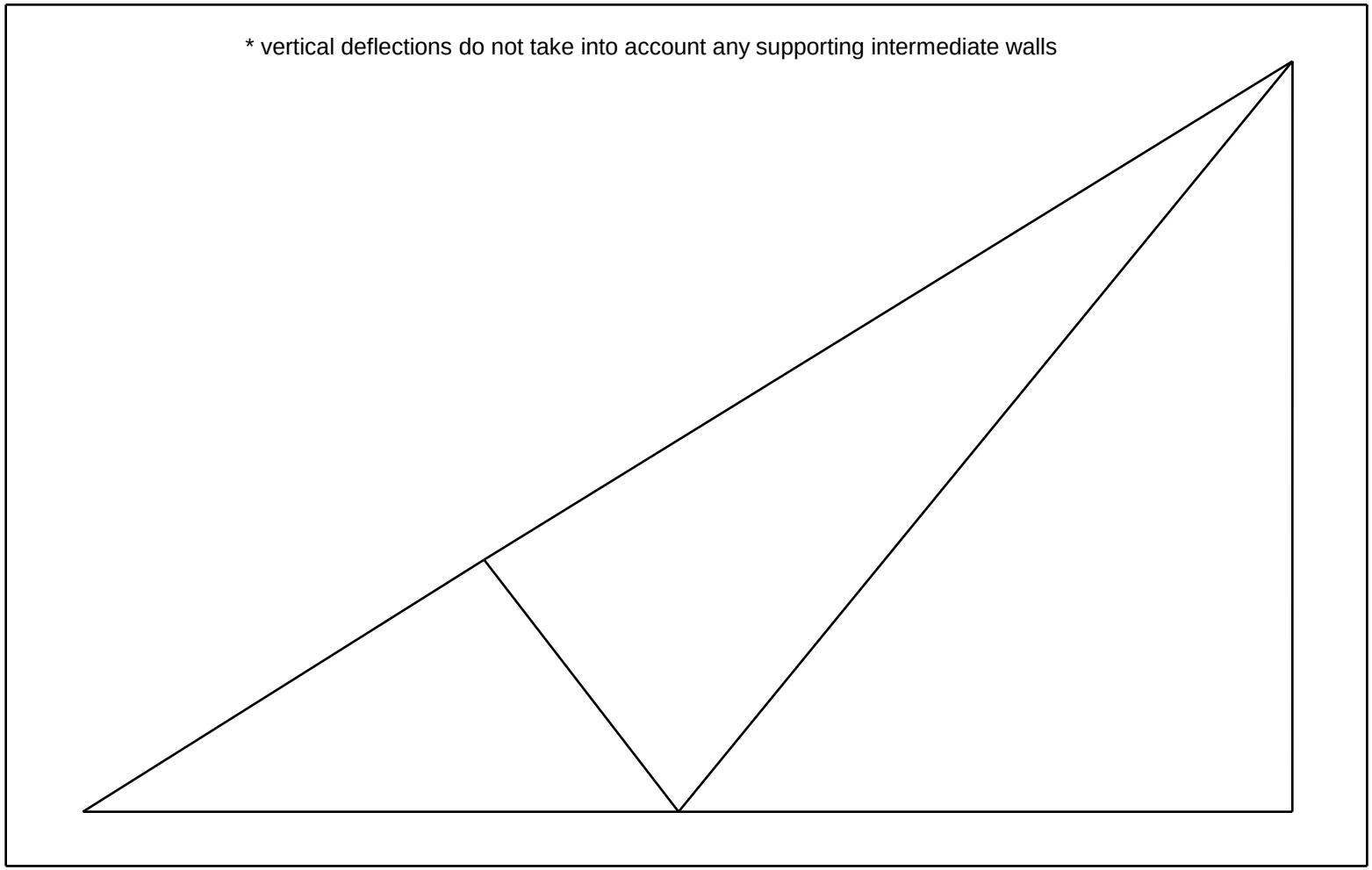
# of segments/beam	1

Maximum Deflections	
1.44E-03	-8.05E-04

** vertical deflections do not take into account any supporting intermediate walls*

Node Results			Beam End Results			
Direction	Deflection	Reaction	Beam	Shear	Ax	BM
DX1	0.00E+00	-403	1-1	-1222	1321	3507
DY1	0.00E+00	-1652	1-2	-980	1156	-5545
RZ1	-4.30E-04	0	2-1	-1337	449	-9457
DX2	7.48E-04	0	2-2	80	-499	-21866
DY2	8.05E-04	0	3-1	102	0	-3507
RZ2	-1.17E-03	0	3-2	428	0	803
DX3	1.44E-03	0	4-1	0	0	0
DY3	0.00E+00	-153	4-2	0	0	0
RZ3	0.00E+00	-21139	5-1	-677	383	-158
DX4	0.00E+00	460	5-2	-689	366	-3912
DY4	0.00E+00	-768	6-1	57	32	-384
RZ4	0.00E+00	1072	6-2	57	-71	384
DX5	0.00E+00	-57	7-1	-3	524	-111
DY5	0.00E+00	-32	7-2	92	398	343
RZ5	0.00E+00	384				

Beam	X	Shear	Mom	Ax	DX	DY	RZ
1	0.00	-1222	3507	1321	0.00E+00	0.00E+00	-4.30E-04
1	7.99	-1033	-5265	1192	7.31E-04	-7.93E-04	-1.48E-03
2	0.00	-1337	-9457	449	7.48E-04	-8.05E-04	-1.17E-03
2	16.00	-465	-13978	-134	9.70E-04	3.12E-04	-1.31E-02
3	0.00	102	-3507	0	0.00E+00	0.00E+00	-4.30E-04
3	9.80	348	1221	0	0.00E+00	-7.18E-20	1.33E-04
4	0.00	0	0	0	0.00E+00	0.00E+00	0.00E+00
4	10.10	0	0	0	0.00E+00	0.00E+00	0.00E+00
5	0.00	-677	-158	383	0.00E+00	0.00E+00	0.00E+00
5	5.52	-686	-3913	370	7.48E-04	-8.05E-04	-1.16E-03
6	0.00	57	-384	32	0.00E+00	0.00E+00	0.00E+00
6	13.40	57	384	-58	1.44E-03	6.99E-07	8.85E-06
7	0.00	-3	-111	524	0.00E+00	0.00E+00	0.00E+00
7	16.78	82	348	411	1.44E-03	5.60E-07	2.63E-06



Scaled 2X Deflected Truss Plot
Roof Plane MP 1 for Freedom Solar, LLC Client FREDERICK J BUSHEY