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Instant Roof Framing Analysis

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STRUCTURAL ANALYSIS

for the

ROOFTOP PV SOLAR INSTALLATION

Project: Rainer Spies, 102 Serendipity Drive, Fuquay-Varina, NC 27526

Prepared for:

FREEDOM SOLAR POWER

Freedom Solar, LLC

4801 Freidrich Ln, Ste 100 - Austin, TX 78744

Calculation Report Index

Project Number: 36.114400, Rev. 0

Report Date: 04/30/2024

Report Prepared by:

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Loading Summary

Exposure and Occupancy Categories		
B		*Exposure Category (ASCE 7-10 Table 26.7.3, Page 274)*
II		*Building Use Occupancy / Risk Category (ASCE 7-10 Table 1.5-1, Page 5)*

Wind Loading:			
v	116	*mph*	*ASCE 7-10, Figure 26.5-1 A, B or C, pp 249-251. [(116 mph, 50 year wind MRI)]*
qz	20.36	*psf*	*Velocity qz, calculated at height z [ASD]*

Snow Loading			
pg	15	*psf*	*Ground Snow Load pg (ASCE 7-10 Table 7.2-1, Page 56-60)*
Total Snow Load			
ps	15.00	*psf*	*Effective snow load on roof and modules*

Module Data			
REC Solar: REC420AA Pure-R			
Dimensions	*mm*	*ft*	*in*
Length	1,730	5.68	68.11
Width	1,118	3.67	44.02
Area (m^2, ft^2)	1.9	20.82	
Weight	kg	lb	
Module	21.50	47.40	

Roof Panel (Cladding) Loading Summary		Module Loading Summary			
Support Point Loads		*Upward*	*Upward*	*Upward*	*Downward*
Roof Zones		1	2	3	All
Net load per module	*lb*	-27	-49	-70	174

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*	3	
Safety Factor		1.10	
Pull-out for 5/16 threaded fasteners	*lb/in*	220	
Factored max fastener uplift capacity	*lb*	599	
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*	599	

Roof Zones		*1*	*2*	*3*
Net lift per module	*lb*	27	49	70
Min tot bolt thread embedment depth rq'd	*in*	0.13	0.25	0.35
Net uplift pressure 7. 0.6D - 0.6W	*psf*	-2.37	-4.32	-6.20
Allowable lift area / support point	*sf*	253.02	138.66	96.51
Max rail span per framing spacing	*ft*	4.00	4.00	4.00
Landscape Modules				
Length along rafter	*ft*	3.67		
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*	7.34	7.34	7.34
Factored lift per support point	*lb*	-17	-32	-46
Portrait Modules				
Length along rafter	*ft*	5.68		
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*	11.35	11.35	11.35
Factored lift per support point	*lb*	-27	-49	-70

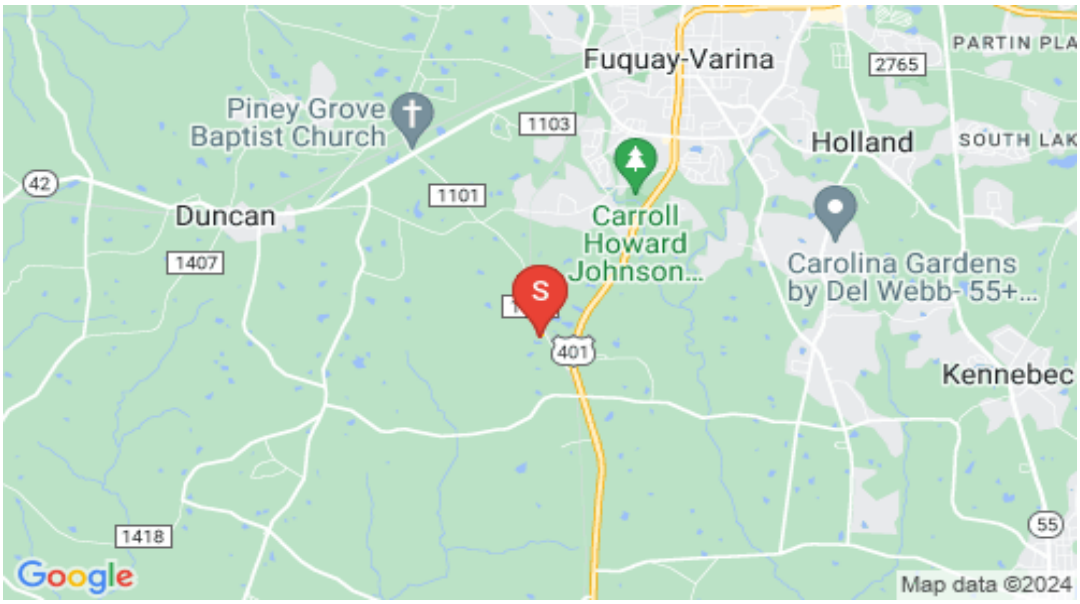
Stanchion support threaded fastener sizes are indicated in the Module Loading Summary table above. Lift forces were determined from GCp and other coefficients contained in the ASCE nomographs

Conclusions

We were asked to review the roof of Rainer Spies, located at 102 Serendipity Drive, Fuquay-Varina, 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 04/19/2024. 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 Pegasus Solar InstaFlash PIF-RB0 stanchions were selected for this project by Freedom Solar, LLC. The racking and support stanchions shall be placed as shown on their plans, dated 04/29/2024, 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 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 7-10 Minimum Design Loads for Buildings and Other Structures*
2) *2015 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.*

Location: MP 1

Member: Truss - Total Length 22.5 ft, Unsupported 22.5 ft

Geometric Data			
Θ	*deg.*	27.00	*Angle of roof plane from horizontal, in degrees*
ω	*deg.*	0.00	*Angle the solar panel makes with the roof surface*
L	*ft.*	46.50	*Length of roof plane, in feet (meters)*
W	*ft.*	20.08	*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=	20.36	*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*	22.50

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

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

** Mem properties based upon field measurements*

Truss top chord

Module Physical Data			
Weight	kg	lb	psf load
Module	21.50	47.40	2.28
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*	5.7		
Area / support point	*sf*	11.4		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	22.50		
Maximum member free span	*ft*	22.50	Truss top chord span	

Zones	1	2	3	Downward, Zones 1, 2 & 3
GCp	-0.94	-1.20	-1.45	GCp 0.71

ASCE 7-10 Chapter 2 Combinations of Loads, Table 2.4, Page 8 (in psf)				
Zones	1	2	3	1, 2 & 3
2.2 SYMBOLS AND NOTATION	*Module Upward*	*Module Upward*	*Module Upward*	*Downward*
D = dead load of PV Module + Stanchion	2.42	2.42	2.42	2.42
S = snow load	15.00	15.00	15.00	15.00
W = wind load	-11.55	-14.81	-17.95	8.75

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 or 0.7)eE + 0.75S	17.42	17.42	17.42	17.61
Module Support point load (lb)	198	198	198	200
Cr Factored Module Support point load (lb)	172	172	172	174

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.6D - 0.6W	-2.37	-4.32	-6.20	4.56
Module Support point load (lb)	-27	-49	-70	52

DOWNWARD

Presume loading directly over member.

Combined Dead and Wind Pressure Downward Loading					
	Truss top 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	7.08		174		Portrait
1	12.76			Support placed on adjoining truss	Portrait
2	12.84			Support placed on adjoining truss	Portrait
2	18.52		174		Portrait

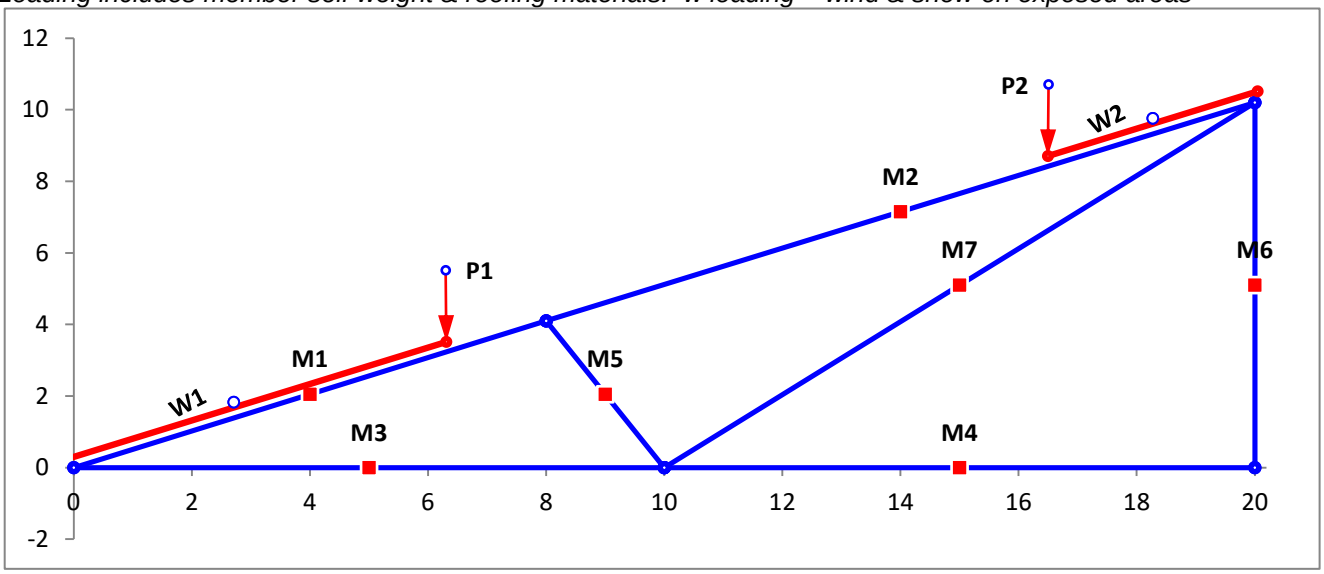
Truss Data and Loading for MP 1

Roof slope (degrees)	27.00			Length of roof plane	22.50
Top ridge height above floor plane	10.21			Length of floor plane	20.08

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 7-10 Table 7.3-1, Page 61)
Ct	=	1.0	Thermal Factor, Ct (ASCE 7-10 Table 7.3-2, Page 61)
Is	=	1.0	Snow Importance Factor, Is (ASCE 7-10 Table 1.5-2, Page 5)
p_g	=	15	Ground Snow Load pg (ASCE 7-10 Table 7.2-1, Page 56-60)

p_f	=	**0.7CeCtIsPg**	Flat Roof Snow Load, pf (ASCE 7-10 Table 7.3-1, Page 61)
p_f	=	**9.45**	psf

but where Pf is not less than the following:

Minimum Snow Load pm (ASCE 7-10 Table 7.3.4, Page 62)

p_m	=	**15**	When Pg <=20 psf, then use Pf = Pg x Is

p_f	=	**15**	psf. Resultant Snow pressure to be used with Roof slope factor below
p_s	=	$C_s p_f$	Sloped Roof Snow Load ps (ASCE 7-10 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 7-10 Table 7.4-1a, Page 62)

Total Snow Load

p_s	=	**15.00**	**psf**	Roof snow load

FEA Calculation Results for Roof Plane MP 1 for Freedom Solar, LLC Client Rainer Spies

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	2006
Total output reactions	0.00	-2006
Output error	-3.89E-14	6.82E-13

0.0001

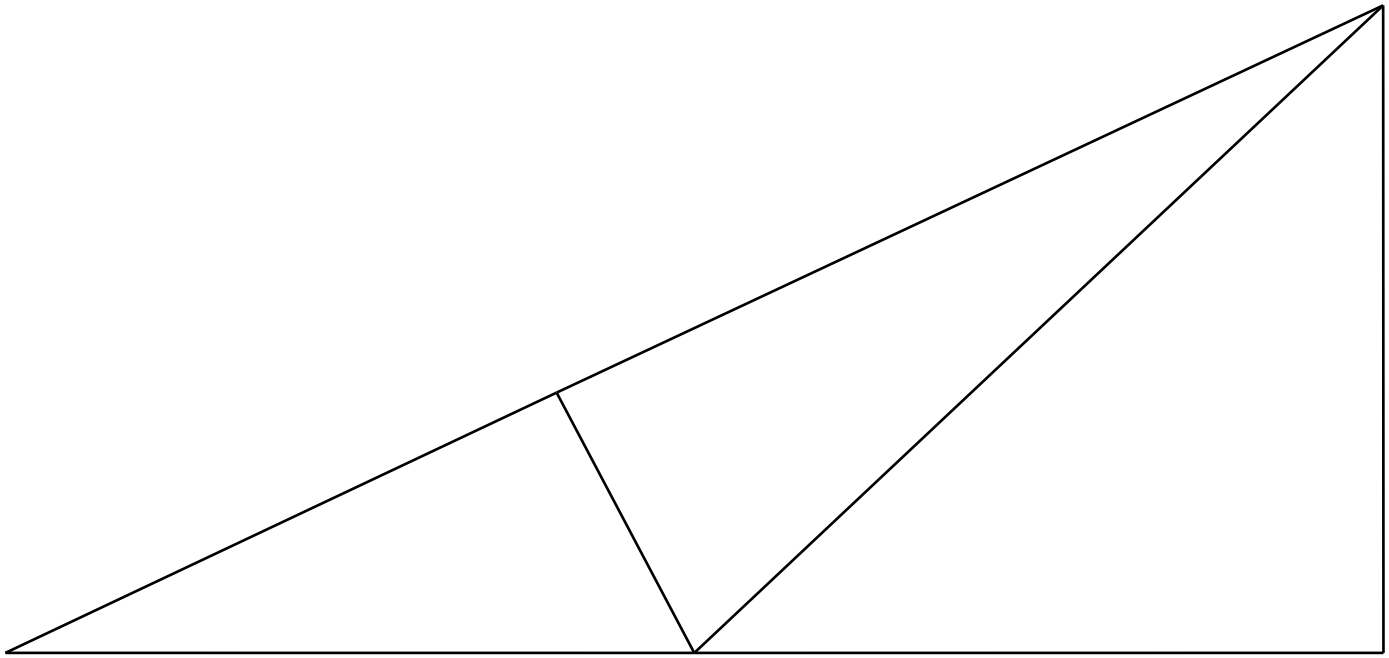
	Shear	Mom	Ax		
Max (psi)	1	11	187		
Allowable (psi)	115	950	5,610	Maximum Deflections	
# of segments/beam		1		-1.71E-03	-1.05E-03

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

Node Results				Beam End Results		
Direction	Deflection	Reaction	Beam	Shear	Axial	BM
DX1	0.00E+00	0	1-1	-439	35	335
DY1	0.00E+00	-524	1-2	-169	-103	-3343
RZ1	1.03E-04	0	2-1	-1353	-762	-6239
DX2	-1.79E-04	0	2-2	-139	-1379	-19888
DY2	3.76E-04	0	3-1	-118	169	-335
RZ2	-2.14E-04	0	3-2	30	169	-1500
DX3	-1.48E-03	0	4-1	-60	1033	385
DY3	1.05E-03	0	4-2	-60	1033	-212
RZ3	1.36E-03	0	5-1	-672	1186	177
DX4	1.14E-04	0	5-2	-679	1173	-2896
DY4	1.12E-04	0	6-1	1033	1541	-212
RZ4	-4.80E-05	0	6-2	1033	1479	10321
DX5	8.13E-04	0	7-1	789	-433	-2062
DY5	0.00E+00	-1482	7-2	870	-516	9567
RZ5	-2.47E-05	0				

Beam	X	Shear	Mom	Axial	DX	DY	RZ
1	0.00	-439	335	35	0.00E+00	0.00E+00	1.03E-04
1	8.99	-234	-3002	-69	-1.89E-04	-3.70E-04	-2.81E-04
2	0.00	-1353	-6239	-762	-1.79E-04	-3.76E-04	-2.14E-04
2	13.46	-637	-12215	-1126	-1.71E-03	-9.32E-04	-2.63E-03
3	0.00	-118	-335	169	0.00E+00	0.00E+00	1.03E-04
3	10.00	-51	-1073	169	1.14E-04	-1.12E-04	-1.12E-04
4	0.00	-60	385	1033	1.14E-04	-1.12E-04	-4.80E-05
4	10.00	-60	-212	1033	8.13E-04	0.00E+00	-3.22E-05
5	0.00	-672	177	1186	1.14E-04	-1.12E-04	-4.80E-05
5	4.56	-677	-2897	1176	-1.79E-04	-3.76E-04	-2.22E-04
6	0.00	1033	-212	1541	8.13E-04	0.00E+00	-2.47E-05
6	10.20	1033	10321	1489	-1.48E-03	-1.05E-03	1.36E-03
7	0.00	789	-2062	-433	1.14E-04	-1.12E-04	-4.80E-05
7	14.28	861	9572	-506	-1.48E-03	-1.05E-03	1.39E-03

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



Scaled 2X Deflected Truss Plot
Roof Plane MP 1 for Freedom Solar, LLC Client Rainer Spies