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Instant Roof Framing Analysis

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STRUCTURAL ANALYSIS

for the

ROOFTOP PV SOLAR INSTALLATION

Project: Sharon Bruce, 55 Welcome 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: 36.115522, Rev. 0

Report Date: 08/06/2024

Report Prepared by:

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DN: c=US, o=TECTONICORP PC, dnQualifier=A01410C0000018E57987 26E0001A3B4, cn=Richard Pantel
Date: 2024.08.06 16:15:55 -04'00'

V240625
ID.L1PW

Loading Summary

Exposure and Occupancy Categories		
B		*Exposure Category (ASCE 7-10 Table 26.7.3, Page 266)*
II		*Building Use Occupancy / Risk Category (ASCE 7-10 Table 1.5-1, Page 4)*

Wind Loading:			
v	115	*mph*	*Over-ridden per client request. Original data from Municipality provided wind / snow loadings.*
qz	20.14	*psf*	*Velocity qz, calculated at height z [ASD]*

Snow Loading			
pg	15.00	*psf*	*Ground Snow Load pg (Over-ridden per client request. Original data from Municipality provided wind / snow loadings.)*
Total Snow Load			
ps	15.00	*psf*	*Effective snow load on roof and modules*

Module Data			
REC Solar: REC460AA Pure-RX			
Dimensions	*mm*	*ft*	*in*
Length	1,728	5.67	68.03
Width	1,205	3.95	47.44
Area (m^2, ft^2)	2.1	22.41	
Weight	kg	lb	
Module	23.40	51.59	

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*	-52	-98	-145	173

Positive values indicate net downward force

Primary Stanchion: Pegasus Solar InstaFlash PIF-RB0

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*	3.00
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
Max stanchion uplift capacity			*lb*	618
Max support point uplift capacity			*lb*	599

Predrill hole 0.16" dia or use self tapping

Roof Zones		*1*	*2*	*3*
Net lift per module	*lb*	52	98	145
Min tot bolt thread embedment depth rq'd	*in*	0.26	0.49	0.73
Net uplift pressure 7. 0.6D - 0.6W	*psf*	-2.31	-4.31	-6.39
Allowable lift area / support point	*sf*	259.18	138.94	93.78
Max rail span per framing spacing	*ft*	4.00	4.00	4.00
Landscape Modules				
Length along rafter	*ft*	3.95		
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*	7.91	7.91	7.91
Factored lift per support point	*lb*	-18	-34	-50
Portrait Modules				
Length along rafter	*ft*	5.67		
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*	11.34	11.34	11.34
Factored lift per support point	*lb*	-26	-49	-72

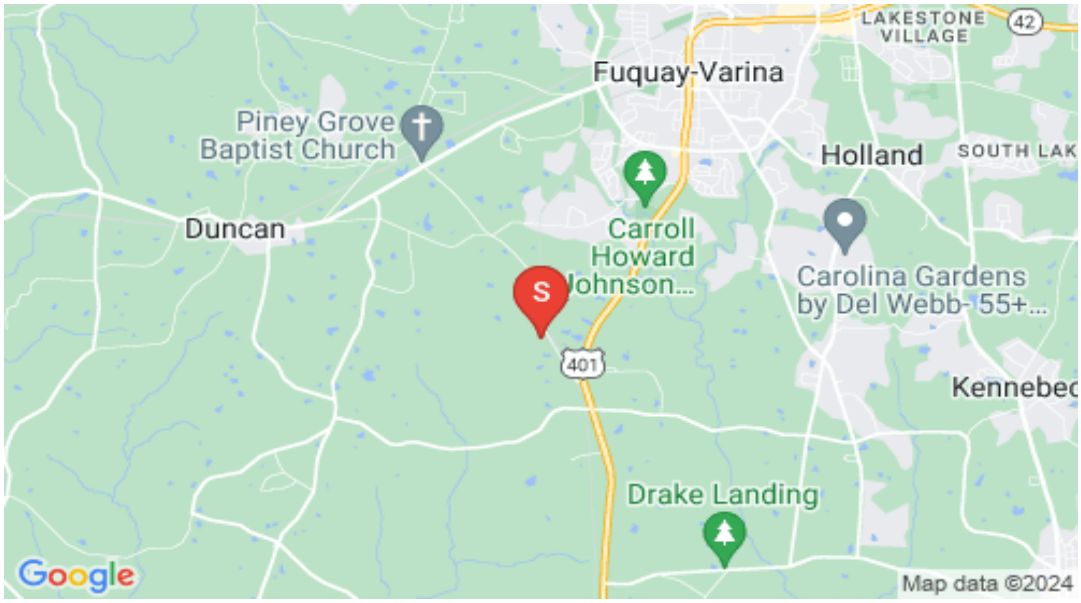
Stanchion support threaded fastener sizes are indicated in the Module Loading Summary table above. Lift forces were determined from GCp and other coefficients contained in the ASCE nomographs

Conclusions

We were asked to review the roof of Sharon Bruce, located at 55 Welcome 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 07/30/2024. 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 08/05/2024, 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

	Ex. Framing	Total Ex DL
MP 1: Truss @ 24" OC	0.79 psf	5.19 psf

** Wood species used in these calculations assumes spruce, pine or fir, #2 grade.*

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.*

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.*	53.33	*Length of roof plane, in feet (meters)*
W	*ft.*	35.25	*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 =	3.53	*ft*

Wind Velocity Pressure, q_z evaluated at the height z						
q_z=	20.14	*psf*	*Vasd* q_z=	12.34	*psf*	Basic wind pressure
V=	115	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*	40.00

2	# Rafters / Rack Support Width
4.00	Rack Support Spacing (ft)
48	Max. Rack Support Spacing (in)
3	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	23.40	51.59	2.30
4 Stanchions	1.36	3.0	0.13

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*	11.3		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	40.00		
Maximum member free span	*ft*	40.00	Truss top chord span	

Zones	1	2	3	Downward, Zones 1, 2 & 3
GCp	-0.93	-1.20	-1.48	GCp 0.69

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	2.44	2.44	2.44	2.44
S = snow load	15.00	15.00	15.00	15.00
W = wind load = (Vu Windload) = (Vasd Windload / 0.6)	-11.47	-14.81	-18.27	8.51

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	17.44	17.44	17.44	17.51
Module Support point load (lb)	198	198	198	199
Cr Factored Module Support point load (lb)	172	172	172	173

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.6D - 0.6W	-2.31	-4.31	-6.39	4.57
Module Support point load (lb)	-26	-49	-72	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	18.33		173		Portrait
1	24.00			Support placed on adjoining truss	Portrait
2	24.08			Support placed on adjoining truss	Portrait
2	29.75		173		Portrait
3	29.84		173		Landscape
3	33.79			Support placed on adjoining truss	Landscape

Truss Data and Loading for MP 1

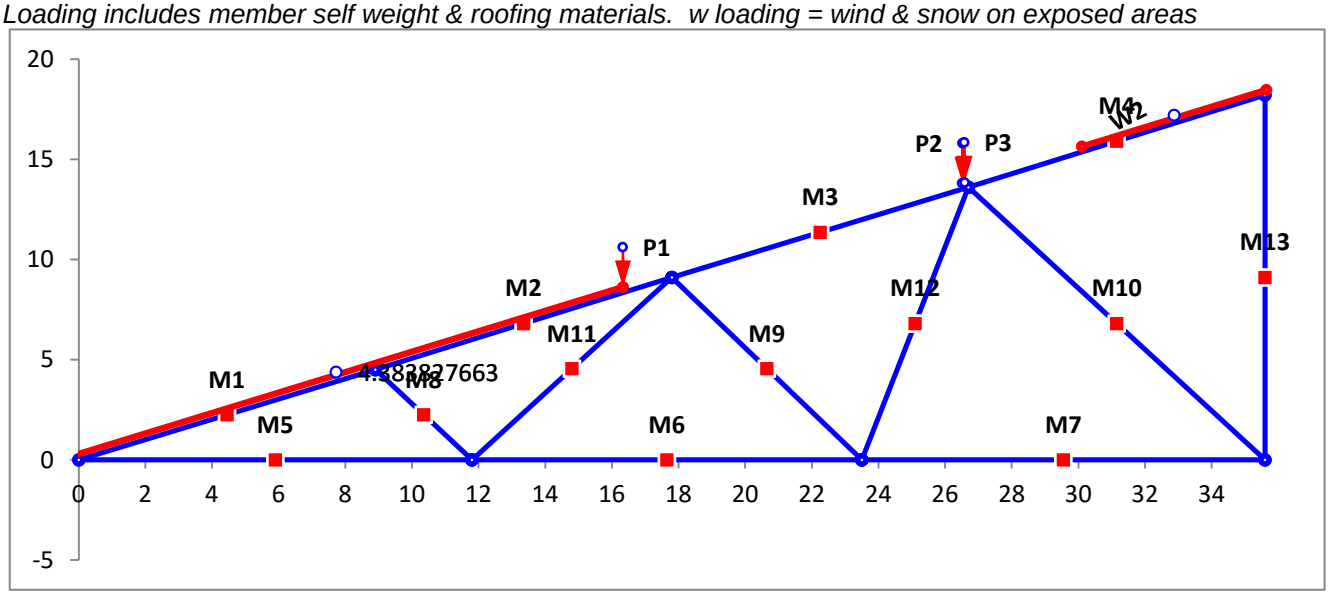
Roof slope (degrees)	27.00
Top ridge height above floor plane	18.16

	Length of roof plane	40.00
	Length of floor plane	35.25

Truss Segments

Roof Plane		*Floor Plane*		*Diagonals*		*Diagonals*	
Mem #	*Mem Type*	Mem #	*Mem Type*	Mem #	*Mem Type*	Mem #	*Mem Type*
1	2x4	5	2x4	8	2x4	11	2x4
2	2x4	6	2x4	9	2x4	12	2x4
3	2x4	7	2x4	10	2x4	13	2x4
4	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 58)
Ct	=	1.0	Thermal Factor, Ct (ASCE 7-10 Table 7.3-2, Page 58)
Is	=	1.0	Snow Importance Factor, Is (ASCE 7-10 Table 1.5-2, Page 5)
p_g	=	15.00	Ground Snow Load pg (Over-ridden per client request. Original data from Municipality
p_f	=	**0.7CeCtIsPg**	Flat Roof Snow Load, pf (ASCE 7-10 Table 7.3-1, Page 58)
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 53)
p_m	=	**15.00**	When Pg <=20 psf, then use Pf = Pg x Is
p_f	=	**15.00**	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 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 7-10 Table 7-2a, Page 59)

Total Snow Load

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

FEA Calculation Results for Roof Plane MP 1 for Freedom Solar, LLC Client SHARON BRUCE

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

Equilibrium check	FX	FY	0.00043
Total applied forces	0.00	2449	
Total output reactions	0.00	-2449	
Output error	4.98E-13	-2.73E-12	

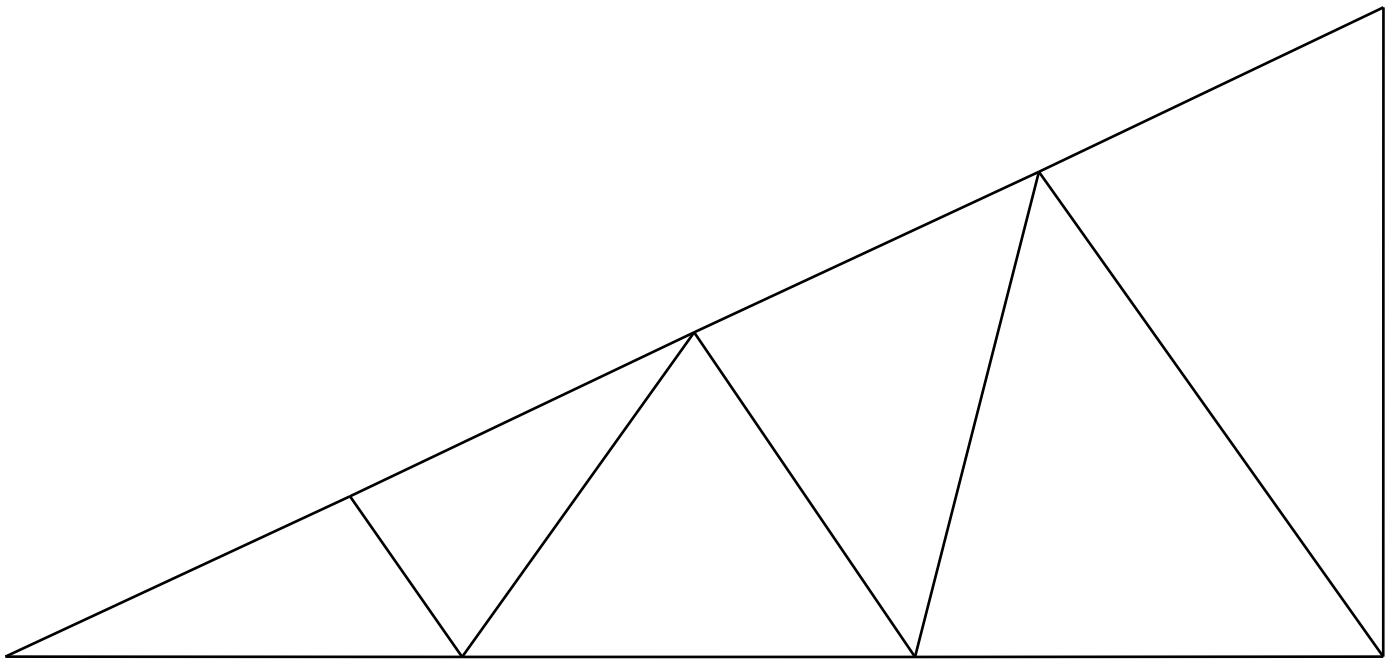
	Shear	Mom	Ax		
Max (psi)	1	13	335		
Allowable (psi)	115	950	5,610	Maximum Deflections	
# of segments/beam		1		1.73E-03	-4.29E-03

** 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	-344	522	719
DY1	0.00E+00	-658	1-2	-58	378	-3992
RZ1	5.06E-04	0	2-1	-231	791	-950
DX2	-1.27E-03	0	2-2	54	643	-4747
DY2	3.40E-03	0	3-1	341	476	-2212
RZ2	4.70E-04	0	3-2	627	331	1223
DX3	-1.05E-03	0	4-1	-1702	-217	3224
DY3	4.25E-03	0	4-2	-1080	-539	-14310
RZ3	1.85E-04	0	5-1	-116	-311	-719
DX4	-5.74E-04	0	5-2	70	-311	-1959
DY4	4.02E-03	0	6-1	52	-637	-1250
RZ4	1.34E-04	0	6-2	52	-637	-647
DX5	1.73E-03	0	7-1	29	-579	-1655
DY5	-7.22E-04	0	7-2	29	-579	-1307
RZ5	2.08E-03	0	8-1	438	152	712
DX6	-2.48E-04	0	8-2	428	136	3042
DY6	4.00E-03	0	9-1	49	188	750
RZ6	2.00E-04	0	9-2	13	130	1161
DX7	-7.52E-04	0	10-1	-45	2767	2112
DY7	4.29E-03	0	10-2	-126	2643	968
RZ7	-9.84E-05	0	11-1	245	-298	-1421
DX8	-1.227E-03	0	11-2	283	-357	1374
DY8	0.000E+00	-1791	12-1	48	-202	258
RZ8	-5.799E-04	0	12-2	73	-311	1033
			13-1	974	-528	-3419
			13-2	974	-712	14310

Beam	X	Shear	Mom	Axial	DX	DY	RZ
1	0.00	-344	719	522	0.00E+00	0.00E+00	5.06E-04
1	9.97	-285	-2324	492	-1.33E-03	-3.37E-03	1.09E-04
2	0.00	-231	-950	791	-1.27E-03	-3.40E-03	4.70E-04
2	10.02	-172	-2873	760	-1.11E-03	-4.22E-03	-2.58E-04
3	0.00	341	-2212	476	-1.05E-03	-4.25E-03	1.85E-04
3	9.97	554	1603	368	-5.86E-04	-4.01E-03	1.15E-04
4	0.00	-1702	3224	-217	-5.74E-04	-4.02E-03	1.34E-04
4	10.02	-1421	-8973	-362	1.56E-03	8.08E-04	-2.03E-03
5	0.00	-116	-719	-311	0.00E+00	0.00E+00	5.06E-04
5	11.80	-28	-1452	-311	-2.48E-04	-4.00E-03	1.38E-04
6	0.00	52	-1250	-637	-2.48E-04	-4.00E-03	2.00E-04
6	11.70	52	-647	-637	-7.52E-04	-4.29E-03	-7.75E-05
7	0.00	29	-1655	-579	-7.52E-04	-4.29E-03	-9.84E-05
7	12.10	29	-1307	-579	-1.23E-03	0.00E+00	-5.53E-04
8	0.00	438	712	152	-2.48E-04	-4.00E-03	2.00E-04
8	5.35	430	3040	140	-1.27E-03	-3.40E-03	4.44E-04
9	0.00	49	750	188	-7.52E-04	-4.29E-03	-9.84E-05
9	10.74	18	1158	138	-1.05E-03	-4.25E-03	1.71E-04
10	0.00	-45	2112	2767	-1.23E-03	0.00E+00	-5.80E-04
10	16.25	-118	964	2656	-5.74E-04	-4.01E-03	1.08E-04
11	0.00	245	-1421	-298	-2.48E-04	-4.00E-03	2.00E-04
11	10.90	278	1377	-348	-1.05E-03	-4.25E-03	2.10E-04
12	0.00	48	258	-202	-7.52E-04	-4.29E-03	-9.84E-05
12	13.97	70	1034	-298	-5.74E-04	-4.01E-03	1.31E-04
13	0.00	974	-3419	-528	-1.23E-03	0.00E+00	-5.80E-04
13	18.20	974	14310	-694	1.73E-03	7.23E-04	2.12E-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 SHARON BRUCE