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Instant Roof Framing Analysis

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STRUCTURAL ANALYSIS

for the

ROOFTOP PV SOLAR INSTALLATION

Project: Anthony Desorbo; Location: 6615 Old Us Highway 421, Lillington, NC 27546

Prepared for:

FREEDOM SOLAR POWER

Freedom Solar, LLC

4801 Freidrich Ln, Ste 100 - Austin, TX 78744

Calculation Report Index

Project Number: 36.111386, Rev. 0

Report Date: 07/19/2023

Report Prepared by:

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DN: c=US, o=TECTONICORP PC, dnQualifier=A01410D00000178D0DC BFCA00007095, cn=Richard Pantel
Date: 2023.07.19 21:03:40 -04'00'

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	20.90	*psf*	*Velocity qz, calculated at height z [ASD]*

Snow Loading			
pg	15	*psf*	*Ground Snow Load pg (ASCE 7-16 Table 7.2-1, Page 52-53)*
Total Snow Load			
ps	15.00	*psf*	*Effective snow load on roof and modules*

Module Data			
WAAREE ENERGIES LIMITED: WSMD-400			
Dimensions	*mm*	*ft*	*in*
Length	1,923	6.31	75.70
Width	1,039	3.41	40.90
Area (m^2, ft^2)	2.0	21.50	
Weight	kg	lb	
Module	22.00	48.50	

Roof Panel (Cladding) Loading Summary		Module Loading Summary			
Support Point Loads		*Upward*	*Upward*	*Upward*	*Downward*
Roof Zone		1,2e	2n,2r,3e	3r	All
Net total load / support point	*lb*	-75	-159	-192	219

Positive values indicate net downward force

Lag Bolt Data	Size	5/16x2.20	Pre-drill	0.16" dia	Material	Stainless

Rack Support Lag Bolt Pull-out Calculations in US Spruce Roof Framing				
Roof Zone		1,2e	2n,2r,3e	3r
Bolt Pullout Per Module Connection	*lb*	75	159	192
Number of Pullout Loads / Support		2	2	2
Safety Factor		1.50	1.50	1.50
Pull-out for 5/16 dia bolts	*lb/in*	206	206	206
Min threaded inches embedment required	*in*	0.27	0.58	0.70
Min threaded Inches embedment provided	*in*	1.20	1.20	1.20
Min Lag Bolt length to use	*in*	2.20	2.20	2.20

Stanchion support Lag Bolts 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 Anthony Desorbo, located at 6615 Old Us Highway 421, 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 07/06/2023. 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 SunPower InvisiMount 6000 series racking system with QuickBolt 17662 stanchions for this project. The racking and support stanchions shall be placed as shown on their plans, dated 07/12/2023, and shall be fastened to the roof framing using lag bolt sizes indicated in this report. Rack support spacing shall be no more than that shown on each framing condition calculation. 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 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 bolting is described below.

Bracket to Roof Framing Lag Bolts

US Spruce framing material has a bolt pullout strength of 207 lb / inch of thread using the 5/16" dia. fasteners. In order to maintain at least a 1.5X Safety Factor for pullout, 1.2 inches of THREAD embedment are required. Use a 2.20" x 5/16" stainless lag bolt, or longer, in order to achieve the above specified embedment into each joist at each rail support point. Predrill with a 0.16" dia pilot hole.
Lag bolt/screws of a relatively small, 5/16 Inch diameter by 3 inches long can be embedded In the top 2x4 chord of a simple span member truss, with a required penetration minimum of 1.5" and a maximum of 2.5".

Notes: (1) Bolt 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) Lag bolts must be located in the middle third of the structural member. (3) Install lag bolts with head and washer flush to 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 2005,Table 11.2A, 11.3.2A.*
5) *American Wood Council, Wood Structural Design, 1992, Figure 6.*

Location: MP 1

Member: Truss - Total Length 32 ft, Unsupported 32 ft

Roof Data			
Θ	*deg.*	26.00	*Angle of plane of roof from horizontal, in degrees*
L	*ft.*	79.50	*Length of Building, in feet (meters).*
W	*ft.*	31.30	*Width of Building, in feet (meters).*
h	*ft.*	19.00	*Height of Building, in feet (meters).*

Roof Wind Zone Width			
	use, a =	3.13	*ft*

Wind Velocity Pressure, q_z evaluated at the height z						
q_z=	20.90	*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*	32.00

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 Data			
WAAREE ENERGIES LIMITED: WSMD-400			
Weight	kg	lb	psf load
Module	22.00	48.50	2.26
4 Stanchions	1.36	3.0	0.14
Total Module and Support load	23.36	51.5	2.40

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*	12.6		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	32.00	
Maximum member free span	*ft*	32.00	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

	Exposed	**FALSE**
	1.5(Lp) =	5.11
γE =	1	
γa =	0.67	

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

Zones	1,2e	2n,2r,3e	3r
p, Windload (psf)	-12.46	-17.96	-20.18

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	2.40	2.40	2.40	2.40
S = snow load	15.00	15.00	15.00	15.00
W = wind load	-12.46	-17.96	-20.18	5.71

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)	17.40	17.40	17.40	19.97
Module Support point load (lb)	219	219	219	252
Cr Factored Module Support point load (lb)	191	191	191	219

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.6D + 0.6W	-2.98	-6.28	-7.61	7.49
Module Support point load (lb)	-38	-79	-96	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	8.87		219		Portrait
1	15.18			Support placed on adjoining truss	Portrait
2	15.26			Support placed on adjoining truss	Portrait
2	21.57		219		Portrait
3	21.65		219		Portrait
3	27.96			Support placed on adjoining truss	Portrait

Truss Data and Loading for MP 1

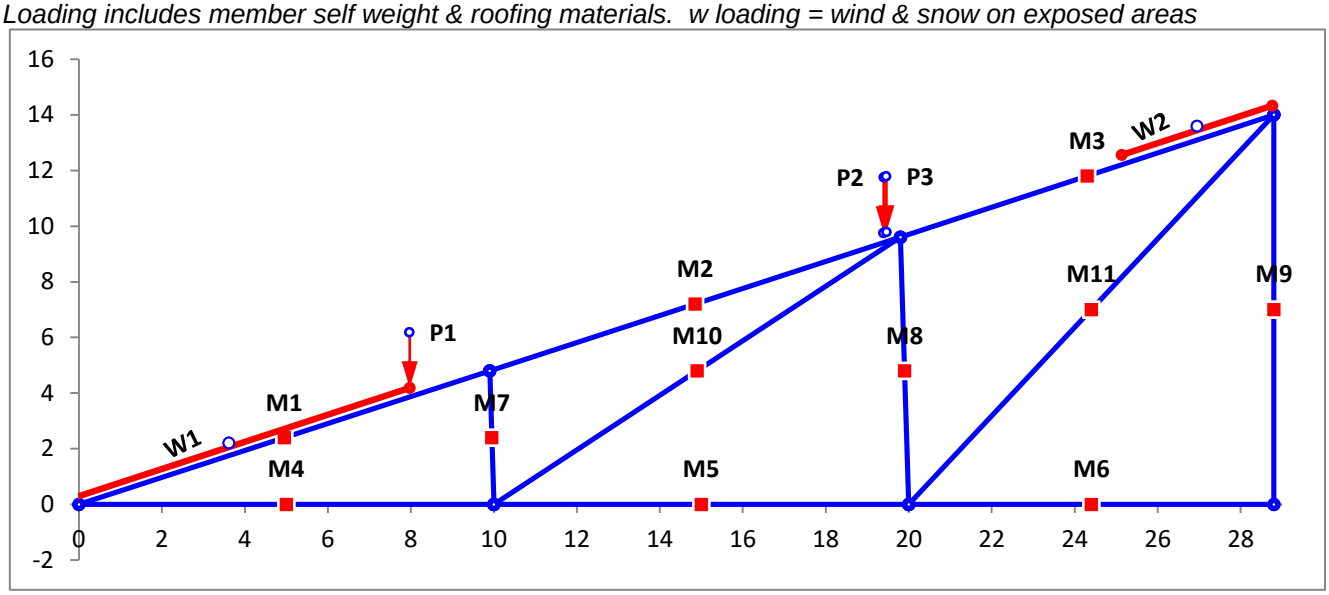
Roof slope (degrees)	26.00
Top ridge height above floor plane	14.03

	Length of roof plane	32.00
	Length of floor plane	30.00

Truss Segments

Roof Plane		*Floor Plane*		*Diagonals*		*Diagonals*	
Mem #	*Mem Type*	Mem #	*Mem Type*	Mem #	*Mem Type*	Mem #	*Mem Type*
1	2x4	4	2x4	7	2x4	10	2x4
2	2x4	5	2x4	8	2x4	11	2x4
3	2x4	6	2x4	9	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	=	15	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	=	**9.45**	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	=	**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 7-16 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	=	**15.00**	**psf**	Roof snow load

FEA Calculation Results for Roof Plane MP 1 for Freedom Solar, LLC Client Anthony DeSorbo

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	2441
Total output reactions	0.00	-2441
Output error	-4.55E-13	-4.55E-13

7.9E-05

# of segments/beam	1

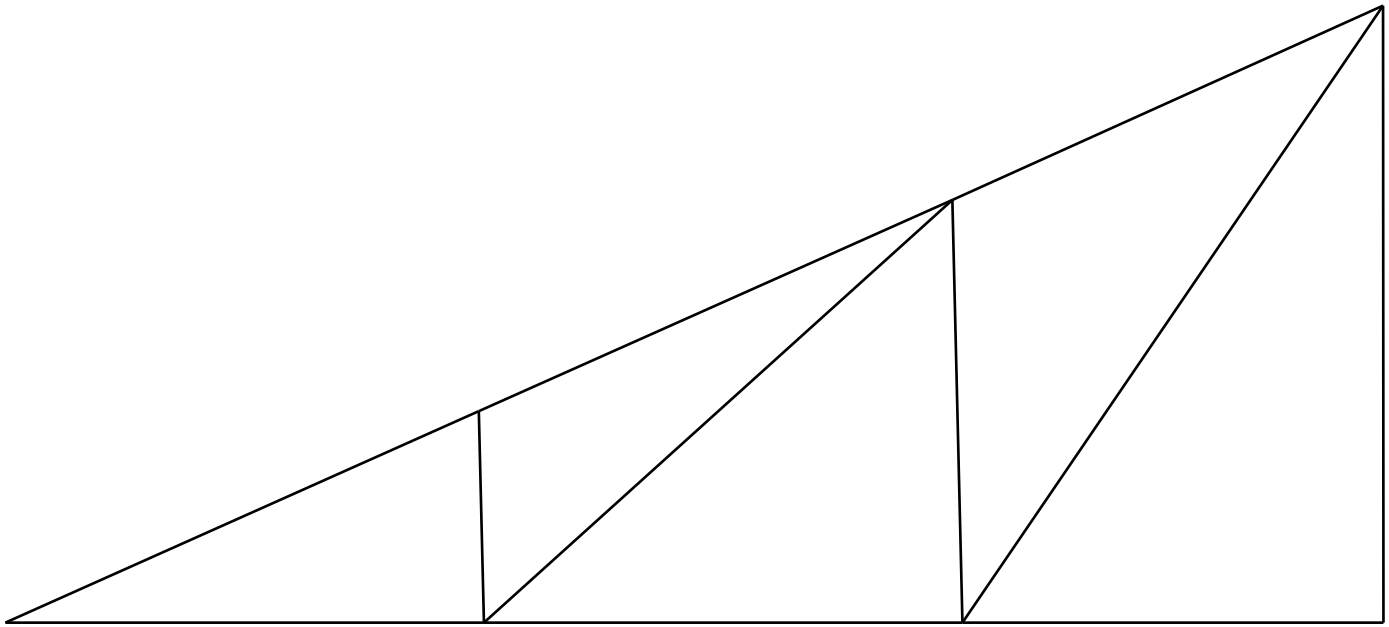
Maximum Deflections	
-4.81E-03	-3.51E-03

** 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	1307	1-1	-30	-1105	-24
DY1	0.00E+00	356	1-2	317	-1274	128
RZ1	1.24E-04	0	2-1	-135	-1241	456
DX2	-1.56E-03	0	2-2	213	-1409	-875
DY2	1.97E-04	0	3-1	-2938	-708	-1934
RZ2	3.55E-04	0	3-2	-1965	-1184	-28531
DX3	-4.79E-03	0	4-1	-99	-299	24
DY3	3.51E-03	0	4-2	48	-299	-951
RZ3	4.33E-04	0	5-1	0	299	0
DX4	-4.38E-03	0	5-2	0	299	0
DY4	6.21E-04	0	6-1	0	0	0
RZ4	6.66E-03	0	6-2	0	0	0
DX5	-3.18E-04	0	7-1	-159	440	1089
DY5	0.00E+00	-234	7-2	-159	424	328
RZ5	0.00E+00	-3094	8-1	-248	3552	1622
DX6	0.00E+00	193	8-2	-249	3497	-759
DY6	0.00E+00	-2112	9-1	1499	451	-5933
RZ6	0.00E+00	3934	9-2	1499	341	15055
DX7	0.00E+00	-1499	10-1	-122	-482	1054
DY7	0.00E+00	-451	10-2	-46	-557	-299
RZ7	0.00E+00	5933	11-1	1126	-987	-5556
			11-2	1206	-1115	13476

Beam	X	Shear	Mom	Ax	DX	DY	RZ
1	0.00	-30	-24	-1105	0.00E+00	0.00E+00	1.24E-04
1	11.00	237	543	-1235	-1.58E-03	-1.87E-04	1.59E-04
2	0.00	-135	456	-1241	-1.56E-03	-1.97E-04	3.55E-04
2	11.00	132	-460	-1370	-4.81E-03	-3.50E-03	2.19E-04
3	0.00	-2938	-1934	-708	-4.79E-03	-3.51E-03	4.33E-04
3	10.02	-2364	-21421	-989	-4.72E-03	-4.58E-04	-1.41E-02
4	0.00	-99	24	-299	0.00E+00	0.00E+00	1.24E-04
4	10.00	-33	-533	-299	-3.18E-04	2.71E-20	-2.15E-04
5	0.00	0	0	299	-3.18E-04	0.00E+00	0.00E+00
5	10.00	0	0	299	0.00E+00	0.00E+00	0.00E+00
6	0.00	0	0	0	0.00E+00	0.00E+00	0.00E+00
6	8.80	0	0	0	0.00E+00	0.00E+00	0.00E+00
7	0.00	-159	1089	440	-3.18E-04	0.00E+00	0.00E+00
7	4.80	-159	328	428	-1.56E-03	-1.97E-04	2.85E-04
8	0.00	-248	1622	3552	0.00E+00	0.00E+00	0.00E+00
8	9.60	-249	-759	3505	-4.79E-03	-3.51E-03	3.80E-04
9	0.00	1499	-5933	451	0.00E+00	0.00E+00	0.00E+00
9	14.00	1499	15055	353	-4.38E-03	-6.20E-04	6.79E-03
10	0.00	-122	1054	-482	-3.18E-04	0.00E+00	0.00E+00
10	13.72	-55	-295	-548	-4.79E-03	-3.51E-03	4.09E-04
11	0.00	1126	-5556	-987	0.00E+00	0.00E+00	0.00E+00
11	16.54	1198	13479	-1103	-4.38E-03	-6.20E-04	6.76E-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 Anthony DeSorbo