iRooFA™

Instant Roof Framing Analysis

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STRUCTURAL ANALYSIS

for the

ROOFTOP PV SOLAR INSTALLATION

Project: John Rhodes, 64 Teak Wood Ct Lillington Nc 27546 Usa, Lillington, NC 27546

Prepared for:

Titan Solar Power

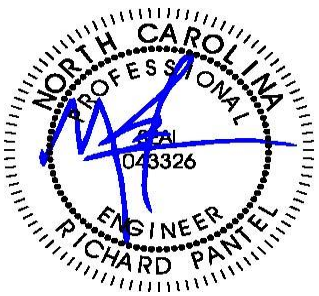
525 W Baseline Rd, - Mesa, AZ 85210

Calculation Report Index

Project Number: 9694.16409.16409, Rev. 0

Report Date: 08/29/2023

Report Prepared by:



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Date: 2023.08.29 12:13:20 -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*	*Over-ridden per client request. Original data from Municipality provided wind / snow loadings.*
qz	20.85	*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			
SilFab: SILFAB SIL-410HC+			
Dimensions	*mm*	*ft*	*in*
Length	1,914	6.28	75.35
Width	1,036	3.40	40.79
Area (m^2, ft^2)	2.0	21.34	
Weight	kg	lb	
Module	21.30	46.96	

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 total load / support point	*lb*	-134	-208	-336	164

Positive values indicate net downward force

Stanchion Fastener Pull-out and Spacing Calculations		
Framing spacing	*ft*	2.00
Max stanchion span	*ft*	4.00
# fasteners per stanchion		2
Depth of screw penetration	*in*	0.5
Safety Factor		1.25
Pull-out for #12 fasteners	*lb/in*	158
Max uplift capacity of stanchion	*lb*	757

Roof Zones		*1,2e*	*2n,2r,3e*	*3r*
Lift Per Module	*lb*	134	208	336
Factored maximum lift to counteract	*lb*	168	260	420
Net uplift pressure 7. 0.60D - 0.6W	*psf*	-5.35	-8.28	-13.38
Allowable lift area / fastener	*sf*	141.64	91.42	56.60
Landscape Modules				
Length along rafter	*ft*	3.40		
Maximum stanchion EW spacing	*ft*	4.00	4.00	4.00
Maximum module area / support point	*sf*	6.8	6.8	6.8
Factored lift per support point	*lb*	-36	-56	-91
Portrait Modules				
Length along rafter	*ft*	6.28		
Maximum stanchion EW spacing	*ft*	4.00	4.00	4.00
Maximum module area / support point	*sf*	12.6	12.6	12.6
Factored lift per support point	*lb*	-67	-104	-168

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 John Rhodes, located at 64 Teak Wood Ct Lillington Nc 27546 Usa, Lillington, NC, by Titan Solar Power, to determine its suitability to support a PV solar system installation.

The referenced building's roof structure was field measured by Titan Solar Power on 08/29/2023. 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 Titan Solar Power. Loads are calculated to combine the existing building and environmental loads with the proposed new PV array loads.

Titan Solar Power selected the Unirac NXT Umount Rail racking with Unirac NXT Horizon Stronghold Attachment stanchions for this project. The racking and support stanchions shall be placed as shown on their plans, dated 08/29/2023, 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.

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 fastening is described above.

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 19 ft, Unsupported 19 ft

Geometric Data			
Θ	*deg.*	18.00	*Angle of roof plane from horizontal, in degrees*
L	*ft.*	46.33	*Length of roof plane, in feet (meters)*
W	*ft.*	18.17	*Plan view width of roof plane, in feet (meters)*
h	*ft.*	15.00	*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=	20.85	*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*	19.00

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	21.30	46.96	2.20
4 Stanchions	1.36	3.0	0.14
Total Module and Support load	22.66	50.0	2.34

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*	19.00	
Maximum member free span	*ft*	19.00	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) =	5.10
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)	-16.35	-21.24	-29.73

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	2.34	2.34	2.34	2.34
S = snow load	10.00	10.00	10.00	10.00
W = wind load	-16.35	-21.24	-29.73	5.96

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)	12.34	12.34	12.34	15.02
Module Support point load (lb)	155	155	155	189
Cr Factored Module Support point load (lb)	135	135	135	164

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.60D - 0.6W	-5.35	-8.28	-13.38	7.44
Module Support point load (lb)	-67	-104	-168	93

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	0.59		164		Portrait
1	6.87			Support placed on adjoining truss	Portrait
2	6.95			Support placed on adjoining truss	Portrait
2	13.23		164		Portrait
3	13.32		164		Portrait
3	19.60			Support outside of max stressed section	Portrait

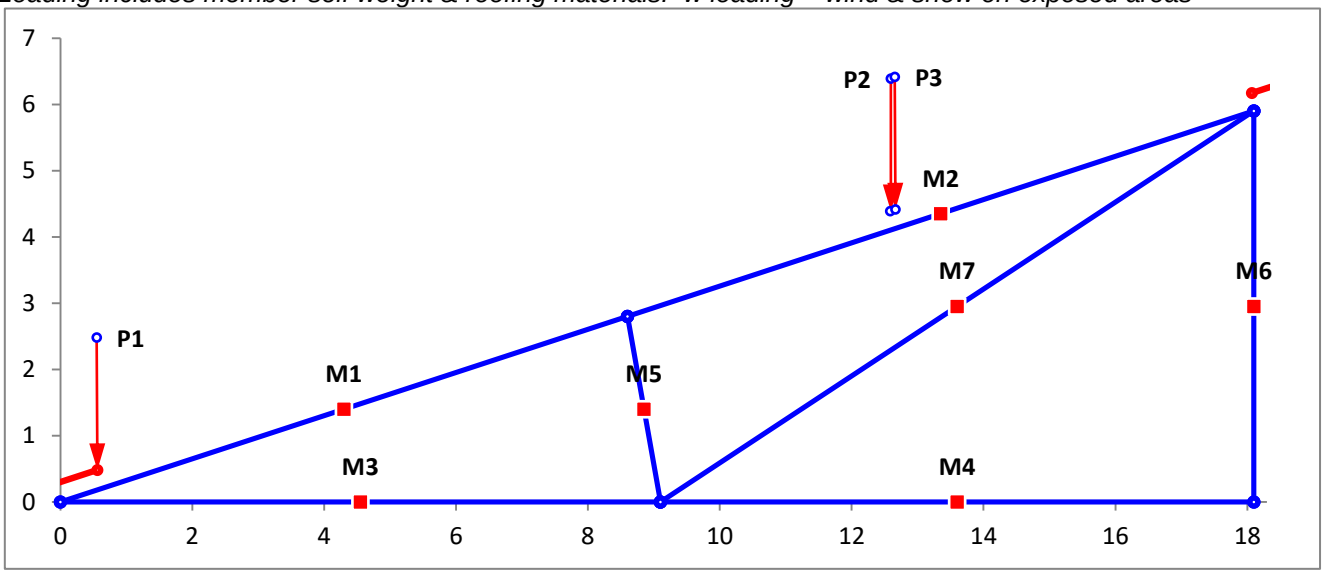
Truss Data and Loading for MP 1

Roof slope (degrees)	18.00		Length of roof plane	19.00
Top ridge height above floor plane	5.87		Length of floor plane	18.17

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 (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 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 Titan Solar Power Client John Rhodes

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	994
Total output reactions	0.00	-994
Output error	-3.82E-14	-1.14E-13

1.8E-05

# of segments/beam	1

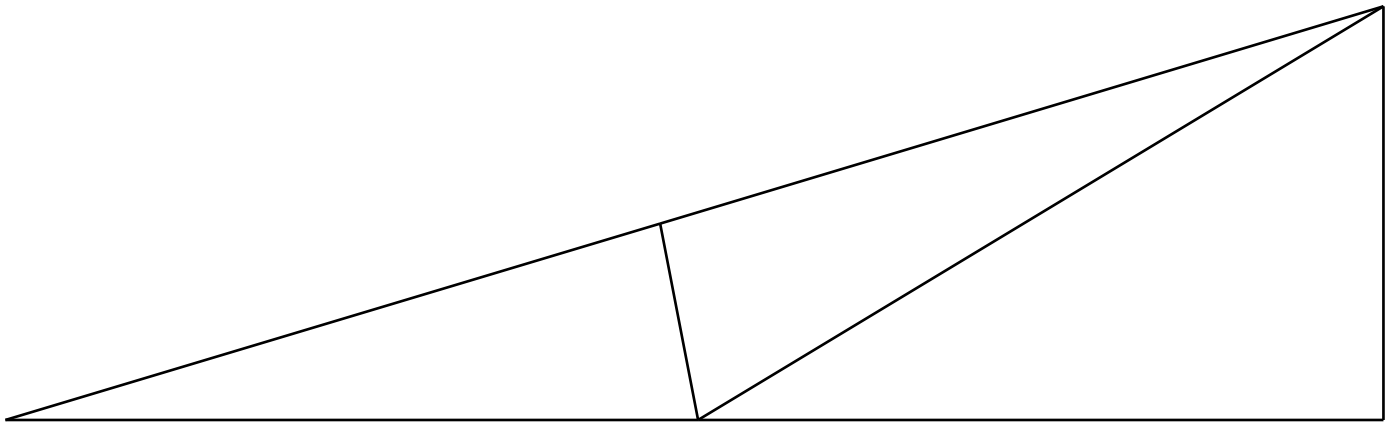
Maximum Deflections	
-8.46E-05	-2.11E-05

** 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	129	1-1	-359	-19	1172
DY1	0.00E+00	-519	1-2	-81	-109	-780
RZ1	-2.68E-04	0	2-1	-162	71	50
DX2	-7.28E-05	0	2-2	133	-25	-661
DY2	2.11E-05	0	3-1	-184	0	-1172
RZ2	1.75E-04	0	3-2	110	0	-447
DX3	-1.96E-05	0	4-1	0	0	0
DY3	0.00E+00	-205	4-2	0	0	0
RZ3	0.00E+00	-634	5-1	168	112	351
DX4	0.00E+00	-134	5-2	167	106	830
DY4	0.00E+00	-262	6-1	-5	6	16
RZ4	0.00E+00	-838	6-2	-5	-16	-16
DX5	0.00E+00	5	7-1	-17	-3	40
DY5	0.00E+00	-6	7-2	39	-40	43
RZ5	0.00E+00	-16				

Beam	X	Shear	Mom	Ax	DX	DY	RZ
1	0.00	-359	1172	-19	0.00E+00	0.00E+00	-2.68E-04
1	9.04	-150	-422	-87	-8.46E-05	-1.73E-05	-6.19E-05
2	0.00	-162	50	71	-7.28E-05	-2.11E-05	1.75E-04
2	9.99	56	-264	0	-3.27E-05	4.27E-06	-2.07E-04
3	0.00	-184	-1172	0	0.00E+00	0.00E+00	-2.68E-04
3	9.10	36	-68	0	0.00E+00	2.49E-20	-4.99E-05
4	0.00	0	0	0	0.00E+00	0.00E+00	0.00E+00
4	9.00	0	0	0	0.00E+00	0.00E+00	0.00E+00
5	0.00	168	351	112	0.00E+00	0.00E+00	0.00E+00
5	2.84	168	830	108	-7.28E-05	-2.10E-05	1.37E-04
6	0.00	-5	16	6	0.00E+00	0.00E+00	0.00E+00
6	5.90	-5	-16	-11	-1.96E-05	2.38E-07	-8.40E-07
7	0.00	-17	40	-3	0.00E+00	0.00E+00	0.00E+00
7	10.76	32	46	-35	-1.98E-05	1.32E-07	-8.48E-07

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



Scaled 2X Deflected Truss Plot
Roof Plane MP 1 for Titan Solar Power Client John Rhodes