Patented. Copyright 2020-2024 Richard Pantel. All Rights Reserved. Paper or PDF copies of this report may be distributed only to employees of the company listed below under "Prepared for", or to Authorities Having Jursidiction (AHJ's) for their review purposes. This document contains Intellectual Property (IP) created by the Author, and as such, no parts of this calculation report or related data input form(s) may be copied in format, content or intent without permission in writing from the Author. Dis-assembly or reverse engineering of this calculation report or related data input form is strictly prohibited. The Author's contact information is: RPantel@iroofa.solar, web-site: www.iroofa.solar; tel: 908-507-5500. Trademark: iRooF® and iRooFA®.



www.iroofa.solar

tel: 540.313.5317 - email: info@iRooFA.solar

STRUCTURAL ANALYSIS for the ROOFTOP PV SOLAR INSTALLATION

Project: Lee Osterhout, 42 Oakland Drive Sanford Nc 27332, Sanford, NC 27332

Prepared for:



Freedom Solar, LLC

4801 Freidrich Ln, Ste 100 - Austin, TX 78744

Calculation Report Index

Pages Description Pages <u>Description</u> 1 Cover Loading Summary

Roof Structural Calculations for PV Solar Installation Roof Structural Calculations for PV Solar Installation

5-7 Location: MP 1 8-10 Location: MP 2 11-11 **Snow Loading Calculations**

Project Number: 36.114630, Rev. 0 Report Date: 06/03/2024 Report Prepared by:



Richard Pantel, P.E. NC License No. 43326 Sealed 06/03/2024



Truss FEA Calculations

Digitally signed by Richard Pantel DN: c=US, o=TECTONICORP PC, 26E0001A3B4, cn=Richard Pantel Date: 2024.06.03 17:06:55 -04'00'

12-15

Loading Summary

Exposure and Occupancy Categories							
В	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	117	mph	ASCE 7-10, Figure 26.5-1 A, B or C, pp 249-251. [(117 mph, 50			
V	117	Πρπ	year wind MRI)]			
qz	20.76	psf	Velocity qz, calculated at height z [ASD]			

Snow Loading							
pg	pg 10.00 psf Ground Snow Load pg (ASCE 7-10 Table 7.2-1, Page 52-53)						
Total Snow	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 Sum	Module Loading Summary				
Support Point Loads		Upward	Upward	Upward	Downward
Roof Zones		1	2	3	All
Net load per module	lb	-271	-366	-366	295

Positive values indicate net downward force

Stand	Stanchion Fastener Pull-out and Spacing Calculation								
Framing spacing	ft	2.00							
Rails / Module			ea	2					
Max proposed stanchi	on span		ft	6.00					
# fasteners per stanch		1							
Bolt thread embedmer	nt depth		in	3					
Safety Factor				1.10					
Pull-out for 5/16 thread	ded fastene	rs	lb/in	220					
Factored max fastener	Factored max fastener uplift capacity								
Fastener details	Size	5/16	Predrill						
Max stanchion uplift ca	lb	618							
Max support point uplit	lb	599	1						

Predrill hole 0.16" dia or use self tapping

Roof Zones		1	2	3
Net lift per module	lb	271	366	366
Min tot bolt thread embedment depth rq'd	in	1.36	1.83	1.83
Net uplift pressure 7. 0.6D - 0.6W	psf	-7.23	-9.75	-9.75
Allowable lift area / support point	sf	82.85	61.42	61.42
Max rail span per framing spacing	ft	6.00	6.00	6.00
Landscape Modules				
Length along rafter	ft	3.46		
Lift calc'ed max stanchion EW spacing	ft	> 6	> 6	> 6
Max stanchion EW spacing	ft	6.00	6.00	6.00
Maximum module area / support point	sf	10.37	10.37	10.37
Factored lift per support point	lb	-75	-101	-101
Portrait Modules				
Length along rafter	ft	6.26		
Lift calc'ed max stanchion EW spacing	ft	> 6	> 6	> 6
Max stanchion EW spacing	ft	6.00	6.00	6.00
Maximum module area / support point	sf	18.77	18.77	18.77
Factored lift per support point	lb	-136	-183	-183

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 Lee Osterhout, located at 42 Oakland Drive Sanford Nc 27332, Sanford, 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 05/16/2024. 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 06/03/2024, 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 = 24.00 inches.



Google Location Map

Framing Summary

	Ex. Framing	TOTAL EX DL
MP 1: Truss @ 24" OC	0.79 psf	5.19 psf
MP 2: 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 roofs' framing systems are 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.	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.	28.00	Length of roof plane, in feet (meters)			
W	ft.	18.50	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 = 3.00 ft						

Wind Velocity Pressure, q_z evaluated at the height z									
$q_z =$	q_z = 20.76 psf Vasd q_z = 12.61 psf Basic wind pressure								
V=	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	22.50				

3	# Rafters / Rack Support Width
6.00	Rack Support Spacing (ft)
72	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 P	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 mem	bers' self weight added to FEA analy		

Rack Support Spacing					
Across rafters	ft	6.0			
Along rafter slope	ft	6.3			
Area / support point	sf	18.8			
Uphill gap between modules	in	1.0	0.08	ft	

Member To	otal Length	ft	22.50				
Maximum ı	Maximum member free span		22.50	Truss top cho	ord span		
	Zones	1	2	3		Downward, Z	ones 1, 2 & 3
	GCp	-0.93	-1.13	-1.13		GCp	0.87

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	Module	Module	Downward			
2.2 STIVIDOLS AND NOTATION	Upward	Upward	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 = (Vu Windload) = (Vasd Windload / 0.6)	-19.61	-23.82	-23.82	18.22			

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	12.38	12.38	12.38	18.08	
Module Support point load (lb)	232	232	232	339	
Cr Factored Module Support point load (lb)	202	202	202	295	

Use this loading combination for UPWARD for Proposed PV Dead Load						
7. 0.6D - 0.6W	-7.23	-9.75	-9.75	4.54		
Module Support point load (lb)	-136	-183	-183	85		

DOWNWARD

Presume loading directly over member.

		Combined	Dead and	Wind Pressure Downward Loading	
	Trus	s 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	0.25		295		Portrait
1	6.51			Support placed on adjoining truss	Portrait
2	6.59			Support placed on adjoining truss	Portrait
2	12.85		295		Portrait
3	12.93		295		Portrait
3	19.19			Support placed on adjoining truss	Portrait

Truss Data and Loading for MP 1

Roof slope (degrees)	34.00
Top ridge height above floor plane	12.58

Length of roof plane	22.50
Length of floor plane	18.50

Truss Segments							
Roof	Plane	Floor Plane					
Mem #	Mem Type	Mem #	Mem Type		N		
1	2x4	3	2x4				
2	2x4	4	2x4				

М3

6

8

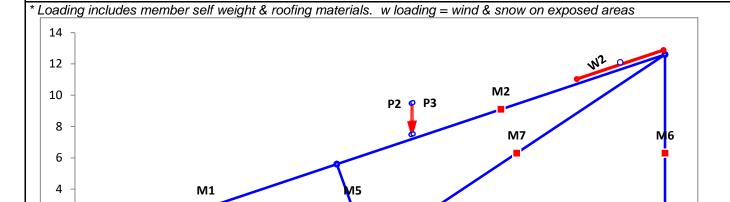
_					
	Diago	onals	Diagonals		
ı	Mem # Mem Type		Mem #	Мет Туре	
	5	2x4	7	2x4	
	6	6 2x4			

M4

14

16

18



10

12

2

-2

Location: MP 2

Member: Truss - Total Length 11 ft, Unsupported 11 ft

Geometric Data						
θ	Angle of roof plane from horizontal, in degrees					
ω <i>deg.</i> 0.00			Angle the solar panel makes with the roof surface			
L	ft.	24.00	Length of roof plane, in feet (meters)			
W ft. 9.00		9.00	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 =	3.00	ft		

Wind Velocity Pressure, q_z evaluated at the height z								
$q_z =$	20.76	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	11.00			

3	# Rafters / Rack Support Width
6.00	Rack Support Spacing (ft)
72	Max. Rack Support Spacing (in)
1	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 P	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 analys		

Rack Support Spacing					
Across rafters	ft	6.0			
Along rafter slope	ft	6.3			
Area / support point	sf	18.8			
Uphill gap between modules	in	1.0	0.08	ft	

						_	
Member Total Length		ft	11.00				
Maximum i	member free span	ft	11.00	Truss top chord span			
	Zones	1	2	3		Downward, Z	ones 1, 2 & 3
	GCp	-0.93	-1.13	-1.13		GCp	0.87

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	Module	Module	Downward			
2.2 STWIDGES AND NOTATION	Upward	Upward	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 = (Vu Windload) = (Vasd Windload / 0.6)	-19.61	-23.82	-23.82	18.22			

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	12.38	12.38	12.38	18.08		
Module Support point load (lb)	232	232	232	339		
Cr Factored Module Support point load (lb)	202	202	202	295		

Use this loading combination for UPWARD for Proposed PV Dead Load							
7. 0.6D - 0.6W	-7.23	-9.75	-9.75	4.54			
Module Support point load (lb)	-136	-183	-183	85			

DOWNWARD

Presume loading directly over member.

	Combined Dead and Wind Pressure Downward Loading								
	Trus	s 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	2.15		295		Portrait				
1	8.41			Support placed on adjoining truss	Portrait				

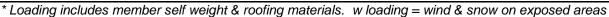
Truss Data and Loading for MP 2

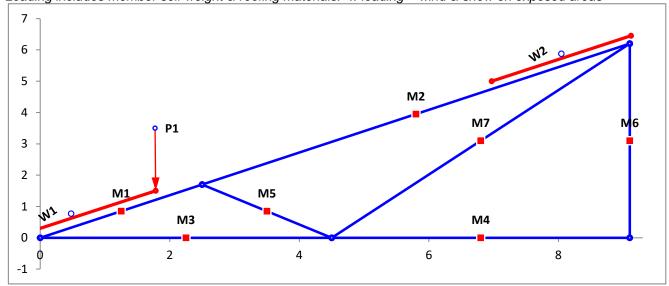
Roof slope (degrees)	34.00
Top ridge height above floor plane	6.15

Length of roof plane	11.00
Length of floor plane	9.00

Truss Segments							
Roof	Plane	Floor	· Plane				
Mem #	Mem Type	Mem #	Mem Type		N		
1	2x4	3	2x4				
2	2x4	4	2x4				

_							
	Diago	onals	Diagonals				
	Mem # Mem Type		Mem #	Мет Туре			
	5	2x4	7	2x4			
ı	6	2x4					





Snow Loading Analysis

where:

Fully Exposed Exposure category Exposure Factor, Ce (ASCE 7-10 Table 7.3-1, Page 58) Ce 0.9 Thermal Factor, Ct (ASCE 7-10 Table 7.3-2, Page 58) Ct 1.0 ls 1.0 Snow Importance Factor, Is (ASCE 7-10 Table 1.5-2, Page 5) Ground Snow Load pg (ASCE 7-10 Table 7.2-1, Page 52-53) 10.00 p_g 0.7CeCtIsPg Flat Roof Snow Load, pf (ASCE 7-10 Table 7.3-1, Page 58) 6.30 but where Pf is not less than the following: Minimum Snow Load pm (ASCE 7-10 Table 7.3.4, Page 53) 10.00 When $Pg \le 20 psf$, then use Pf = Pg x ls p_{m} 10.00 psf. Resultant Snow pressure to be used with Roof slope factor below Sloped Roof Snow Load ps (ASCE 7-10 Table 7.4, Page 54) p_s C_sp_f Roof Type Warm Roofs Roof slope factor Cs for Warm Roofs, where Ct = 1.0

Roof surface condition = Slippery Roof

Roof Slope Factor, Cs (ASCE 7-10 Table 7-2a, Page 59) $C_s =$

Total Snow Load

10.00 psf Roof snow load = p_s

FEA Calculation Results for Roof Plane MP 1 for Freedom Solar, LLC Client Lee Osterhout

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	2542
Total output reactions	0.00	-2542
Output error	6.69E-13	-1.36E-12

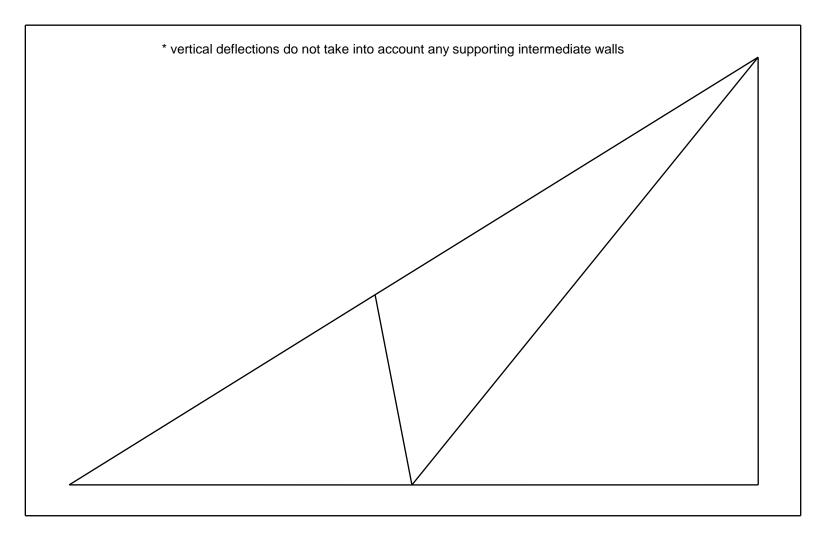
0.00011

	Shear	Mom	Ax		
Max (psi)	1	11	178		
Allowable (psi)	115	950	5,610	Maximum Deflections	
# of segme	1		-1.41E-03	-1.23E-03	
			-		

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

	Node Results			Bean	n End Res	ults
Direction	Deflection	Reaction	Beam	Shear	Axial	BM
DX1	0.00E+00	0	1-1	-1258	600	5720
DY1	0.00E+00	-1223	1-2	-890	352	-4480
RZ1	-4.01E-04	0	2-1	-1369	-360	-6927
DX2	-2.57E-04	0	2-2	-194	-1151	-18430
DY2	9.12E-04	0	3-1	155	206	-5720
RZ2	-1.63E-04	0	3-2	585	206	1268
DX3	-1.15E-03	0	4-1	-147	806	686
DY3	1.23E-03	0	4-2	-147	806	-691
RZ3	1.33E-03	0	5-1	-840	172	2337
DX4	1.30E-04	0	5-2	-844	150	-2447
DY4	9.16E-04	0	6-1	806	1466	-691
RZ4	-1.55E-04	0	6-2	806	1374	9461
DX5	6.43E-04	0	7-1	656	-449	-1755
DY5	0.00E+00	-1319	7-2	740	-561	8970
RZ5	-1.56E-04	0				

Beam	Χ	Shear	Mom	Axial	DX	DY	RZ
1	0.00	-1258	5720	600	0.00E+00	0.00E+00	-4.01E-04
1	10.01	-958	-4125	398	-2.70E-04	-9.03E-04	-3.35E-04
2	0.00	-1369	-6927	-360	-2.57E-04	-9.12E-04	-1.63E-04
2	12.54	-634	-11459	-855	-1.41E-03	-1.05E-03	-2.55E-03
3	0.00	155	-5720	206	0.00E+00	0.00E+00	-4.01E-04
3	9.30	509	1664	206	1.30E-04	-9.16E-04	2.66E-04
4	0.00	-147	686	806	1.30E-04	-9.16E-04	-1.55E-04
4	9.40	-147	-691	806	6.43E-04	0.00E+00	-1.70E-04
5	0.00	-840	2337	172	1.30E-04	-9.16E-04	-1.55E-04
5	5.69	-843	-2448	155	-2.57E-04	-9.12E-04	-2.44E-04
6	0.00	806	-691	1466	6.43E-04	0.00E+00	-1.56E-04
6	12.60	806	9461	1386	-1.15E-03	-1.23E-03	1.34E-03
7	0.00	656	-1755	-449	1.30E-04	-9.16E-04	-1.55E-04
7	15.72	730	8974	-548	-1.15E-03	-1.23E-03	1.35E-03



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

FEA Calculation Results for Roof Plane MP 2 for Freedom Solar, LLC Client Lee Osterhout

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	1101
Total output reactions	0.00	-1101
Output error	1.41E-12	-4.55E-13

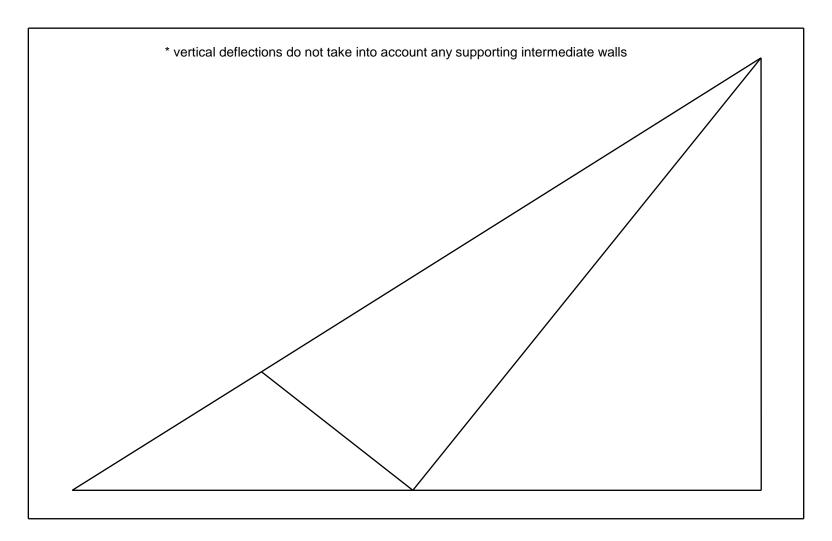
\sim	\sim	\sim	Λ	4
U	U	0	U	ч

	Shear	Mom	Ax		
Max (psi)	2	15	302		
Allowable (psi)	115	950	5,610	Maximum Deflections	
# of segments/beam		1		-8.37E-04	-2.65E-04

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

	Node Re	esults		Beam End Results		
Direction	Deflection	Reaction	Beam	Shear	Axial	BM
DX1	0.00E+00	0	1-1	-552	-208	694
DY1	0.00E+00	-344	1-2	-280	-393	-826
RZ1	1.26E-04	0	2-1	-2769	-739	502
DX2	-2.40E-04	0	2-2	-2233	-1104	-21045
DY2	2.65E-04	0	3-1	-5	483	-694
RZ2	1.30E-04	0	3-2	50	483	-811
DX3	-6.70E-04	0	4-1	420	1438	-524
DY3	1.38E-04	0	4-2	420	1438	1407
RZ3	1.10E-03	0	5-1	329	2495	466
DX4	1.47E-04	0	5-2	325	2491	1328
DY4	3.67E-05	0	6-1	1438	337	1407
RZ4	6.70E-05	0	6-2	1438	311	10324
DX5	5.95E-04	0	7-1	1480	-766	-753
DY5	0.00E+00	-757	7-2	1502	-796	10721
RZ5	1.22E-04	0				

Beam	Χ	Shear	Mom	Axial	DX	DY	RZ
1	0.00	-552	694	-208	0.00E+00	0.00E+00	1.26E-04
1	3.02	-299	-724	-380	-2.44E-04	-2.63E-04	-3.41E-05
2	0.00	-2769	502	-739	-2.40E-04	-2.65E-04	1.30E-04
2	7.99	-2508	-16656	-917	-8.37E-04	-2.43E-05	-2.60E-03
3	0.00	-5	-694	483	0.00E+00	0.00E+00	1.26E-04
3	4.50	14	-624	483	1.47E-04	-3.67E-05	1.89E-06
4	0.00	420	-524	1438	1.47E-04	-3.67E-05	6.70E-05
4	4.60	420	1407	1438	5.95E-04	0.00E+00	1.44E-04
5	0.00	329	466	2495	1.47E-04	-3.67E-05	6.70E-05
5	2.62	327	1327	2492	-2.40E-04	-2.65E-04	9.55E-05
6	0.00	1438	1407	337	5.95E-04	0.00E+00	1.22E-04
6	6.20	1438	10324	317	-6.70E-04	-1.38E-04	1.05E-03
7	0.00	1480	-753	-766	1.47E-04	-3.67E-05	6.70E-05
7	7.72	1498	10723	-790	-6.70E-04	-1.38E-04	1.12E-03
					· · · · · · · · · · · · · · · · · · ·		



Scaled 2X Deflected Truss Plot
Roof Plane MP 2 for Freedom Solar, LLC Client Lee Osterhout