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 Jurisdiction (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®.

iRooFA™

Instant Roof Framing Analysis

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 POWER

Freedom Solar, LLC

4801 Freidrich Ln, Ste 100 - Austin, TX 78744

Calculation Report Index

Pages	Description
1	Cover
	Roof Structural Calculations for PV Solar Installation
5-7	Location: MP 1
11-11	Snow Loading Calculations
12-15	Truss FEA Calculations
2-4	Loading Summary
	Roof Structural Calculations for PV Solar Installation
8-10	Location: MP 2

Project Number: 36.114630, Rev. 0

Report Date: 06/03/2024

Report Prepared by:

NORTH CAROLINA PROFESSIONAL SEAL 043326 ENGINEER RICHARD PANTEL

Richard Pantel, P.E.

NC License No. 43326

Sealed 06/03/2024

Richard Pantel

Digitally signed by Richard Pantel
DN: c=US, o=TECTONICORP PC, dnQualifier=A01410C0000018E57987 26E0001A3B4, cn=Richard Pantel
Date: 2024.06.03 17:06:55 -04'00'

V40522a
ID.L1W7

iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

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

Snow Loading			
pg	10.00	*psf*	*Ground Snow Load pg (ASCE 7-10 Table 7.2-1, Page 52-53)*
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 Summary		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

Stanchion Fastener Pull-out and Spacing Calculations				
Framing spacing			*ft*	2.00
Rails / Module			*ea*	2
Max proposed stanchion span			*ft*	6.00
# 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
Max stanchion uplift capacity			*lb*	618
Max support point uplift capacity			*lb*	599

Predrill hole 0.16" dia or use self tapping

 iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

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.

 iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

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.*

 iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

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=	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*	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 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 analysis*

Rack Support Spacing and Loading				
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*	22.50		
Maximum member free span	*ft*	22.50	Truss top chord span	

Zones	1	2	3	Downward, Zones 1, 2 & 3
GCp	-0.93	-1.13	-1.13	GCp 0.87

iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

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	2.38	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					
	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	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

iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

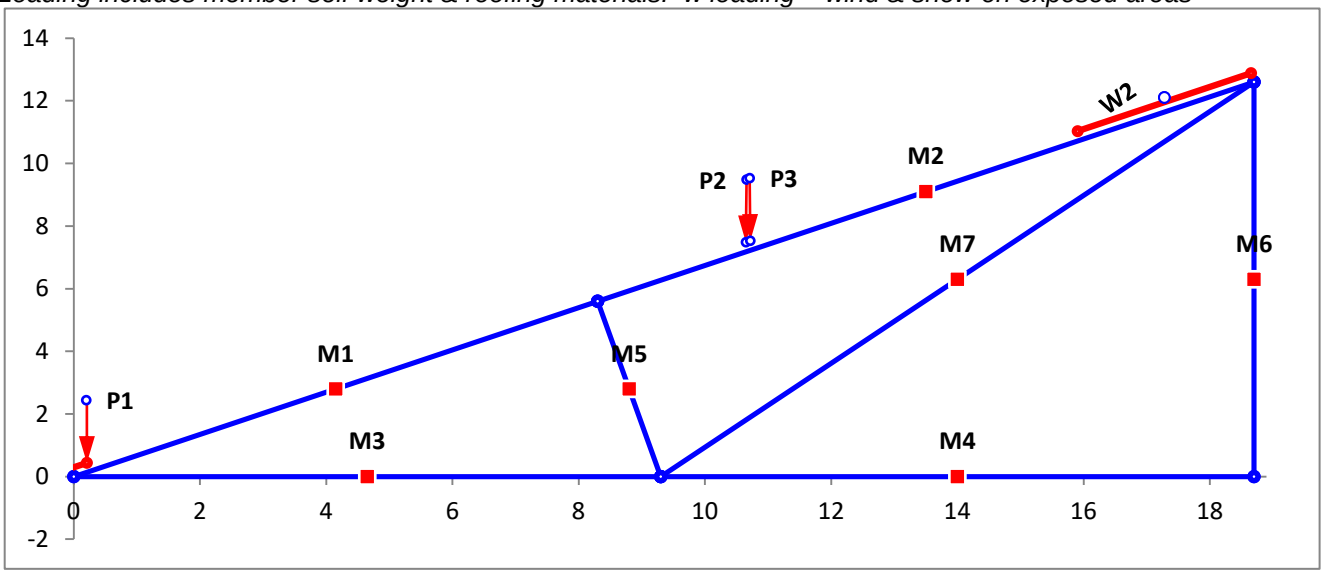
Truss Data and Loading for MP 1

Roof slope (degrees)	34.00			Length of roof plane	22.50
Top ridge height above floor plane	12.58			Length of floor plane	18.50

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*



iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

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.*	24.00	*Length of roof plane, in feet (meters)*
W	*ft.*	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 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 analysis*

Rack Support Spacing and Loading				
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 member free span	*ft*	11.00	Truss top chord span

Zones	1	2	3	Downward, Zones 1, 2 & 3
GCp	-0.93	-1.13	-1.13	GCp 0.87

iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

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	2.38	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					
	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	2.15		295		Portrait
1	8.41			Support placed on adjoining truss	Portrait

iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

Truss Data and Loading for MP 2

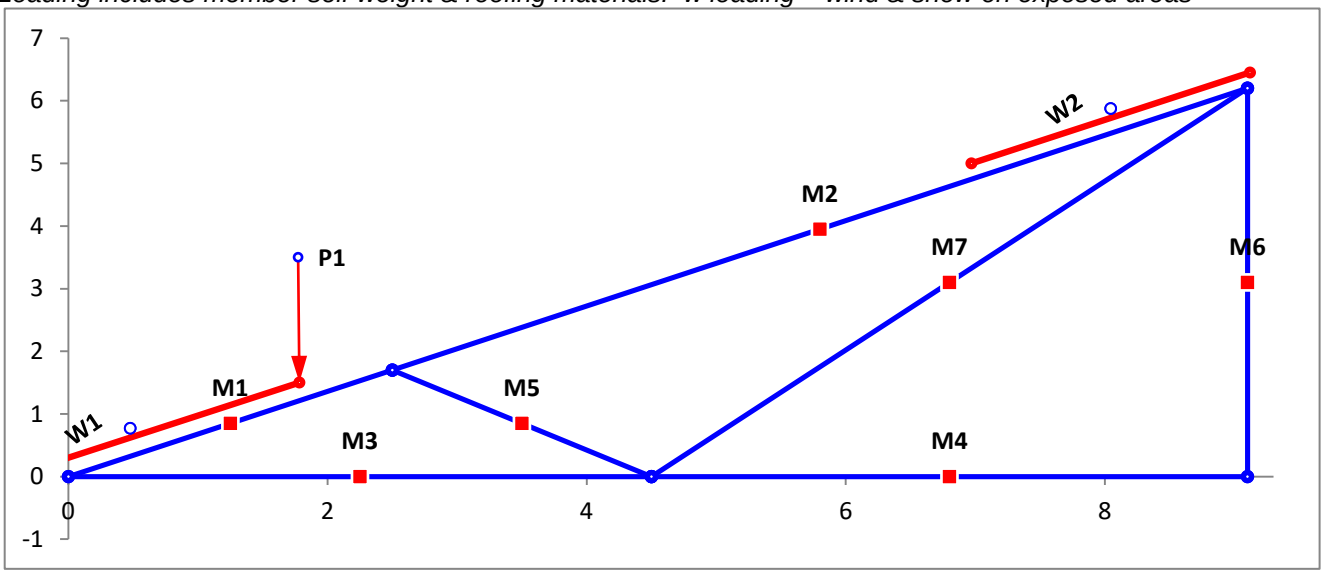
Roof slope (degrees)	34.00
Top ridge height above floor plane	6.15

	Length of roof plane	11.00
	Length of floor plane	9.00

Truss Segments

Roof Plane		*Floor Plane*		*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*



iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

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	=	10.00	Ground Snow Load pg (ASCE 7-10 Table 7.2-1, Page 52-53)

p_f = **0.7CeCtIsPg** Flat Roof Snow Load, pf (ASCE 7-10 Table 7.3-1, Page 58)

p_f = **6.30** 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 = **10.00** When Pg <=20 psf, then use Pf = Pg x Is

p_f = **10.00** 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	=	**10.00**	**psf**	Roof snow load

iRooFA® Copyright © 2020-2024 Richard Pantel. All Rights Reserved.

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

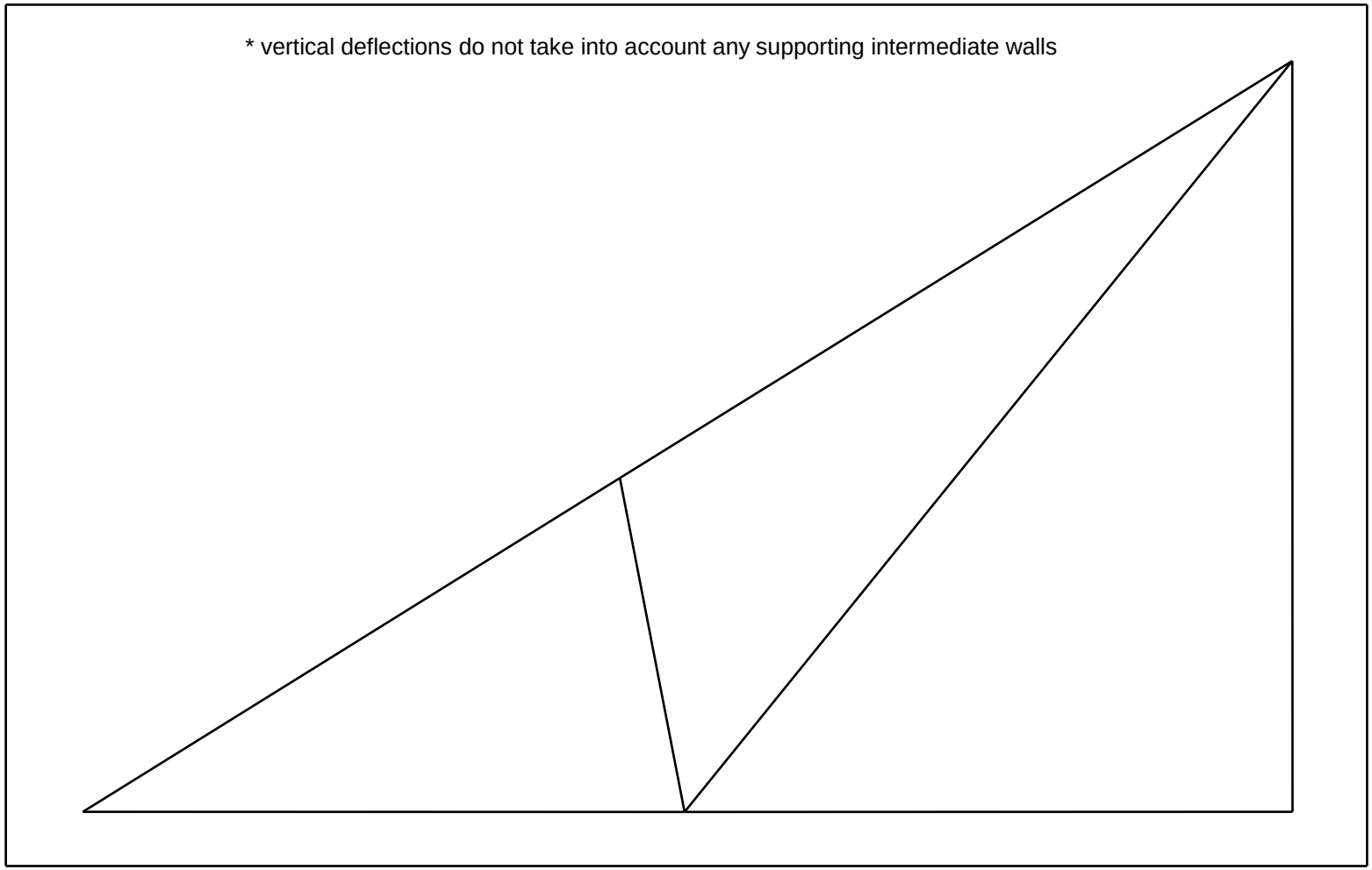
Equilibrium check	FX	FY	0.00011
Total applied forces	0.00	2542	
Total output reactions	0.00	-2542	
Output error	6.69E-13	-1.36E-12	

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

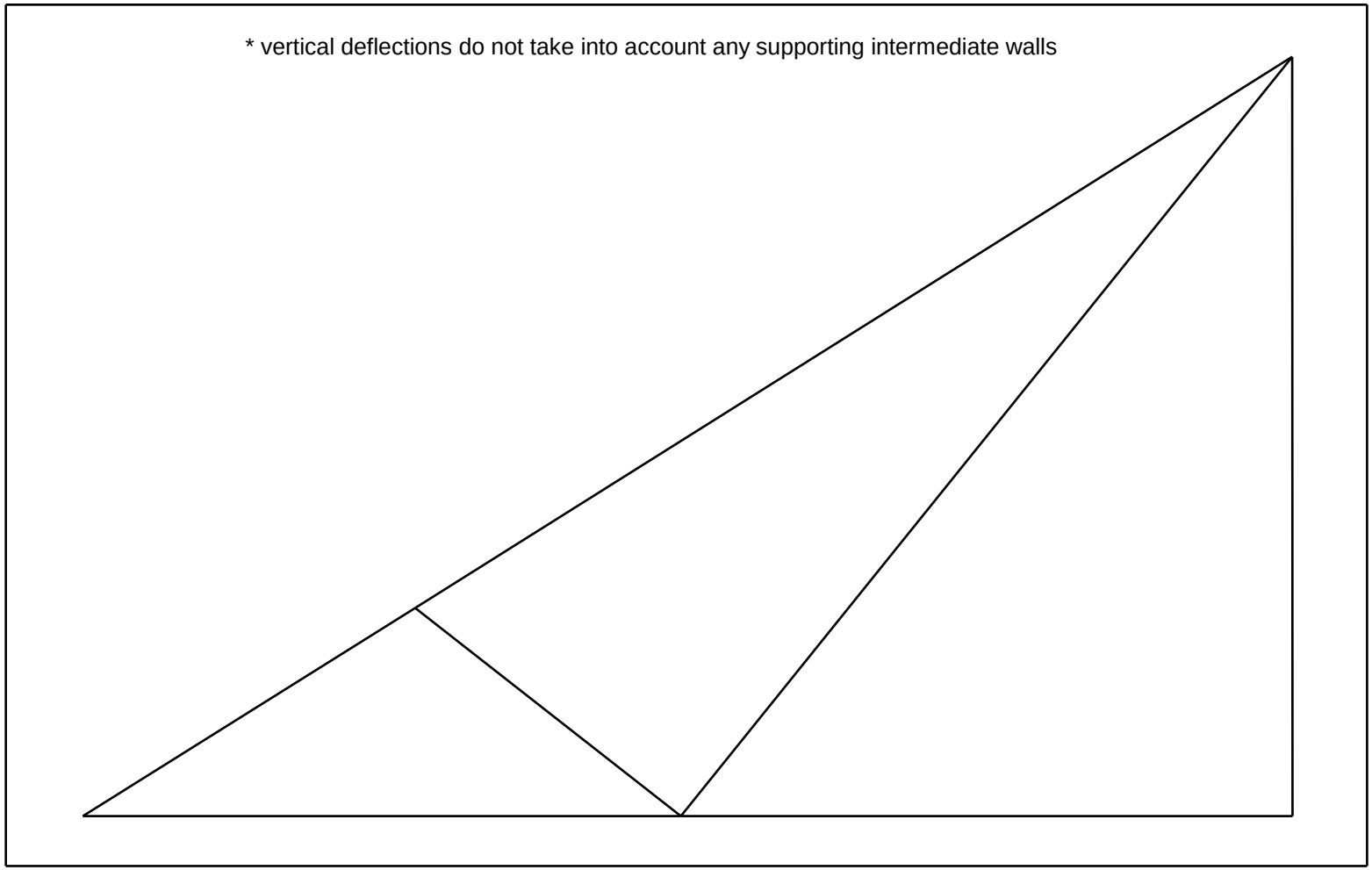
0.0001

	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 Results			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	X	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