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Columbia County Building Department — Plans Reviewed for Code Compliance — State of Florida

STRUCTURAL ANALYSIS

for the

ROOFTOP PV SOLAR INSTALLATION

Project: Abdelrahman Abuayyash, 223 Se Victoria Glen, Lake City, FL 32025

Prepared for:

sunergy

Sunergy

7625 Little Rd Ste 200a - New Port Richey, FL 34654

Calculation Report Index

Project Number: 66.400399.1, Rev. 0

Report Date: 11/08/2023

Report Prepared by:

This item has been digitally signed and sealed by Richard Pantel, P.E. on the date adjacent to the seal. Printed copies of this document are not considered signed and sealed and the signature must be verified on any electronic copies.

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Sealed 11/08/2023

Richard Pantel

Digitally signed by Richard Pantel DN: c=US, st=Virginia, l=Round Hill, o=TectoniCorp, P.C., cn=Richard Pantel email=rpantel@princeton-engineering.com Date: 2023.11.08 21:58:18 +00:00

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	165	*mph*	*Over-ridden per client request. Original data from Municipality provided wind / snow loadings.*
qz	41.47	*psf*	*Velocity qz, calculated at height z [ASD]*

Snow Loading			
pg	0	*psf*	*Ground Snow Load pg (Over-ridden per client request. Original data from Municipality provided wind / snow loadings.)*

Module Data			
Mission Solar Energy LLC: MSE385SX5R			
Dimensions	*mm*	*ft*	*in*
Length	1,905	6.25	75.00
Width	1,041	3.42	41.00
Area (m^2, ft^2)	2.0	21.35	
Weight	kg	lb	
Module	22.23	49.00	

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 load per module	*lb*	-442	-688	-788	100

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*	4.00	
# fasteners per stanchion		2	
Screw thread embedment depth	*in*	2	
Safety Factor		1.10	
Pull-out for M5 threaded fasteners	*lb/in*	103	
Factored max fastener uplift capacity	*lb*	376	
Fastener details *Material* Stainless	*Size*	M5	
Max stanchion uplift capacity	*lb*	400	
Max support point uplift capacity	*lb*	376	

Roof Zones		*1,2e*	*2n,2r,3e*	*3r*
Net lift per module	*lb*	442	688	788
Min tot screw thread embedment depth rq'd	*in*	2.35	3.66	4.19
Net uplift pressure 7. 0.60D - 0.6W	*psf*	-17.69	-27.53	-31.51
Allowable lift area / support point	*sf*	21.27	13.67	11.94
Max rail span per framing spacing	*ft*	4.00	4.00	4.00
Landscape Modules				
Length along rafter	*ft*	3.42		
Lift calc'ed max stanchion EW spacing	*ft*	> 6	6.00	6.00
Max stanchion EW spacing	*ft*	4.00	4.00	4.00
Maximum module area / support point	*sf*	6.83	6.83	6.83
Factored lift per support point	*lb*	-121	-188	-215
Portrait Modules				
Length along rafter	*ft*	6.25		
Lift calc'ed max stanchion EW spacing	*ft*	6.00	4.00	2.00
Max stanchion EW spacing	*ft*	4.00	4.00	2.00
Maximum module area / support point	*sf*	12.50	12.50	6.25
Factored lift per support point	*lb*	-221	-344	-197

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

Princeton Engineering was asked to review the roof of Abdelrahman Abuayyash, located at 223 Se Victoria Glen, Lake City, FL, by Sunergy, to determine its suitability to support a PV solar system installation.

The referenced building's roof structure was field measured by Sunergy. 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 Sunergy. Loads are calculated to combine the existing building and environmental loads with the proposed new PV array loads.

Sunergy selected the K2-Systems CrossRail 44-X racking with K2-Systems Splice Foot XL w/2 bolts stanchions for this project. The racking and support stanchions shall be placed as shown on their plans, dated 11/08/2023, 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 and in accordance with the FBC 2020 Section R324.4 and the FBC's reference to IRC 2018 Section 1607.12.5.2, 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 7-16 Minimum Design Loads for Buildings and Other Structures*
2) *IBC 2018*
3) *FBC 2020*
4) *2022 Florida Statues and 2023 Florida Administrative Codes*
5) *American Wood Council, NDS 2018,Table 12.2A, 12.3.3A.*
6) *American Wood Council, Wood Structural Design, 1992, Figure 6.*

Location: MP 1

Member: Truss - Total Length 19.67 ft, Unsupported 19.67 ft

Geometric Data			
Θ	*deg.*	22.00	*Angle of roof plane from horizontal, in degrees*
ω	*deg.*	0.00	*Angle the solar panel makes with the roof surface*
L	*ft.*	51.67	*Length of roof plane, in feet (meters)*
W	*ft.*	18.67	*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=	41.47	*psf*	*Vasd* q_z=	24.96	*psf*	Basic wind pressure
V=	165	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*	19.67

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	22.23	49.00	2.29
4 Stanchions	1.27	2.8	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*	6.3		
Area / support point	*sf*	12.5		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	19.67	
Maximum member free span	*ft*	19.67	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

Min.d1: Exposed	**FALSE**
Max.d1: Exposed	**TRUE**
1.5(Lp) =	5.13
γE =	1.5
γa =	0.67

Use EXPOSED for uplift calculations

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

Zones	1,2e	2n,2r,3e	3r
p, Windload (psf)	-37.09	-53.49	-60.12

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	2.43	2.43	2.43	2.43
W = wind load	-37.09	-53.49	-60.12	11.32

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				
5. D - 0.6W	2.43	2.43	2.43	9.22
Module Support point load (lb)	30	30	30	115
Cr Factored Module Support point load (lb)	26	26	26	100

Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.60D - 0.6W	-17.69	-27.53	-31.51	7.61
Module Support point load (lb)	-221	-344	-394	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	0.42		100		Portrait
1	6.67			Support placed on adjoining truss	Portrait
2	6.75			Support placed on adjoining truss	Portrait
2	13.00		100		Portrait
3	13.09		100		Portrait
3	19.34			Support placed on adjoining truss	Portrait

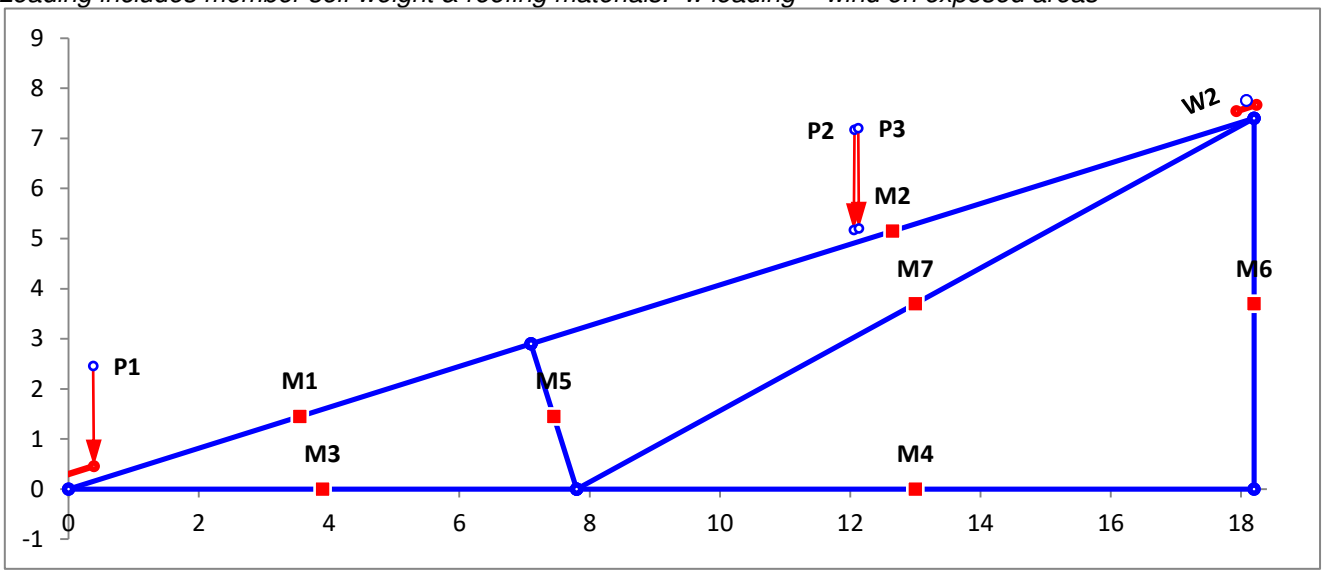
Truss Data and Loading for MP 1

Roof slope (degrees)	22.00		Length of roof plane	19.67
Top ridge height above floor plane	7.37		Length of floor plane	18.25

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 on exposed areas*



Location: MP 2

Member: Truss - Total Length 15.25 ft, Unsupported 15.25 ft

Geometric Data			
Θ	*deg.*	22.00	*Angle of roof plane from horizontal, in degrees*
ω	*deg.*	0.00	*Angle the solar panel makes with the roof surface*
L	*ft.*	49.92	*Length of roof plane, in feet (meters)*
W	*ft.*	16.25	*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=	41.47	*psf*	*Vasd* q_z=	24.96	*psf*	Basic wind pressure
V=	165	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*	15.25

2	# Rafters / Rack Support Width
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Member Properties		**Member**
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Weight	kg	lb	psf load
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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*	12.5		
Uphill gap between modules	*in*	1.0	0.08	*ft*

Member Total Length	*ft*	15.25	
Maximum member free span	*ft*	15.25	Top truss chord span

ASCE 7-16 Method for Calculating Uplift on PV Modules

Notation
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Use this loading combination for UPWARD for Proposed PV Dead Load				
7. 0.60D - 0.6W	-17.69	-27.53	-31.51	7.61
Module Support point load (lb)	-221	-344	-394	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	0.42		100		Portrait
1	6.67			Support placed on adjoining truss	Portrait
2	6.75			Support placed on adjoining truss	Portrait
2	13.00		100		Portrait

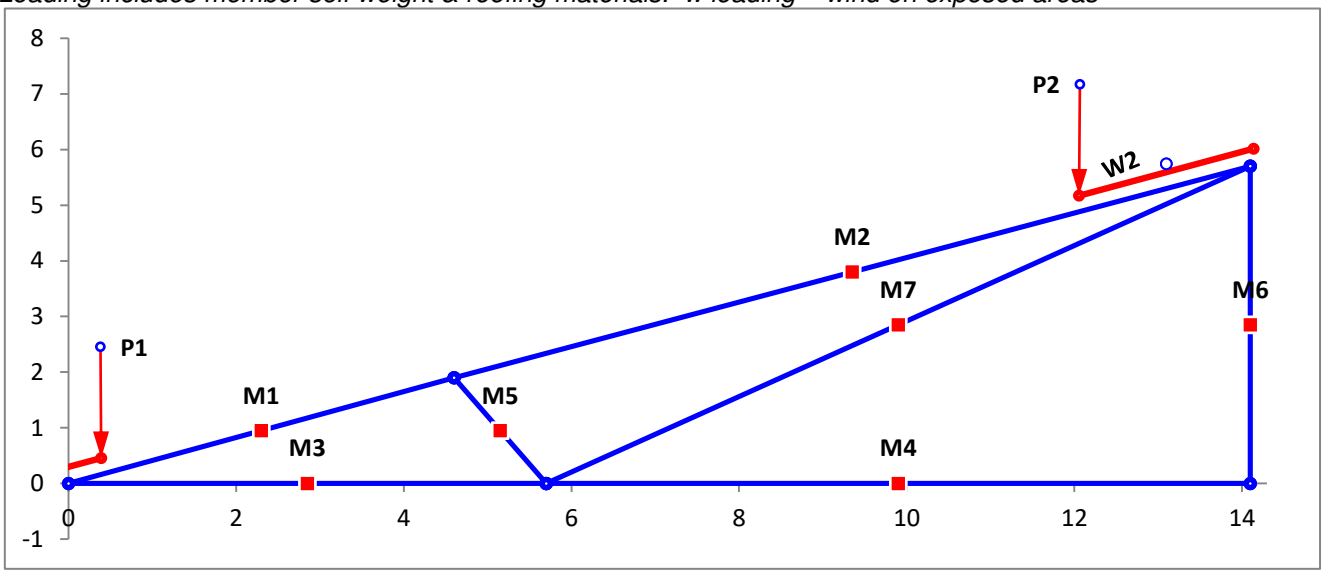
Truss Data and Loading for MP 2

Roof slope (degrees)	22.00		Length of roof plane	15.25
Top ridge height above floor plane	5.71		Length of floor plane	14.17

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 on exposed areas*



FEA Calculation Results for Roof Plane MP 1 for Sunergy Client ABDELRAHMAN ABUAYYASH

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	1416
Total output reactions	0.00	-1416
Output error	1.07E-14	-6.82E-13

1.6E-05

# of segments/beam	1

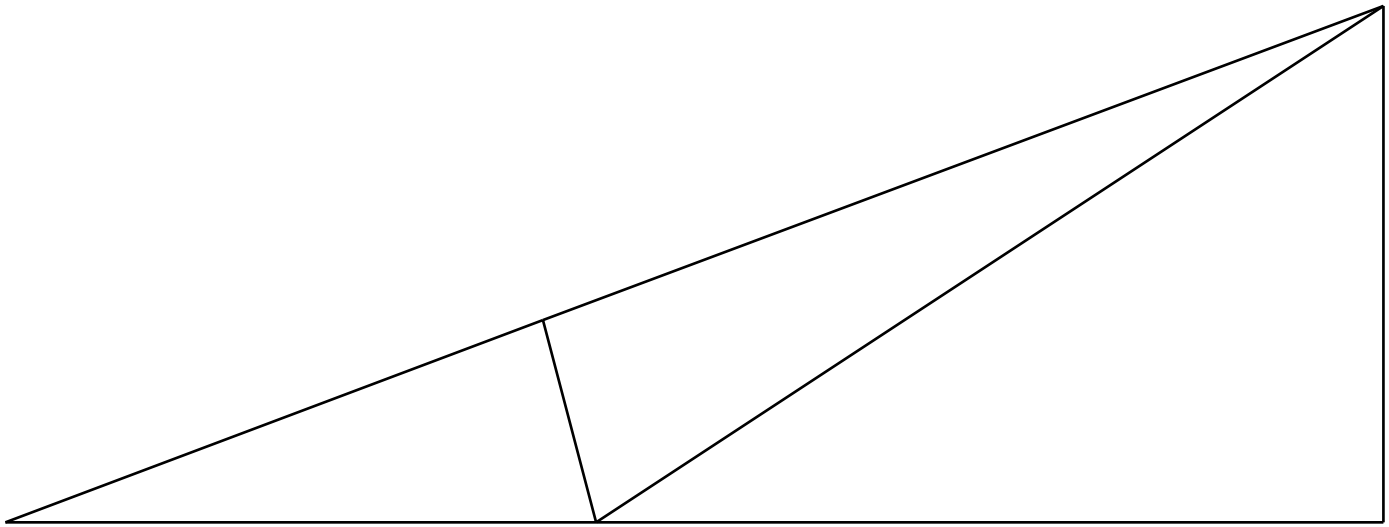
Maximum Deflections	
1.45E-04	-1.07E-04

** 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	-39	1-1	-480	238	1235
DY1	0.00E+00	-583	1-2	-290	160	-1841
RZ1	-1.55E-04	0	2-1	-523	105	-2528
DX2	1.37E-04	0	2-2	281	-221	-4899
DY2	1.07E-04	0	3-1	-49	0	-1235
RZ2	-1.73E-04	0	3-2	158	0	-250
DX3	1.45E-04	0	4-1	0	0	0
DY3	0.00E+00	-387	4-2	0	0	0
RZ3	0.00E+00	-4705	5-1	-86	229	-429
DX4	0.00E+00	64	5-2	-88	222	-687
DY4	0.00E+00	-435	6-1	25	10	-92
RZ4	0.00E+00	145	6-2	25	-25	92
DX5	0.00E+00	-25	7-1	-18	104	34
DY5	0.00E+00	-10	7-2	58	49	102
RZ5	0.00E+00	92				

Beam	X	Shear	Mom	Ax	DX	DY	RZ
1	0.00	-480	1235	238	0.00E+00	0.00E+00	-1.55E-04
1	7.67	-347	-1541	184	1.25E-04	-1.02E-04	-4.11E-04
2	0.00	-523	-2528	105	1.37E-04	-1.07E-04	-1.73E-04
2	11.98	-15	-2538	-101	5.04E-05	3.83E-05	-1.79E-03
3	0.00	-49	-1235	0	0.00E+00	0.00E+00	-1.55E-04
3	7.80	95	80	0	0.00E+00	-4.91E-20	-2.41E-05
4	0.00	0	0	0	0.00E+00	0.00E+00	0.00E+00
4	10.40	0	0	0	0.00E+00	0.00E+00	0.00E+00
5	0.00	-86	-429	229	0.00E+00	0.00E+00	0.00E+00
5	2.98	-87	-687	224	1.37E-04	-1.07E-04	-1.29E-04
6	0.00	25	-92	10	0.00E+00	0.00E+00	0.00E+00
6	7.40	25	92	-18	1.45E-04	3.81E-07	3.85E-06
7	0.00	-18	34	104	0.00E+00	0.00E+00	0.00E+00
7	12.76	48	107	56	1.44E-04	2.24E-07	-4.35E-07

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



Scaled 2X Deflected Truss Plot
Roof Plane MP 1 for Sunergy Client ABDELRAHMAN ABUAYYASH

FEA Calculation Results for Roof Plane MP 2 for Sunergy Client ABDELRAHMAN ABUAYYASH

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	1004
Total output reactions	0.00	-1004
Output error	-4.97E-14	-3.41E-13

1.7E-05

# of segments/beam	1

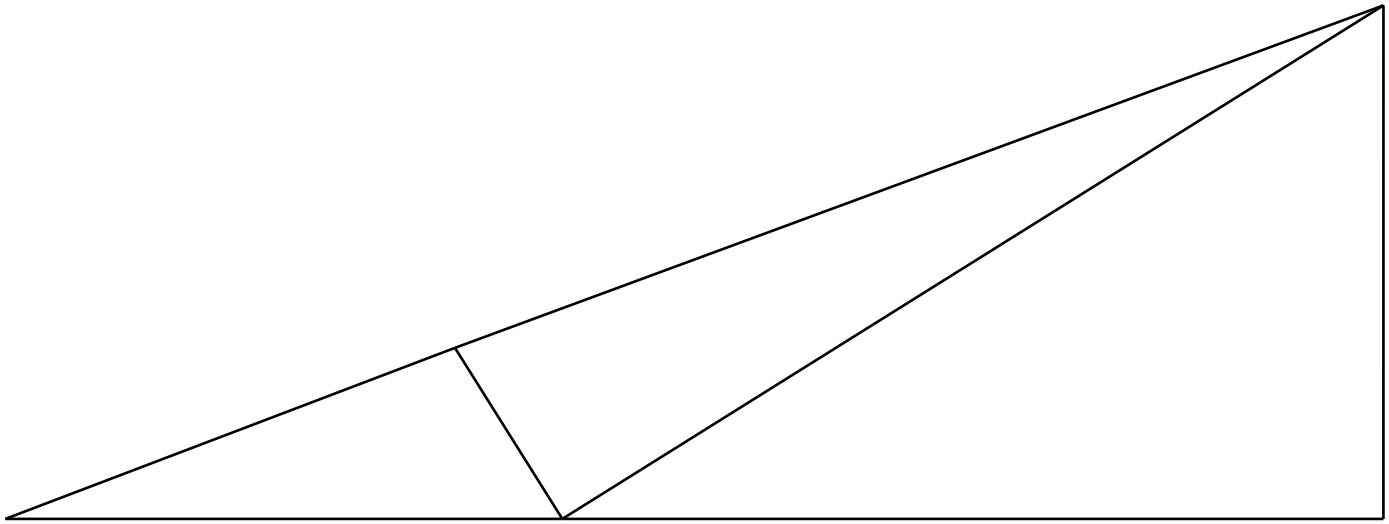
Maximum Deflections	
1.14E-04	-1.17E-04

** 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	-32	1-1	-335	173	59
DY1	0.00E+00	-524	1-2	-186	112	-1277
RZ1	1.45E-04	0	2-1	-547	101	-1446
DX2	3.49E-05	0	2-2	87	-153	-5154
DY2	1.17E-04	0	3-1	-148	0	-59
RZ2	-4.99E-05	0	3-2	-76	0	-1003
DX3	1.14E-04	0	4-1	0	0	0
DY3	0.00E+00	-153	4-2	0	0	0
RZ3	0.00E+00	-4994	5-1	46	361	-267
DX4	0.00E+00	66	5-2	43	357	-168
DY4	0.00E+00	-322	6-1	34	6	-96
RZ4	0.00E+00	-739	6-2	34	-16	96
DX5	0.00E+00	-34	7-1	-9	98	4
DY5	0.00E+00	-6	7-2	42	63	64
RZ5	0.00E+00	96				

Beam	X	Shear	Mom	Ax	DX	DY	RZ
1	0.00	-335	59	173	0.00E+00	0.00E+00	1.45E-04
1	4.98	-222	-1086	126	2.72E-05	-1.14E-04	-2.43E-04
2	0.00	-547	-1446	101	3.49E-05	-1.17E-04	-4.99E-05
2	10.23	-158	-3177	-54	3.57E-05	3.13E-05	-1.66E-03
3	0.00	-148	-59	0	0.00E+00	0.00E+00	1.45E-04
3	5.70	-121	-764	0	0.00E+00	7.62E-21	-1.94E-04
4	0.00	0	0	0	0.00E+00	0.00E+00	0.00E+00
4	8.40	0	0	0	0.00E+00	0.00E+00	0.00E+00
5	0.00	46	-267	361	0.00E+00	0.00E+00	0.00E+00
5	2.20	44	-169	359	3.50E-05	-1.17E-04	-1.23E-05
6	0.00	34	-96	6	0.00E+00	0.00E+00	0.00E+00
6	5.70	34	96	-11	1.14E-04	2.91E-07	5.21E-06
7	0.00	-9	4	98	0.00E+00	0.00E+00	0.00E+00
7	10.15	34	68	68	1.14E-04	1.66E-07	8.65E-08

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



Scaled 2X Deflected Truss Plot
Roof Plane MP 2 for Sunergy Client ABDELRAHMAN ABUAYYASH