

January 17, 2022

Power Home Solar and Roofing
919 North Main Street
Mooresville, North Carolina, 28115

Design Criteria:

Wind Speed (ASD)- 116.0 mph
Ground Snow Load- 15.0 psf
Risk Category- 2
Exposure Category- C

RE: Structural Roof Evaluation for the Elizabeth Bohle Residence: 12804 NC-27, Broadway, North Carolina

We have evaluated the roof structure under the proposed solar panel array. The information used to evaluate this structure was gathered during a field visit by Power Home Solar and Roofing on behalf of Right Angle Engineering. The design criteria used to analyze this structure are listed above and included with this letter. The adopted building codes in this jurisdiction are: The 2018 North Carolina Residential Building code and ASCE 7-16.

Array Name	Panel Quantity	Connection Type	Min # Connections	Reinforcements
Array 1	8	L-Foot	12	None
Array 2	6	L-Foot	13	None

Solar Panel Anchorage

The solar panel anchorage shall be installed according to the manufactures most current installation manual. For the loads to be evenly distributed, the roof attachments should be staggered and spread evenly throughout the panel array. Attachment points should be spaced at a maximum of 48 inches on center. Roof anchors that are attached to the substructure should have a 5/16" or 18/8 SS lag screw with 2.5" minimum penetration centered on each truss top chord or rafter.

Conclusion

Based on our assessment, we have determined that the existing roof framing will safely and adequately support the additional loads imposed by the solar panels without reinforcement. The equipment will not create a negative impact on the building's structural design, including any additional loads imposed (dead, snow, wind/seismic). A roof evaluation was performed with the required loading in accordance with section 324.4 of the Residential Code

Regards,



01/17/2022

Robert D. Smythe, P.E.
Right Angle Engineering

Scope of work and limitations

The evaluation is based on information provided by the client. All information is verified by the engineer from pictures, video, and third party software. Verification of the field observations is the responsibility of the contractor. The contractor shall verify the framing sizes, spacing, spans, and roof pitch noted in this letter and/or sealed plans. The contractor shall notify the engineer if there are any discrepancies, or if there is any damage to the structure (i.e., fire damage, water damage, dry rot, deflections, broken member, broken connection, etc). The scope of work is strictly limited to the fastener attachments and underlying roof framing directly under each solar array. Right Angle Engineering assumes no responsibility for improper installation of solar panels or their components. Waterproofing around the roof penetrations is the responsibility of others. Alterations to this engineering evaluation and/or sealed plans shall not be made without direct written consent of the engineer of record.

Design Criteria

Design Wind Speed	116.0	mph
Exposure Category	C	
Risk Category	2	
Mean Roof Height	30	ft
Roof Type	Gable Roof	
Building Type	Enclosed	

Roof Dead Load

Asphalt Shingles	2.0	psf
5/8" Plywood Sheathing	2.0	psf
Insulation	1.2	psf
Roof Framing	1.1	psf
1/2" Gypsum Sheathing	2.2	psf
Solar Panel Array	2.39	psf
Dead Load Without Panels	8.5	psf
Dead Load With Panels	10.89	psf

Roof Live Load

Existing Roof Live Load	20	psf	ASCE 7-16 Table 4.3-1
Roof Live Load with Solar Panels	0.0	psf	

Roof Snow Load-ASCE 7-16

Ground Snow Load(p_g)	15.0	psf	Section 7.2
Exposure Factor (C_e)	0.9		Table 7.3-1
Thermal Factor (C_t)	1.1		Table 7.3-2
Importance Factor (I_s)	1		Table 1.5-2
Flat Roof Snow Load (P_f)	10.4		Equation 7.3-1
Slippery Surface Slope Factor (C_s)	0.66		Figure 7.4-1
Non-Slippery Surface Slope Factor (C_s)	1	psf	Figure 7.4-1
Roof Snow Load	10.4	psf	Equation 7.4-1
Reduced Snow Load (Slippery Surface)	6.88	psf	Equation 7.4-1

Array Name - Array 1

Roof Slope	30.26	degrees
Number of panels	8	
Panel Area	140.66	ft ²

Wind Calculations - ASCE 7-16

GCp Zone 2	-1.8		Figure 30.3-(2A-5B)
Gcpi	-0.18		Table 26.13-1
kh	0.98		Table 26.10-1
kht	1		Equation 26.8-1
kd	0.85		Table 26.6-1
Velocity Pressure	28.2	psf	Equation 26.10-1
Zone 2 Pressure	-45.69	psf	Equation 30.7-1

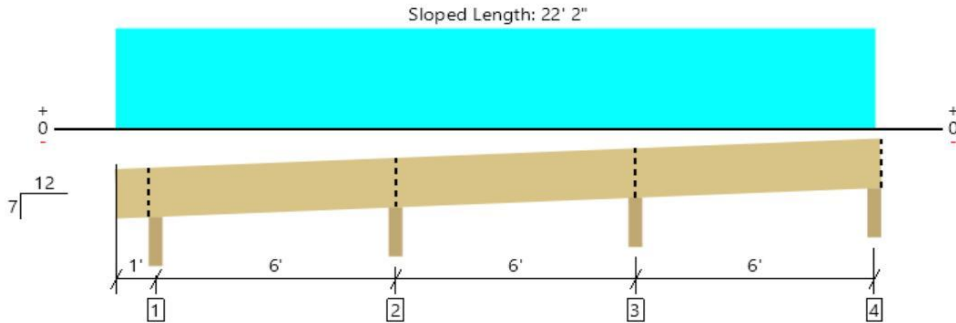
Roof Connection

Shear Capacity	190.0	lbs	NDS 2015 Table 12k
Pullout capacity	266.0	lbs/in	
Minimum # of connections	12		
Lag screw embedment	2.5	in	
Total pullout capacity	665.0	in	

Beam Stress

Beam Span	72, 72, 72	in	
Spacing	24.0	in	
Roof Framing type	2x4 Trusses DF#2		
Panel orientation	Portrait		
Number of panels per rafter	1		
Panel distance from eave	48.0	in	
Shear without Panels	191	lbs	see attached analysis
Shear with Panels	208	lbs	see attached analysis
Shear percent increase	109.0		
Bending Moment without Panels	226	ft-lbs	see attached analysis
Bending Moment with Panels	239	ft-lbs	see attached analysis
Bending percent increase	106.0		

Roof, roof: Joist before panels
1 piece(s) 2 x 4 DF No.2 @ 24" OC



All locations are measured from the outside face of left support (or left cantilever end). All dimensions are horizontal.

Member Length : 22' 4"

Design Results	Actual @ Location	Allowed	Result	LDF	Load: Combination (Pattern)
Member Reaction (lbs)	405 @ 13'	3799 (3.50")	Passed (11%)	--	1.0 D + 1.0 Lr (Adj Spans)
Shear (lbs)	191 @ 13' 4 3/4"	788	Passed (24%)	1.25	1.0 D + 1.0 Lr (Adj Spans)
Moment (Ft-lbs)	-226 @ 13'	495	Passed (46%)	1.25	1.0 D + 1.0 Lr (Adj Spans)
Live Load Defl. (in)	0.112 @ 16' 2 3/16"	0.344	Passed (L/734)	--	1.0 D + 1.0 Lr (Alt Spans)
Total Load Defl. (in)	0.157 @ 16' 2 5/8"	0.458	Passed (L/525)	--	1.0 D + 1.0 Lr (Alt Spans)

System : Roof
 Member Type : Joist
 Building Use : Residential
 Building Code : IBC 2018
 Design Methodology : ASD
 Member Pitch : 7/12

- Deflection criteria: LL (L/240) and TL (L/180).
- Overhang deflection criteria: LL (2L/240) and TL (2L/180).
- Allowed moment does not reflect the adjustment for the beam stability factor.
- A 15% increase in the moment capacity has been added to account for repetitive member usage.
- Applicable calculations are based on NDS.

Supports	Bearing Length			Loads to Supports (lbs)				Accessories
	Total	Available	Required	Dead	Roof Live	Snow	Total	
1 - Beveled Plate - DF	3.50"	3.50"	1.50"	69	146	76	291	Blocking
2 - Beveled Plate - DF	3.50"	3.50"	1.50"	128	274	142	544	Blocking
3 - Beveled Plate - DF	3.50"	3.50"	1.50"	130	276	143	549	Blocking
4 - Beveled Plate - DF	3.50"	3.50"	1.50"	48	103	54	205	Blocking

• Blocking Panels are assumed to carry no loads applied directly above them and the full load is applied to the member being designed.

Lateral Bracing	Bracing Intervals	Comments
Top Edge (Lu)	22' 2" o/c	
Bottom Edge (Lu)	22' o/c	

•Maximum allowable bracing intervals based on applied load.

Vertical Load	Location (Side)	Spacing	Dead (0.90)	Roof Live (non-snow: 1.25)	Snow (1.15)	Comments
1 - Uniform (PSF)	0 to 19'	24"	8.5	20.0	10.4	Dead load and snow load on roof before panels are added

Member Notes
Roof joist before solar panels are added

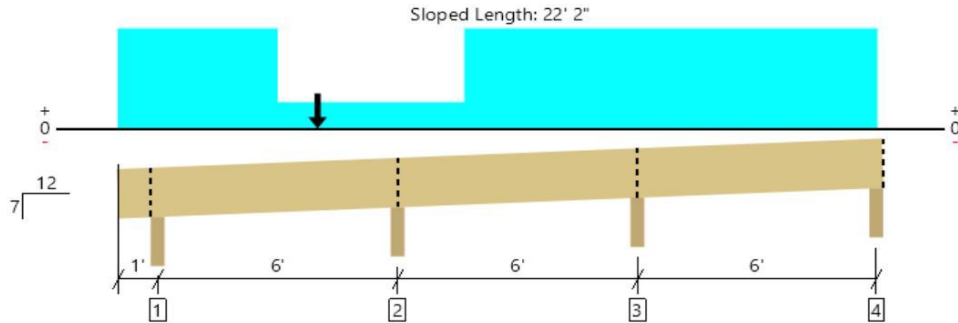
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The product application, input design loads, dimensions and support information have been provided by Imported test Software Operator

ForteWEB Software Operator	Job Notes
Taylor Smythe Right Angle Engineering (925) 787-3067 taylor@rightangleeng.com	Roof Joist before and after solar panels are added



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Roof, roof: Joist with solar panels
1 piece(s) 2 x 4 DF No.2 @ 24" OC



All locations are measured from the outside face of left support (or left cantilever end). All dimensions are horizontal.

Member Length : 22' 4"

Design Results	Actual @ Location	Allowed	Result	LDF	Load: Combination (Pattern)
Member Reaction (lbs)	435 @ 13'	3799 (3.50")	Passed (11%)	--	1.0 D + 1.0 Lr (Adj Spans)
Shear (lbs)	208 @ 13' 4 3/4"	788	Passed (26%)	1.25	1.0 D + 1.0 Lr (Adj Spans)
Moment (Ft-lbs)	-239 @ 13'	495	Passed (48%)	1.25	1.0 D + 1.0 Lr (Adj Spans)
Live Load Defl. (in)	0.107 @ 16' 2 1/2"	0.344	Passed (L/770)	--	1.0 D + 1.0 Lr (Alt Spans)
Total Load Defl. (in)	0.167 @ 16' 2 13/16"	0.458	Passed (L/494)	--	1.0 D + 1.0 Lr (Alt Spans)

System : Roof
 Member Type : Joist
 Building Use : Residential
 Building Code : IBC 2018
 Design Methodology : ASD
 Member Pitch : 7/12

- Deflection criteria: LL (L/240) and TL (L/180).
- Overhang deflection criteria: LL (2L/240) and TL (2L/180).
- Allowed moment does not reflect the adjustment for the beam stability factor.
- A 15% increase in the moment capacity has been added to account for repetitive member usage.
- Applicable calculations are based on NDS.

Supports	Bearing Length			Loads to Supports (lbs)				Accessories
	Total	Available	Required	Dead	Roof Live	Snow	Total	
1 - Beveled Plate - DF	3.50"	3.50"	1.50"	95	127	82	304	Blocking
2 - Beveled Plate - DF	3.50"	3.50"	1.50"	188	101	114	403	Blocking
3 - Beveled Plate - DF	3.50"	3.50"	1.50"	162	273	137	572	Blocking
4 - Beveled Plate - DF	3.50"	3.50"	1.50"	62	102	55	219	Blocking

• Blocking Panels are assumed to carry no loads applied directly above them and the full load is applied to the member being designed.

Lateral Bracing	Bracing Intervals	Comments
Top Edge (Lu)	22' 2" o/c	
Bottom Edge (Lu)	20' 8" o/c	

•Maximum allowable bracing intervals based on applied load.

Vertical Loads	Location (Side)	Spacing	Dead (0.90)	Roof Live (non-snow: 1.25)	Snow (1.15)	Comments
1 - Uniform (PSF)	0 to 19'	24"	10.9	-	-	DL
2 - Uniform (PSF)	0 to 4'	24"	-	20.0	10.4	DL+SL below panels
3 - Point (lb)	5'	N/A	28	-	70	solar and SL
4 - Uniform (PSF)	8' 8 1/16" to 19'	24"	-	20.0	10.4	DL+SL above panels

Member Notes
Roof joist with solar panels

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ForteWEB Software Operator	Job Notes
Taylor Smythe Right Angle Engineering (925) 787-3067 taylor@rightangleeng.com	Roof Joist before and after solar panels are added



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Array Name - Array 2

Roof Slope	14.04	degrees
Number of panels	6	
Panel Area	105.495	ft^2

Wind Calculations - ASCE 7-16

GCp Zone 2	-3.0		Figure 30.3-(2A-5B)
Gcpi	-0.18		Table 26.13-1
kh	0.98		Table 26.10-1
kht	1		Equation 26.8-1
kd	0.85		Table 26.6-1
Velocity Pressure	28.2	psf	Equation 26.10-1
Zone 2 Pressure	-79.53	psf	Equation 30.7-1

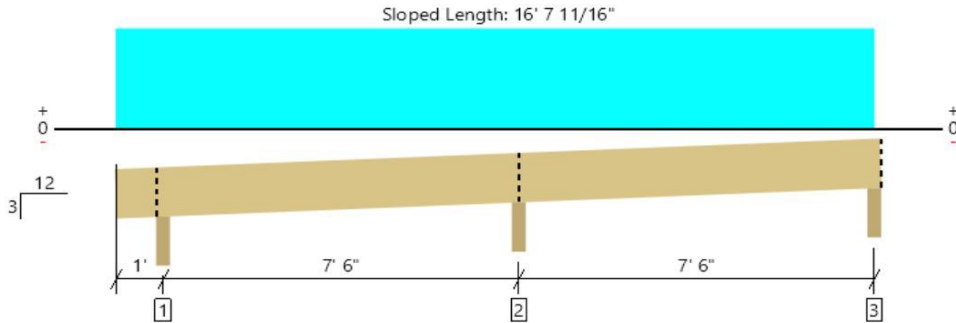
Roof Connection

Shear Capacity	190.0	lbs	NDS 2015 Table 12k
Pullout capacity	266.0	lbs/in	
Minimum # of connections	13		
Lag screw embedment	2.5	in	
Total pullout capacity	665.0	in	

Beam Stress

Beam Span	90, 90	in	
Spacing	24.0	in	
Roof Framing type	2x4 Trusses DF#2		
Panel orientation	Portrait		
Number of panels per rafter	2		
Panel distance from eave	6.0	in	
Shear without Panels	243	lbs	see attached analysis
Shear with Panels	168	lbs	see attached analysis
Shear percent increase	69.0		
Bending Moment without Panels	396	ft-lbs	see attached analysis
Bending Moment with Panels	255	ft-lbs	see attached analysis
Bending percent increase	64.0		

Roof, roof: Joist before panels
1 piece(s) 2 x 4 DF No.2 @ 24" OC



All locations are measured from the outside face of left support (or left cantilever end). All dimensions are horizontal.

Member Length : 16' 8 9/16"

Design Results	Actual @ Location	Allowed	Result	LDF	Load: Combination (Pattern)
Member Reaction (lbs)	533 @ 8' 6"	3382 (3.50")	Passed (16%)	--	1.0 D + 1.0 Lr (Adj Spans)
Shear (lbs)	243 @ 8' 11 1/8"	788	Passed (31%)	1.25	1.0 D + 1.0 Lr (Adj Spans)
Moment (Ft-lbs)	-396 @ 8' 6"	495	Passed (80%)	1.25	1.0 D + 1.0 Lr (Adj Spans)
Live Load Defl. (in)	0.193 @ 12' 6 1/2"	0.383	Passed (L/476)	--	1.0 D + 1.0 Lr (Alt Spans)
Total Load Defl. (in)	0.256 @ 12' 7 3/16"	0.511	Passed (L/360)	--	1.0 D + 1.0 Lr (Alt Spans)

System : Roof
 Member Type : Joist
 Building Use : Residential
 Building Code : IBC 2018
 Design Methodology : ASD
 Member Pitch : 3/12

- Deflection criteria: LL (L/240) and TL (L/180).
- Overhang deflection criteria: LL (2L/240) and TL (2L/180).
- Allowed moment does not reflect the adjustment for the beam stability factor.
- A 15% increase in the moment capacity has been added to account for repetitive member usage.
- Applicable calculations are based on NDS.

Supports	Bearing Length			Loads to Supports (lbs)				Accessories
	Total	Available	Required	Dead	Roof Live	Snow	Total	
1 - Beveled Plate - DF	3.50"	3.50"	1.50"	68	165	86	319	Blocking
2 - Beveled Plate - DF	3.50"	3.50"	1.50"	162	371	193	726	Blocking
3 - Beveled Plate - DF	3.50"	3.50"	1.50"	50	124	64	238	Blocking

• Blocking Panels are assumed to carry no loads applied directly above them and the full load is applied to the member being designed.

Lateral Bracing	Bracing Intervals	Comments
Top Edge (Lu)	16' 8" o/c	
Bottom Edge (Lu)	10' 10" o/c	

•Maximum allowable bracing intervals based on applied load.

Vertical Load	Location (Side)	Spacing	Dead (0.90)	Roof Live (non-snow: 1.25)	Snow (1.15)	Comments
1 - Uniform (PSF)	0 to 16'	24"	8.5	20.0	10.4	Dead load and snow load on roof before panels are added

Member Notes
 Roof joist before solar panels are added

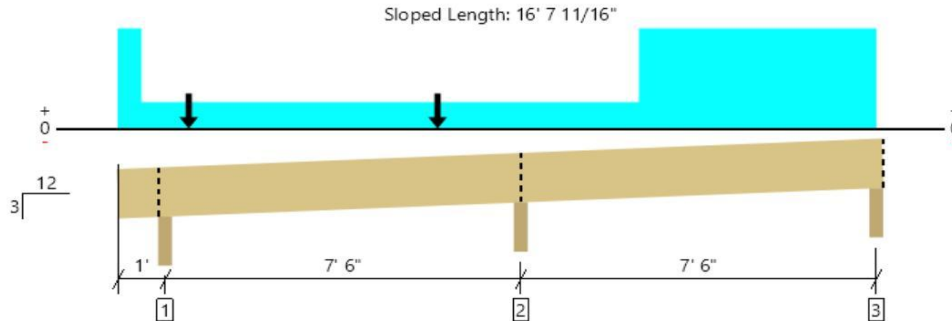
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Taylor Smythe Right Angle Engineering (925) 787-3067 taylor@rightangleeng.com	Roof joist before and after solar panels are added



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Roof, roof: Joist with solar panels
1 piece(s) 2 x 4 DF No.2 @ 24" OC



All locations are measured from the outside face of left support (or left cantilever end). All dimensions are horizontal.

Member Length : 16' 8 9/16"

Design Results	Actual @ Location	Allowed	Result	LDF	Load: Combination (Pattern)
Member Reaction (lbs)	329 @ 8' 6"	3382 (3.50")	Passed (10%)	--	1.0 D + 1.0 S (Adj Spans)
Shear (lbs)	168 @ 8' 7/8"	725	Passed (23%)	1.15	1.0 D + 1.0 S (Adj Spans)
Moment (Ft-lbs)	-255 @ 8' 6"	456	Passed (56%)	1.15	1.0 D + 1.0 S (Adj Spans)
Live Load Defl. (in)	0.191 @ 12' 6 9/16"	0.383	Passed (L/483)	--	1.0 D + 1.0 Lr (All Spans)
Total Load Defl. (in)	0.261 @ 12' 7 13/16"	0.511	Passed (L/352)	--	1.0 D + 1.0 Lr (All Spans)

System : Roof
 Member Type : Joist
 Building Use : Residential
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 Member Pitch : 3/12

- Deflection criteria: LL (L/240) and TL (L/180).
- Overhang deflection criteria: LL (2L/240) and TL (2L/180).
- Allowed moment does not reflect the adjustment for the beam stability factor.
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- Applicable calculations are based on NDS.

Supports	Bearing Length			Loads to Supports (lbs)				Accessories
	Total	Available	Required	Dead	Roof Live	Snow	Total	
1 - Beveled Plate - DF	3.50"	3.50"	1.50"	108	16/-1	66	190/-1	Blocking
2 - Beveled Plate - DF	3.50"	3.50"	1.50"	227	90	102	419	Blocking
3 - Beveled Plate - DF	3.50"	3.50"	1.50"	62	122	61	245	Blocking

• Blocking Panels are assumed to carry no loads applied directly above them and the full load is applied to the member being designed.

Lateral Bracing	Bracing Intervals	Comments
Top Edge (Lu)	16' 8" o/c	
Bottom Edge (Lu)	16' 8" o/c	

•Maximum allowable bracing intervals based on applied load.

Vertical Loads	Location (Side)	Spacing	Dead (0.90)	Roof Live (non-snow: 1.25)	Snow (1.15)	Comments
1 - Uniform (PSF)	0 to 16'	24"	10.9	-	-	DL
2 - Uniform (PSF)	0 to 6"	24"	-	20.0	10.4	DL+SL below panels
3 - Point (lb)	1' 6"	N/A	19	-	54	solar and SL
4 - Point (lb)	6' 9"	N/A	19	-	54	solar and SL
5 - Uniform (PSF)	10' 11 15/16" to 16'	24"	-	20.0	10.4	DL+SL above panels

Member Notes
Roof joist with solar panels

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