

October 7, 2021

Power Home Solar and Roofing 919 North Main Street Mooresville, NC 28115 **Design Criteria:**

Design Wind Speed (ASD)- 116 mph Ground Snow Load- 15 psf Risk Category- II Exposure category- C

RE: Structural Roof Evaluation for the *Fleming Residence: 261 Tower Drive*, *Broadway*, *North Carolina*

As per your request, we have evaluated the roof structure under the proposed solar panel array. The information used to evaluate this structure was gathered by Power Home Solar and Roofing on behalf of Right Angle Engineering. The roof structure consists of pre-manufactured trusses spaced at 24" on center. The roof material consists of asphalt shingles. 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 Building Code, the 2018 North Carolina Existing Building Code, and ASCE 7-16.

North Carolina Existing Building Code (NCEBC) 2018 section 807.4 indicates that alterations to an existing building that results in less than a 10% increase in the total stress may be performed without a structural evaluation of the existing building. As demonstrated in the attached calculations, the additional weight of the solar panels will be less than 10% increase in the gravity loading and the stress on the existing roof framing.

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. In order 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" on center. The racking system should be installed per the manufacture's specifications. There should be a minimum of 35 L-foot attachment points to the roof. Each attachment should have a 5/16" or 18/8 SS lag screw with 2.5" minimum penetration centered on each truss top chord or rafter. Waterproofing around the roof penetrations is the responsibility of others. Right Angle Engineering assumes no responsibility for improper installation of the solar panels.

Regards,

Robert D Smythe, P.E. Right Angle Engineering

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10/7/21



Design Criteria:			
Design Wind Speed (3 second gust)	116	mph	•
Exposure Category	С	·	
Risk Category	2		
Mean Roof Height	30	ft	
Roof Type	Gable Roof		
Building Type	enclosed		
Roof Dead Load- ASCE Table	C3-1		
Asphalt Shingles	2	psf	
5/8" Plywood Sheathing	2	psf	
Roof Framing	4	psf	
Insulation	3.85	psf	
Gypsum sheathing	2	psf	
Solar Panel Array	3	psf	
Dead Load Without Panels	13.85	psf	
Dead Load With Solar panels	16.85	psf	
Doofting Load			ı
Roof Live Load		•	
Existing Roof Live Load	20	psf	ASCE 7-16 Table 4.3-1
Roof Live Load with Solar Panels	0	psf	2018 NCBC 1607.12.5
Roof Snow Load-ASCE 7-16			l
Ground Snow Load (pg)	15	psf	Section 7.2
Exposure Factor (Ce)	0.9		Table 7.3-1
Thermal Factor (Ct)	1.1		Table 7.3-2
Importance Factor (Is)	1		Table 1.5-2
Flat Roof Snow Load (Pf)	10		Equation 7.3-1
Slippery surface Slope Factor (Cs)	0.62		Figure 7-2
Nonslippery Surface Slope Factor			
(Cs)	1		Figure 7-2
Roof Snow Load	10	nof	Faustian 7.4.1
Reduced Roof Snow Load (Slippery	10	psf	Equation 7.4-1
Surface)	6	psf	Equation 7.4-1
Load Combinations - ASCE 7-	16 Section 2.4.1		
		With Solar	
	Without Solar Panels	panels	
D+Lr	33.8 psf	16.8 psf	

24.2 psf

23.3 psf

D + S



Solar Array 1- Roof 1				
Roof Slope	33	degrees		
Number of panels	11			
Panel Area	192.5	ft^2		
Wind Colonlations ACCE 7.16	_	_		
Wind Calculations- ASCE 7-16				
GCp Zone 1	-1		_	30.3-(2A-5B)
GC _p Zone 2	-1.8		_	30.3-(2A-5B)
GC _p Zone 3	-2.8		_	30.3-(2A-5B)
Gcpi	0.18		Table 2	26.13-1
Velocity Pressure (qh)	28.7	psf		
qh= .00256KhKhtKdV^2			-	on 26.10-1
Kh	0.98		Table 2	26.10-1
Kht	1		Equation	on 26.8-1
Kd	0.85		Table 2	26.6-1
Designed wind pressure (P)		psf	Equation	on 30.8-1
P = qh(GCh) - (GChi)				
Zone 1 Pressure (P)	-33.9	psf		
Zone 2 Pressure (P)	-56.8	psf		
Zone 3 Pressure (P)	-85.5	psf		
De af Course ation				
Roof Connection		<u>-</u>		
Shear Capacity	190	lbs	NDS 20)15 Table 12K
Shear tributary area	37.1	ft^2		
Pullout Capacity	266	lbs/in		
Lag screw embedment	2.5	in		
Total pullout capacity	665	lbs	NDS 20)15 Table 12.2A
Pullout max tributary area	11.7	ft^2		
Factor of Safety	1.41			
Minimum number of connections	18			
Beam Stress NCEBC 2018 Section 806.	2			
Beam Span	16	ft		•
Spacing	2	ft		
Roof Framing type	pre-manufactur	ed trusses		
Panel Orientation	portrait			
Number of Panels per rafter	2			
Panel distance from eave	4	Maril C.	D	
	Without Solar	With Solar	Percent	
Bending Moment	Panels 2166.4 ft-lbs	Panels 1549.3 ft-lbs	71.5%	Less than 105%
Vertical Reaction (V1)	541.6 lbs	399.2 lbs	71.5% 73.7%	Less than 105%
Vertical Reaction (V2)	541.6 lbs	351.96 lbs	65%	Less than 105%
	1			200,0



Number of panels	Solar Array 2- Roof 2				
Number of panels Panel Area 6 Wind Calculations- ASCE 7-16 GCp Zone 1 -1 Figure 30.3-(2A-5B) GCp Zone 2 -1.2 Figure 30.3-(2A-5B) GCp Zone 3 -1.2 Figure 30.3-(2A-5B) Gcpi 0.18 Table 26.13-1 Velocity Pressure (qh) 28.7 psf qh= .00256KnKnk/aV^2 Equation 26.10-1 Kn 0.98 Table 26.10-1 Kn 1 Equation 26.8-1 Kd 0.85 Table 26.6-1 Designed wind pressure (P) psf Equation 30.8-1 P= qh(GCh) - (GCh) 95f Equation 30.8-1 Zone 1 Pressure (P) -33.9 psf Zone 2 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Zone 4 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Zone 1 Pressure (P) -35. <td< td=""><td>-</td><td>33</td><td>degrees</td><td></td><td></td></td<>	-	33	degrees		
Panel Area 105 ft^2	•		acgrees		
Wind Calculations- ASCE 7-16 GCp Zone 1 -1 Figure 30.3-(2A-5B) GCp Zone 2 -1.2 Figure 30.3-(2A-5B) GCp Zone 3 -1.2 Figure 30.3-(2A-5B) GCpi 0.18 Table 26.13-1 Velocity Pressure (qh) 28.7 psf qh= .00256KnKmKdV^22 Equation 26.10-1 Kh 0.98 Table 26.10-1 Kh 1 Equation 26.8-1 Kd 0.85 Table 26.6-1 Designed wind pressure (P) psf Equation 30.8-1 P= qh(GCh) - (GCh)) Psf Equation 30.8-1 Zone 1 Pressure (P) -33.9 psf Zone 2 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Zone 2 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Zone 4 Pressure (P) -39.6 psf Dulout capacity 665 <td>·</td> <td></td> <td>ft^2</td> <td></td> <td></td>	·		ft^2		
GCp Zone 1					
Cop Zone 2	Wind Calculations- ASCE 7-16				
Cop	GC _p Zone 1	-1		Figure	30.3-(2A-5B)
Sepair Capital Capit	GC _p Zone 2	-1.2		Figure	30.3-(2A-5B)
Velocity Pressure (qn) 28.7 psf qh=.00256KnKntKaV^2 Equation 26.10-1 Kh 0.98 Table 26.10-1 Knt 1 Equation 26.8-1 Ka 0.85 Table 26.6-1 Designed wind pressure (P) psf Equation 30.8-1 P= qn(GCh) - (GCn) Psf Equation 30.8-1 Zone 1 Pressure (P) -33.9 psf Zone 2 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Valuation 2 Pressure (P) -39.6 psf Shear Capacity 190 lbs NDS 2015 Table 12K Shear tributary area 2.5 in NDS 2015 Table 12K Pullout Capacity 665 lbs NDS 2015 Table 12.2A Pullout max tributary area 16.8 ft^2 Factor of Safety 2.01 NDS 2015 Table 12.2A Without	GC _p Zone 3	-1.2		Figure	30.3-(2A-5B)
Comparison of	Gcpi	0.18		Table 2	26.13-1
Table 26.10-1	Velocity Pressure (qh)	28.7	psf		
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Kd 0.85 Table 26.6-1 Designed wind pressure (P) psf Equation 30.8-1 P= qh(GCh) - (GChi)) Feather (GChi) Feather (GChi) Zone 1 Pressure (P) -33.9 psf Zone 2 Pressure (P) -39.6 psf Zone 3 Pressure (P) -39.6 psf Lag Screw Connection Shear Capacity 190 lbs NDS 2015 Table 12K Shear tributary area 37.1 ft²2 Pullout Capacity 266 lbs/in Lag screw embedment 2.5 in Total pullout capacity 665 lbs Pullout max tributary area 16.8 ft²2 Factor of Safety 2.01 Minimum number of connections 10 Beam Span 16 ft Spacing 2 ft Roof Framing type pre-manufactured trusses Panel Orientation portrait Number of Panels per rafter 1 Panels Panels <td< td=""><td>Kh</td><td>0.98</td><td></td><td>Table 2</td><td>26.10-1</td></td<>	Kh	0.98		Table 2	26.10-1
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P = qh(GCh) - (GChi) Zone 1 Pressure (P)	Kd	0.85		Table 2	26.6-1
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Zone 2 Pressure (P) Zone 3 Pressure (P) Lag Screw Connection Shear Capacity Shear tributary area 37.1 It^2 Pullout Capacity 266 Ibs/in Lag screw embedment 2.5 In Total pullout capacity 665 Ibs NDS 2015 Table 12.2A Pullout max tributary area 16.8 It^2 Factor of Safety 2.01 Minimum number of connections Beam Stress NCEBC 2018 Section 806.2 Beam Span 16 Roof Framing type Panel Orientation Number of Panels per rafter Panel distance from eave Bending Moment Vertical Reaction (V1) Bess NDS 2015 Table 12.2A It ft pre-manufactured trusses Panels Panels Panels Panels Panels Panels Panels Pacent Panels Panels Pacent Pace	P = qh(GCh) - (GChi)				
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Beam Span 16 ft Spacing 2 ft Roof Framing type pre-manufactured trusses Panel Orientation portrait Number of Panels per rafter 1 Panel distance from eave 8 Without Solar With Solar Percent Panels Panels Increase Bending Moment Vertical Reaction (V1) 541.6 lbs 380.9 lbs 70.3% Less than 105% Less than 105%	Minimum number of connections	10			
Beam Span 16 ft Spacing 2 ft Roof Framing type pre-manufactured trusses Panel Orientation portrait Number of Panels per rafter 1 Panel distance from eave 8 Without Solar With Solar Percent Panels Panels Increase Bending Moment Vertical Reaction (V1) 541.6 lbs 380.9 lbs 70.3% Less than 105% Less than 105%	Beam Stress NCEBC 2018 Section 806	.2			l
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Without Solar With Solar Percent Panels Panels Increase Bending Moment Vertical Reaction (V1) 541.6 lbs 380.9 lbs 70.3% Less than 105% Less than 105%	•				
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Bending Moment 2166.4 ft-lbs 1572.1 ft-lbs 72.6% Less than 105% Vertical Reaction (V1) 541.6 lbs 380.9 lbs 70.3% Less than 105%					
Vertical Reaction (V1) 541.6 lbs 380.9 lbs 70.3% Less than 105%	Randing Moment				Less than 105%
	· · ·				



Solar Array 3- Roof 3				
Roof Slope	36	degrees		
Number of panels	4	acgices		
Panel Area	70	ft^2		
Wind Calculations- ASCE 7-16				
GC _p Zone 1	-1		Figure	30.3-(2A-5B)
GC _P Zone 2	-1.2		Figure	30.3-(2A-5B)
GCp Zone 3	-1.2		Figure	30.3-(2A-5B)
Gcpi	0.18		Table 2	6.13-1
Velocity Pressure (qh)	28.7	psf		
qh= .00256KhKhtKdV^2			Equation	on 26.10-1
Kh	0.98		Table 2	6.10-1
Kht	1		Equation	on 26.8-1
Kd	0.85		Table 2	6.6-1
Designed wind pressure (P)		psf	Equation	on 30.8-1
P = qh(GCh) - (GChi)				
Zone 1 Pressure (P)	-33.9	psf		
Zone 2 Pressure (P)	-39.6	psf		
Zone 3 Pressure (P)	-39.6	psf		
<u>Lag Screw Connection</u>				
Shear Capacity	190	lbs	NDS 20	15 Table 12K
Shear tributary area	34.4	ft^2		
Pullout Capacity	266	lbs/in		
Lag screw embedment	2.5	in		
Total pullout capacity	665	lbs	NDS 2015 Table 12.2A	
Pullout max tributary area	16.8	ft^2		
Factor of Safety	2.01			
Minimum number of connections	6			
Beam Stress NCEBC 2018 Section 806	2			I
Beam Span	12	ft		
Spacing	2	ft		
Roof Framing type	pre-manufactur			
Panel Orientation	portrait			
Number of Panels per rafter	1			
Panel distance from eave	4			
	Without Solar	With Solar	Percent	
2 " - 1	Panels	Panels	Increase	1
Bending Moment	1218.6 ft-lbs	918 ft-lbs	75.3%	Less than 105%
Vertical Reaction (V1) Vertical Reaction (V2)	406.2 lbs 406.2 lbs	285.8 lbs 285.8 lbs	70.4% 70.4%	Less than 105% Less than 105%
vertical Reaction (V2)	400.2 108	203.8 IUS	70.4%	Less than 105%