STRUCTURAL CALCULATIONS FOR PV INSTALLATION

Prepared for

SOLAR-ROOF-CHECK

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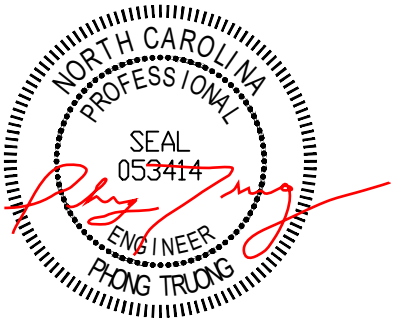
USER:	**Kevin Nguyen**
COMPANY NAME:	**Solar-Roof-Check**
SRC JOB ID:	**35092**
JOB REPORT DATE:	**2022-07-21**
JOB NUMBER:	**123**
JOB NAME:	**Petri Brand**
JOB ADDRESS:	**111 Clearwater Harbor**
	Sanford, NC 27332



Program Version: 2020-05-08:7

USER INPUT:

1.	Ceiling Type		**:= 1/2 gyp. Bd.**
2.	Collar Tie Spacing (ft)		**:= 0**
3.	Roof Coverage %		**:= 24.51**
4.	Roof Framing Size		**:= 2x4@24**
5.	Ground Snow (psf)		**:= 10**
6.	Vertical Snow Load on slope (psf)		**:= 9.4**
7.	Lag Screw Diameter (in)	:= **d**	**:= 5/16**
8.	Lag Screw Embedment (in)	:= **e**	**:= 2.5**
9.	Overall Span (ft)		**:= 30**
10.	PV Weight (psf)	:= $\mathbf{DL_{pv}}$	**:= 3.00**
11.	Rafter Sloped Span (ft)	:= $\mathbf{L_r}$	**:= 7.5**
12.	Rail System		**:= RailLess**
13.	Roofing Type		**:= Comp. Shingle**
14.	Roof Mean Height (ft)	:= **h**	**:= 25**
15.	Roof Slope (degrees)	:= @	**:= 20**
16.	Roof Structure Type		**:= Truss**
17.	Sloped Ceiling?		**:= No**
18.	S_{fh} = RF Mount Horizontal Spacing (ft)		**:= 4.00**
19.	S_{fv} = RF Mount Vertical Spacing (ft)		**:= 3.42**
20.	RF Mount Staggered		**:= Yes**
21.	Wind Exposure		**:= C**
22.	Wind Speed (mph)	:= **V**	**:= 120**
23.	L_{pv}=PV Length (in)		**:= 74**
24.	W_{pv} = PV Width (in)		**:= 41**
25.	Gable, Hip, or Flat/Monoslope		**:= Gable Roof**
26.	Roof Overhangs		**:= Yes**
27.	S_r= Rafter Spacing (ft)		**:= 2.00**
28.	PV Orientation		**:= Landscape**
29.	Elevation Above Sea Level (ft)	:= **Elev**	**:= 398**

FORMULA SYMBOLS:

TA_{fp} := Tributary Area to RF Mounts with **Portrait** PV Orientation (sf)

TA_{fl} := Tributary Area to RF Mounts with **Landscape** PV Orientation (sf)

TA_r := Tributary Area to Rafters (sf)

γ_{af} := Pressure Equalization Factor for RF Mounts with **Portrait** PV Orientation

γ_{af} := Pressure Equalization Factor for RF Mounts with **Landscape** PV Orientation

γ_{ar} := Pressure Equalization Factor for Rafters

P_{1fp} := Design Wind Pressure to RF Mounts with **Portrait** PV Orientation – **Zone 1** (psf)

P_{2fp} := Design Wind Pressure to RF Mounts with **Portrait** PV Orientation – **Zone 2** (psf)

P_{1fl} := Design Wind Pressure to RF Mounts with **Landscape** PV Orientation – **Zone 1** (psf)

P_{2fl} := Design Wind Pressure to RF Mounts with **Landscape** PV Orientation – **Zone 2** (psf)

P_{rup} := Design Wind Pressure **Up** to Rafters (psf)

P_{rdn} := Design Wind Pressure **Down** to Rafters (psf)

GC_{p1} := External Pressure Coefficient for RF Mounts – **Zone 1** (depends on TA Fastener)

GC_{p2} := External Pressure Coefficient for RF Mounts – **Zone 2** (depends on TA Fastener)

GC_{pup} := External Pressure Coefficient, **Wind Up** for Rafters (depends on TAr)

GC_{pdn} := External Pressure Coefficient, **Wind Down** for Rafters (depends on TAr)

S := Snow on Roof (psf)

S_{fh} := RF Mount Horizontal Spacing (ft)

S_{fv} := RF Mount Vertical Spacing (ft)

S_r := Rafter Spacing (ft)

L_{pv} := PV Length (ft)

W_{pv} := PV Width (ft)

L_r := Span of Rafter (ft)

γ_E := Edge Array Factor

Dead Loads (DL): = psf		
Roofing		:= **2.20**
Ply		:= **1.50**
Rafter		:= **0.65**
Miscellaneous (Misc)		:= **1.00**
Clg. Joists		:= **0.65**
Insulation (Insul)		:= **0.50**
Ceiling		:= **2.20**
Flat Ceiling	DL_{tc} = Roofing + Ply + Rafter + Misc (psf)	:= **5.35**
	DL_{bc} = Clg.joists + Insul. + Ceiling (psf)	:= **3.35**
	wDL_{tc} = DL_{tc} x Sr (plf)	:= **10.70**
Sloped Ceiling	DL_{tc}=DL.tc + Insul. + Ceiling (psf)	:= **N/A**
	wDL_{tc}=DL_{tc} x Sr (plf)	:= **N/A**

DESIGN CRITERIA	**ASCE REFERENCE**		
Risk Category II	Table 1.5-1		
Importance Factor	Table 1.5-2	I	:= **1.00**
Basic Wind Speed	Fig. 26.5-1b	V	:= **120**
Wind Directionality	Table 26.6-1	K_d	:= **0.85**
Exposure Category:	Sect. 26.7.3		:= **C**
Topographic Factor	Sect. 26.8	K_{zt}	:= **1.00**
Elevation above Sea Level	Table 26.9-1	K_e	:= **0.99**
Velocity Pressure Exposure Coeff.	Table 26.10-1	K_z	:= **0.94**
Velocity Pressure	Eq. 26.10-1	q_h=.00256 x K_z x K_{zt} x K_d x K_e x V^2	:= **29.03**
Edge Array Factor	Sect. 29.4.4	γE (Zone 1) =1.0 γE (Zone2) =1.5	
PV Pressure Equalization Factor	Fig. 29.4-8	γa	:= **0.70**

RF MOUNT- Wind UP Pressure (*Note: Divide TA by 2 for 2 Rail System*)

Portrait Orientation:

ASCE Reference				
		$TA_{fl} = S_{fh} \times L_{pv}$	:=	**N/A**
Fig. 29.4-8		γ_a	:=	**N/A**
Fig. 30.3-2*	**Zone 1**:	GC_{p1}	:=	**N/A**
Eq. 29.4-7		$P_{1f} = q_h \times GC_{p1} \times \gamma_E \times \gamma_a$	:=	**N/A**
Fig. 30.3-2*	**Zone 2e:**	GC_{p2e}	:=	**N/A**
Eq. 29.4-7		$P_{2ef} = q_h \times GC_{p2e} \times \gamma_E \times \gamma_a$	:=	**N/A**
Fig. 30.3-2*	**Zone 2r:**	GC_{p2r}	:=	**N/A**
Eq. 29.4-7		$P_{2rf} = q_h \times GC_{p2r} \times \gamma_E \times \gamma_a$	:=	**N/A**

Landscape Orientation:

ASCE Reference				
		$TA_{fl} = S_{fh} \times W_{pv}$	:=	**13.67**
Fig. 29.4-8		γ_a	:=	**0.70**
Fig. 30.3-2*	**Zone 1:**	GC_{p1}	:=	**2.00**
Eq. 29.4-7		$P_{1f} = q_h \times GC_{p1} \times \gamma_E \times \gamma_a$	:=	**40.90**
Fig. 30.3-2*	**Zone 2e:**	GC_{p2e}	:=	**2.50**
Eq. 29.4-7		$P_{2ef} = q_h \times GC_{p2e} \times \gamma_E \times \gamma_a$	:=	**76.69**
Fig. 30.3-2*	**Zone 2r:**	GC_{p2r}	:=	**2.81**
Eq. 29.4-7		$P_{2rf} = q_h \times GC_{p2r} \times \gamma_E \times \gamma_a$	:=	**86.08**

***NOTE:** For Flat and Monoslope Roofs, refer to Figures 30.3-5A and 30.3-5B

RAFTERS- Wind UP Pressure

ASCE REFERENCE		$TA_r = S_{fh} \times L_r$	:=	**30.00**
Fig. 29.4-8		γ_{ar}	:=	**0.54**
Fig. 30.3-2*	**Zone 1:**	GC_{pup}	:=	**1.62**
Eq. 29.4-7		$P_{rup} = q_h \times GC_{pup} \times \gamma_E \times \gamma_a$	:=	**25.51**

RAFTERS- Wind DOWN Pressure

ASCE REFERENCE		$TA_r = S_{fh} \times L_r$	:=	**30.00**
Fig. 29. 4-8		γ_{ar}	:=	**0.54**
Fig 30. 3-2*	**Zone 1:**	GC_{pdn}	:=	**0.42**
Eq. 29.4-7		$P_{rdn} = q_h \times GC_{pdn} \times \gamma_E \times \gamma_a$	:=	**16.00**

LOAD COMB. #1: WIND UPLIFT ON RF MOUNTS (0.6DL – 0.6 Wind Up) **(Cd = 1.6)**

	t= Withdrawal Capacity (lb/inch)		t :=	**235.00**
	W= Total Withdrawal Capacity	$W := C_d \times t \times e$	W :=	**940.00**
ZONE 1	$P := TA_f \times (0.6 \times P_{1f} - 0.6 \times DL_{PV} \times \cos(\theta \times deg))$		:=	**312.29**
	% = W x 100/P_{1f}		:=	**301.0%**
	Code Compliant if % is equal to or more than 100%			
ZONE 2e	$P := TA_f \times (0.6 \times P_{2ef} - 0.6 \times DL_{PV} \times \cos(\theta \times deg))$		:=	**605.78**
	% = W x 100/P_{2ef}		:=	**155.2%**
	Code Compliant if % is equal to or more than 100%			
ZONE 2r	$P := TA_f \times (0.6 \times P_{2rf} \quad 0.6 \times DL_{PV} \times \cos(\theta \times deg))$		:=	**682.73**
	% = W x 100/P_{2rf}		:=	**137.7%**
	Code Compliant if % is equal to or more than 100%			

LOAD COMB. #2: On RaftersDL RF + DL SOLAR + RF LL (CD=1.25) with LL = 20 psf

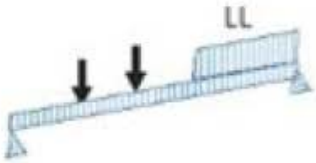
$w := LL \times S_r$ plf (plf) := **39.26**

$P_{sp} := TA_f \times DL_{PV}$:= **41.00**

$c := \frac{(L-5.5)}{2}$ (ft) := **N/A**

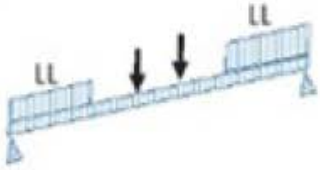
$M_{DL} := \left(wDL_{tc} \times \frac{L^2}{8} + P_{sp} \times \frac{L}{a}\right) \times \cos(\theta)$:= **134.91**

Spans < 10.0 ft



$M_{LL} := \frac{\left(\left(w \times \frac{3}{2 \times L}\right) \times (2 \times L - 3)\right)^2 \times \cos(\theta)}{2 \times w}$:= **106.26**

Spans =>10.0 ft



$M_{LL} := \frac{\frac{\left(\left(w \times c \times (2 \times L - c) + w \times c^2\right)\right)^2}{2 \times L} \times \cos(\theta)}{2 \times w}$:= **N/A**

$M_2 := M_{DL} + M_{LL}$ (lb-ft) := **241.17**

$S_r := M_2 \times \frac{12}{Fb \times Cd_{LL} \times Cf_x \times C_r \times C_{Ls}}$:= **1.34**

$\% := \frac{S_x}{S_r} \times 100$ << If equal to or more than 100% Code Compliant, OK! := **228.0%**

LOAD COMB. #3: On Rafters, Zone 1 DL Rf + DL Solar + Wind Down (Cd =1.6)

$P_3 := TA_f \times (0.6 \times P_{rdn} + DL_{PV} \times \cos\theta)$:= **169.73**

$M_3 := \left(wDL_{tc} \times \frac{L^2}{8}\right) \times \cos(\theta \times deg) + P_3 \times \frac{L}{a}$:= **353.58**

$S_r := M_3 \times \frac{12}{Fb \times Cd_{Wind} \times Cf_x \times C_r \times C_{LS}}$:= **1.54**

$\% := \frac{S_x \times 100}{S_r}$ << If equal to or more than 100% Code Compliant, OK! := **199.1%**

LOAD COMB. #4: On Rafters **DL Rf + DL Solar + Snow (Cd=1.15)**

S:=Sloped Roof Snow Load (psf) := **9.40**

$P_4 := TA_f \times (DL_{PV} \times S)$:= **169.47**

$M_4 := \left(wDL_{tc} \times \frac{L^2}{8} + P_4 \times \frac{L}{a}\right) \times \cos(\theta)$:= **336.11**

$S_r := M_4 \times \frac{12}{Fb \times Cd_{Snow} \times Cf_x \times C_r \times C_{LS}}$:= **2.03**

$\% := \frac{S_x \times 100}{S_r}$ <<If equal to or more than 100% code compliant, ok! := **150.5%**

LOAD COMB. #5: On Rafters, Zone 1 **DL Rf + DL Solar + .75Wind + .75Snow (Cd=1.6)**

S:=Sloped Roof Snow Load (psf) := **9.40**

$P_5 := TA_f \times (DL_{PV} + .75 \times S) \times \cos\theta + TA_f \times 0.75 \times 0.6 \times p_{rdn}$:= **227.47**

$M_5 := \left(wDL_{tc} \times \frac{L^2}{8} + P_5 \times \frac{L}{a}\right) \times \cos(\theta)$:= **449.81**

$S_r := M_5 \times \frac{12}{Fb \times Cd_{Wind} \times Cf_x \times C_r \times C_{LS}}$:= **1.96**

$\% := \frac{S_x \times 100}{S_r}$ <<If equal to or more than 100% Code Compliant, OK! :=**156.5%**

LOADING COMB. #6: **CHECK SEISMIC LOADING:** C=COVERAGE ON ROOF

Existing DL:= DL_{Rf} + Walls Walls:= 5.5 psf := **14.20**

ProposedDL:=ExistingDL + DL_{Solar} x C := **14.94**

$SeismicIncrease := 100 \times \left(\frac{ProposedDL}{ExistingDL}\right) - 100$ <<If equal to or more than 10% Code Compliant, OK! := **5.2%**

SEISMIC SUMMARY: EXISTING BUILDING PROVISIONS

Section 11B.3- Exceptions:

1. The addition complies with the requirements for new structures.
2. The addition does not increase the seismic force by more than 10%.
3. The addition does not decrease the seismic resistance of any structural element.

LOAD COMB. #7: On Rafters, ZONE 1 (0.6)(DL RF + DL SOLAR) - WIND UP (CD=1.6)

$$P_7 := TA_f \times \left(0.6 \times p_{rup} - 0.6 \times DL_{PV} \times \cos\theta\right) \quad := \quad 186.03$$

$$M_7 := \left(P_7 \times \frac{L}{a}\right) - wDL_{tc} \times \frac{L^2}{8} \times \cos\left(\theta \times deg\right) \quad := \quad 267.64$$

$$S_r := M_7 \times \frac{12}{Fb \times Cd_{Wind} \times Cf_x \times C_r \times C_{LS}} \quad := \quad 1.16$$

$$\%_{:=} \frac{S_x \times 100}{S_r}$$

<<IF EQUAL TO OR MORE THAN 100% CODE COMPLIANT, OK!

:= 263.0%

LIMITS OF SCOPE OF WORK AND LIABILITY

Note:

1. Prior to commencement of work, the Solar Installer shall verify that the roof framing sizes, spacing, and spans (between supports), are as noted in these documents. The Engineer of Record must be notified if any discrepancies are discovered, before proceeding.

2. These documents are Stamped for Structural Code compliance of the roof members that support the PV solar system only.

3. These documents are not stamped for rain water leakage prevention.

4. As a precaution, old or wet snow should be removed from the roof, if the snow builds up to 18" or more.

5. Existing deficiencies which are unknown and not observable due to their being concealed inside walls or sandwiched behind gypsum board ceilings at the time of inspection are not included in the scope of work. These calculations are only for the roof framing which supports the new PV modules. These calculations do not include a complete lateral analysis of the building, nor a prediction of the life expectancy of the existing building.

Appendix

Table 3 represents the maximum Moment (M = PL/a) resulting from point loads (RF Mounts), for any spans (L) listed.

a = **4.50**

TABLE 3

The Moment Factor "a" for a 2 Rail System

Length	Staggered		Unstaggered	
	Portrait	Landscape	Portrait	Landscape
L = 4'	4.00	4.00	4.00	2.91
L = 5'	4.00	3.50	3.72	2.50
L = 6'	4.00	3.00	3.43	2.09
L = 7'	3.60	2.84	2.95	1.83
L = 8'	3.20	2.67	2.46	1.56
L = 9'	3.03	2.59	2.34	1.44
L = 10'	2.86	2.50	2.22	1.31
L = 11'	2.77	2.25	2.04	1.19
L = 12'	2.67	2.00	1.85	1.07
L = 13'	2.61	1.88	1.74	0.90
L = 14'	2.55	1.75	1.62	0.92
L = 15'	2.51	1.68	1.50	0.86
L = 16'	2.46	1.60	1.38	0.81
L = 17'	2.43	1.45	1.31	0.76
L = 18'	2.40	1.29	1.23	0.72
L = 19'	2.38	1.24	1.17	0.68
L = 20'	2.35	1.18	1.11	0.65
L = 21'	2.22	1.14	1.06	0.62
L = 22'	2.09	1.10	1.00	0.59

The Moment Factor "a" for a Railless or Shared Rail System

Length	Staggered		Unstaggered	
	Portrait	Landscape	Portrait	Landscape
L = 4'	5.00	5.00	5.00	5.00
L = 5'	5.00	5.00	5.00	5.00
L = 6'	5.00	5.00	5.00	5.00
L = 7'	4.50	4.50	4.50	4.19
L = 8'	4.00	4.00	4.00	3.37
L = 9'	4.00	4.00	4.00	3.12
L = 10'	4.00	4.00	4.00	2.86
L = 11'	4.00	4.00	3.70	2.48
L = 12'	4.00	4.00	3.39	2.09
L = 13'	4.00	3.87	3.35	1.98
L = 14'	4.00	3.73	3.30	1.87
L = 15'	4.00	3.32	2.88	1.78
L = 16'	4.00	2.90	2.46	1.68
L = 17'	4.00	2.74	2.36	1.57
L = 18'	4.00	2.57	2.25	1.45
L = 19'	4.00	2.46	2.18	1.38
L = 20'	4.00	2.35	2.11	1.30
L = 21'	4.00	2.28	2.06	1.25
L = 22'	4.00	2.20	2.00	1.20

REFERENCES: LATEST EDITION

Duration Factors

Cd_{wind}	:=	1.6
Cd_{snow}	:=	1.15
Cd_{DL}	:=	0.9
Cd_{LL}	:=	1.25
C_{LS}	:=	**1.00**
Fb	:=	**1000**

Section Modules

S_x	:=	**3.06**	S_{2x12}	:=	31.640
S_{2x2}	:=	0.563	S_{4x4}	:=	7.150
S_{2x4}	:=	3.063	S_{4x6}	:=	17.650
S_{2x6}	:=	7.563	S_{4x8}	:=	30.660
S_{2x8}	:=	13.140	S_{4x10}	:=	49.900
S_{2x10}	:=	21.390	S_{4x12}	:=	73.800

Size Form Factor

Cf_{2x2}	:=	1.5	Cf_{4x4}	:=	1.5
Cf_{2x4}	:=	1.5	Cf_{4x6}	:=	1.3
Cf_{2x6}	:=	1.3	Cf_{4x8}	:=	1.3
Cf_{2x8}	:=	1.2	Cf_{4x10}	:=	1.2
Cf_{2x10}	:=	1.1	Cf_{4x12}	:=	1.1
Cf_{2x12}	:=	1.0			