



October 2, 2020

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

Design Criteria:

Ultimate Wind Speed- 120 mph
Ground Snow Load- 10 psf
Risk Category- II
Exposure category- C

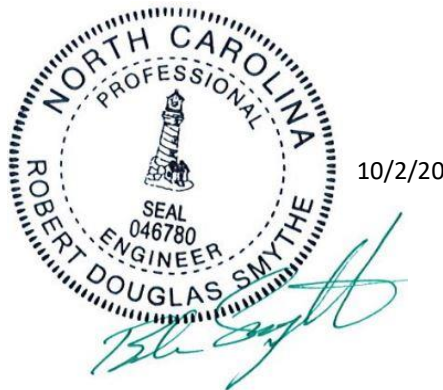
RE: Structural Roof Evaluation for the *Raynor Residence: 433 West Stewart Street, Coats, North Carolina*

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 during a field visit by Power Home Solar and Roofing on behalf of Right Angle Engineering. The roof structure consists of 2x4 rafters spaced at 24" on center. The roof material consists of corrugated metal. The design criteria used to analyze this structure are listed above and included with this letter.

Based on our analysis we have determined that the existing roof framing will not adequately support the additional loads imposed by the solar panels. It is our recommendation that additional web members are added to all rafters at 24" o.c. according to SK-1 in order for the roof structure to adequately support the additional loads of the solar panels. A minimum of 35 protea roof attachments should be staggered such that the loads are evenly distributed. The racking system should be installed per the manufacture's specifications. 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



Design Criteria:

Design Wind Speed (3 second gust)	120	mph
Exposure Category	C	
Risk Category	2	
Mean Roof Height	30	ft
Roof Type	Gable Roof	
Building Type	enclosed	

Roof Dead Load- ASCE Table C3-1

Corrugated Metal	0	psf
5/8" Plywood Sheathing	2	psf
Roof Framing	4	psf
Insulation	0	psf
Gypsum sheathing	0	psf
Solar Panel Array	3	psf
Dead Load Without Panels	6	psf
Dead Load With Solar panels	9	psf

Roof Live Load

Existing Roof Live Load	20	psf	ASCE 7-16 Table 4.3-1
Roof Live Load with Solar Panels	0	psf	

Roof Snow Load-ASCE 7-16

Ground Snow Load (pg)	10	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)	7		Equation 7.3-1
Slippery surface Slope Factor (Cs)	0.73		Figure 7-2
Nonslippery Surface Slope Factor (Cs)	1		Figure 7-2
Roof Snow Load	7	psf	Equation 7.4-1
Reduced Roof Snow Load (Slippery Surface)	5	psf	Equation 7.4-1

Load Combinations - ASCE 7-16 Section 2.4.1

	Without Solar Panels	With Solar panels
D + Lr	26 psf	9 psf
D + S	12.9 psf	14.1 psf

Solar Array 1-

Roof Slope	26	degrees
Number of panels	14	
Panel Area	245	ft ²

Wind Calculations- ASCE 7-16

GC _p Zone 1	-0.9		Figure 30.3-(2A-5B)
GC _p Zone 2	-1.7		Figure 30.3-(2A-5B)
GC _p Zone 3	-2.6		Figure 30.3-(2A-5B)
G _{cpi}	0.18		Table 26.13-1
Velocity Pressure (q _h)	30.7	psf	
$q_h = .00256 K_h K_{ht} K_d V^2$			Equation 26.10-1
K _h	0.98		Table 26.10-1
K _{ht}	1		Equation 26.8-1
K _d	0.85		Table 26.6-1
Designed wind pressure (P)		psf	Equation 30.8-1
$P = q_h(GC_h) - (GC_{hi})$			
Zone 1 Pressure (P)	-33.2	psf	
Zone 2 Pressure (P)	-57.7	psf	
Zone 3 Pressure (P)	-85.4	psf	

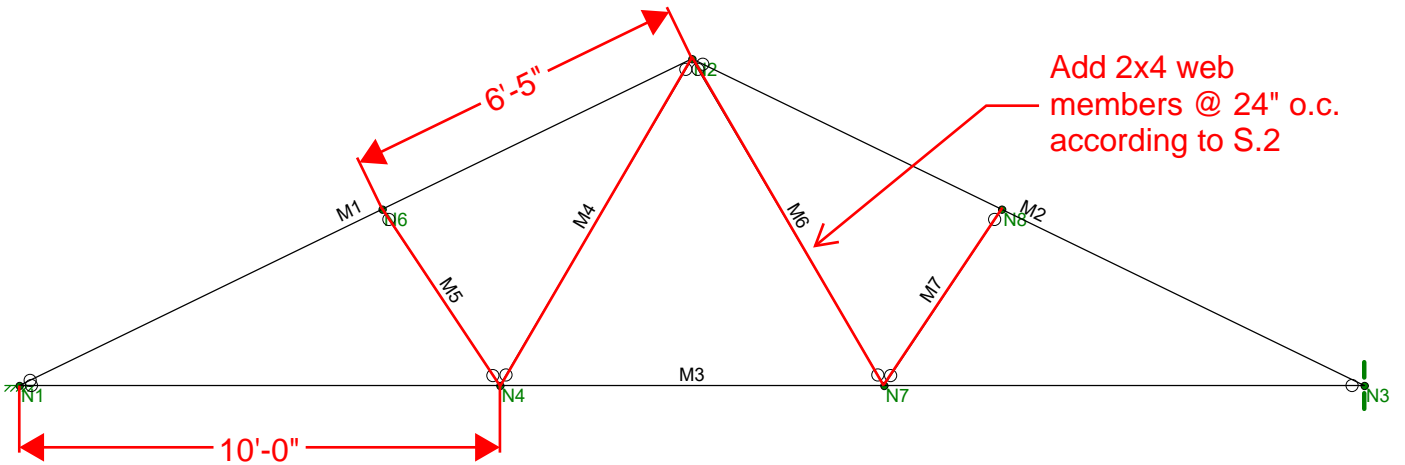
Roof Connection

Shear Capacity	49	lbs	S-5 Load Testing
Shear tributary area	13.8	ft ²	
Total pullout capacity	364	lbs	S-5 Load Testing
Pullout max tributary area	6.3	ft ²	
Factor of Safety	1.11		
Minimum number of connections	35		

Beam Stress

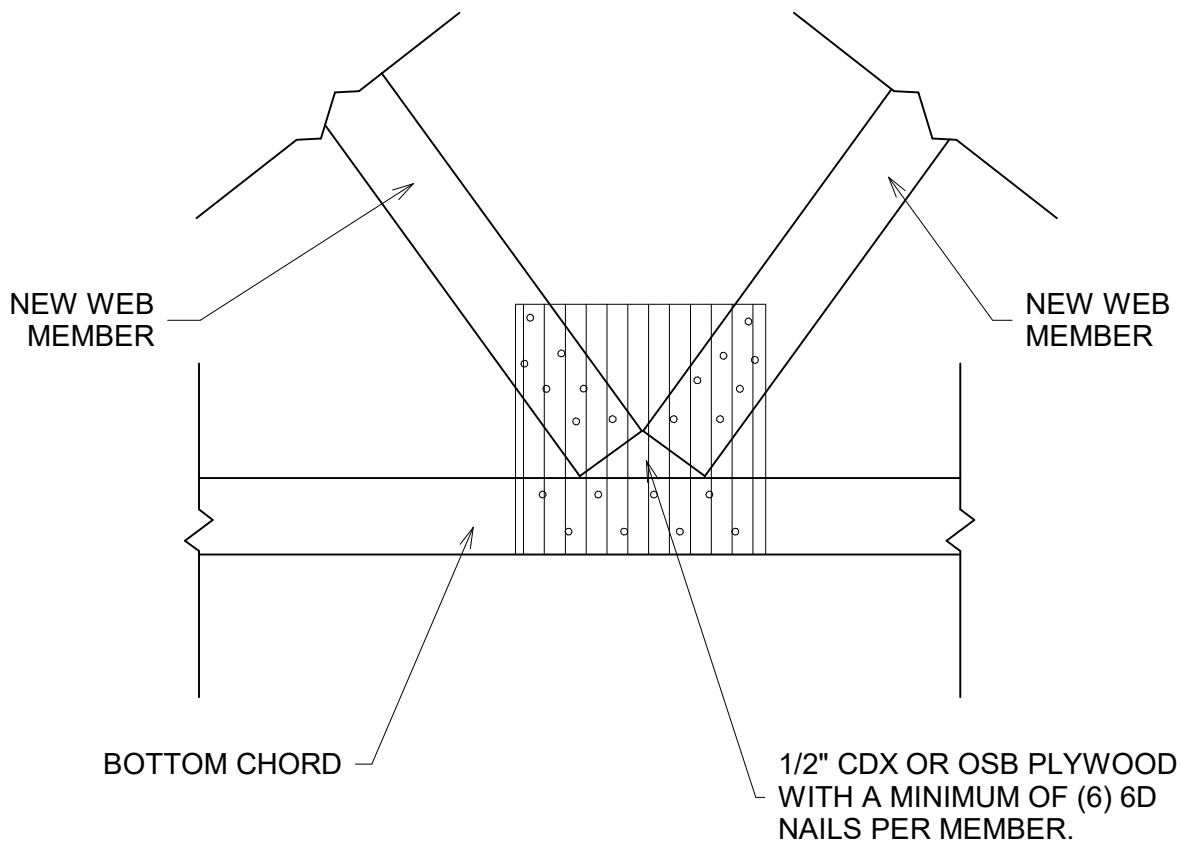
Beam Span	13	ft
Spacing	2	ft
Roof Framing type	2x4 rafters	
Panel Orientation	portrait	
Number of Panels per rafter	2	
Panel distance from eave	2	

	Without Solar Panels	With Solar Panels	Percent Increase	
Bending Moment	1098.5 ft-lbs	495.1 ft-lbs	45.1%	Less than 105%
Vertical Reaction (V1)	338 lbs	166.6 lbs	49.3%	Less than 105%
Vertical Reaction (V2)	338 lbs	131.73 lbs	39%	Less than 105%



Envelope Only Solution

		SK - 1
		Oct 2, 2020 at 4:36 PM
		Anthony Raynor Risa.r2d



① WEB MEMBER CONNECTION
1" = 1'-0"



WEB MEMBER

Project number	0	S.2
Date	11/15/18	
Drawn by	TES	
Checked by	RDS	Scale 1" = 1'-0"

Wood Material Properties

	Label	Type	Database	Species	Grade	Cm	Emod	Nu	Therm (...Dens[k/ft...
1	DF	Solid Sawn	Visually ...	Douglas Fir-Larch	No.1		1	.3	.3 .035
2	SP	Solid Sawn	Visually ...	Southern Pine	No.1		1	.3	.3 .035
3	HF	Solid Sawn	Visually ...	Hem-Fir	No.1		1	.3	.3 .035
4	SPF	Solid Sawn	Visually ...	Spruce-Pine-fir	No.1		1	.3	.3 .035
5	24F-1.8E DF ...	Glulam	NDS Tabl...	24F-1.8E DF BAL	na		1	.3	.3 .035
6	24F-1.8E DF ...	Glulam	NDS Tabl...	24F-1.8E DF UNBAL	na		1	.3	.3 .035
7	24F-1.8E SP ...	Glulam	NDS Tabl...	24F-1.8E SP BAL	na		1	.3	.3 .035
8	24F-1.8E SP ...	Glulam	NDS Tabl...	24F-1.8E SP UNBAL	na		1	.3	.3 .035

Wood Section Sets

	Label	Shape	Type	Design List	Material	Design Rules	A [in2]	I (90,270) [i... I (0,180) [in4]
1	2x4	2X4	Beam	None	DF	Typical	5.25	.984 5.359

Joint Coordinates and Temperatures

	Label	X [ft]	Y [ft]	Temp [F]
1	N1	0	0	0
2	N2	14	6.8	0
3	N3	28	0	0
4	N4	10	0	0
5	N6	7.553957	3.669065	0
6	N7	18	0	0
7	N8	20.446043	3.669065	0

Joint Boundary Conditions

	Joint Label	X [k/in]	Y [k/in]	Rotation[k-ft/rad]
1	N1	Reaction	Reaction	Reaction
2	N3		Reaction	

Wood Design Parameters

	Label	Shape	Length[ft]	Le-out[ft]	Le-in[ft]	le-bend to...	le-bend bo...	K-out	K-in	CV	Cr	Out sway	In sway
1	M1	2x4	15.564	0	0	Lb out					Yes		
2	M2	2x4	15.564	0	0	Lb out					Yes		
3	M3	2x4	28			Lb out					Yes		
4	M4	2x4	7.889			Lb out					Yes		
5	M5	2x4	4.41			Lb out					Yes		
6	M6	2x4	7.889			Lb out					Yes		
7	M7	2x4	4.41			Lb out					Yes		

Member Distributed Loads (BLC 1 : Dead Load)

	Member Label	Direction	Start Magnitude[k/ft,...	End Magnitude[k/ft, F,...	Start Location[ft, %]	End Location[ft, %]
1	M1	Y	-03	-03	0	0
2	M2	Y	-03	-03	0	0

Member Distributed Loads (BLC 2 : roof Load)

	Member Label	Direction	Start Magnitude[k/ft,...	End Magnitude[k/ft, F,...	Start Location[ft, %]	End Location[ft, %]
1	M1	Y	-04	-04	0	0
2	M2	Y	-04	-04	0	0

Load Combinations

	Description	So...	PDelta	S...	BLC	Fac...	BLC	Fac...	BLC	Fac...	BLC	Fac...	BLC	Fac...	BLC	Fac...	BLC	Fac...
1	IBC 16-8	Yes			DL	1												
2	IBC 16-9	Yes			DL	1	LL	1	LLS	1								
3	IBC 16-1...	Yes			DL	1	RLL	1										
4	IBC 16-1...	Yes			DL	1	SL	1	SLN	1								
5	IBC 16-1...	Yes			DL	1	RL	1										
6	IBC 16-1...	Yes			DL	1	LL	.75	LLS	.75	RLL	.75						
7	IBC 16-1...	Yes			DL	1	LL	.75	LLS	.75	SL	.75	SLN	.75				
8	IBC 16-1...	Yes			DL	1	LL	.75	LLS	.75	RL	.75						
9	IBC 16-1...	Yes			DL	1	WL	.6										
10	IBC 16-1...	Yes			DL	1	EL	.7										
11	IBC 16-1...	Yes			DL	1	WL	.45	LL	.75	LLS	.75	RLL	.75				
12	IBC 16-1...	Yes			DL	1	WL	.45	LL	.75	LLS	.75	SL	.75	SLN	.75		
13	IBC 16-1...	Yes			DL	1	WL	.45	LL	.75	LLS	.75	RL	.75				
14	IBC 16-14	Yes			DL	1	EL	.525	LL	.75	LLS	.75	SL	.75	SLN	.75		
15	IBC 16-15	Yes			DL	.6	WL	.6										
16	IBC 16-16	Yes			DL	.6	EL	.7										

Envelope Joint Reactions

	Joint		X [k]	LC	Y [k]	LC	Moment [k-ft]	LC
1	N1	max	0	16	1.143	3	0	16
2		min	0	1	.312	15	0	1
3	N3	max	0	16	1.143	3	0	16
4		min	0	1	.312	15	0	1
5	Totals:	max	0	16	2.286	3		
6		min	0	1	.624	15		

Envelope Joint Displacements

	Joint		X [in]	LC	Y [in]	LC	Rotation [rad]	LC
1	N1	max	0	16	0	16	0	16
2		min	0	1	0	1	0	1
3	N2	max	.031	3	-.042	16	6.602e-03	3
4		min	.009	15	-.155	3	1.742e-03	15
5	N3	max	.063	3	0	16	1.604e-02	3
6		min	.017	15	0	1	4.244e-03	15
7	N4	max	.025	3	-.044	16	-4.008e-05	16
8		min	.007	15	-.159	3	-4.575e-04	3
9	N6	max	.047	3	-.041	16	2.448e-03	3
10		min	.013	15	-.149	3	6.368e-04	15
11	N7	max	.038	3	-.044	16	4.575e-04	3
12		min	.01	15	-.159	3	4.008e-05	15
13	N8	max	.016	3	-.041	16	-6.312e-04	16
14		min	.004	15	-.149	3	-2.427e-03	3

Envelope Member Section Forces

	Member	Sec		Axial[k]	LC	Shear[k]	LC	Moment[k-ft]	LC
1	M1	1	max	2.164	3	.213	3	0	1
2			min	.591	15	.056	15	0	1
3		2	max	2.042	3	-.01	15	-.09	15
4			min	.559	15	-.037	3	-.342	3
5		3	max	1.921	3	-.075	15	.287	3
6			min	.528	15	-.286	3	.075	15

Envelope Member Section Forces (Continued)

Member	Sec		Axial[k]	LC	Shear[k]	LC	Moment[k-ft]	LC
7	4	max	1.713	3	.086	3	-.04	15
8		min	.472	15	.023	15	-.15	3
9	5	max	1.592	3	-.043	15	0	1
10		min	.44	15	-.163	3	0	1
11	M2	1	max	1.592	3	.163	0	1
12		min	.44	15	.043	15	0	1
13	2	max	1.713	3	-.023	15	-.04	15
14		min	.472	15	-.086	3	-.15	3
15	3	max	1.921	3	.286	3	.287	3
16		min	.528	15	.075	15	.075	15
17	4	max	2.042	3	.037	3	-.09	15
18		min	.559	15	.01	15	-.342	3
19	5	max	2.163	3	-.056	15	0	1
20		min	.591	15	-.213	3	0	1
21	M3	1	max	-.507	16	-.003	0	1
22		min	-1.853	3	-.006	3	0	1
23	2	max	-.507	16	.003	1	.014	3
24		min	-1.853	3	.002	15	.006	15
25	3	max	-.326	16	0	1	.011	3
26		min	-1.184	3	0	1	.003	15
27	4	max	-.507	16	-.002	15	.014	3
28		min	-1.853	3	-.003	1	.006	15
29	5	max	-.507	16	.006	3	0	1
30		min	-1.853	3	.003	15	0	1
31	M4	1	max	-.177	16	-.002	0	1
32		min	-.635	3	-.003	3	0	1
33	2	max	-.176	16	0	15	.004	3
34		min	-.633	3	-.001	3	.002	15
35	3	max	-.175	16	0	1	.005	3
36		min	-.631	3	0	1	.003	15
37	4	max	-.174	16	.001	6	.004	3
38		min	-.629	3	0	15	.002	15
39	5	max	-.172	16	.003	6	0	1
40		min	-.626	3	.002	15	0	1
41	M5	1	max	.633	3	0	0	1
42		min	.168	15	-.002	3	0	1
43	2	max	.631	3	0	15	.001	3
44		min	.167	15	0	3	0	15
45	3	max	.63	3	0	1	.002	3
46		min	.167	15	0	1	.001	15
47	4	max	.629	3	0	6	.001	3
48		min	.166	15	0	15	0	15
49	5	max	.628	3	.002	6	0	1
50		min	.165	15	0	15	0	1
51	M6	1	max	-.177	16	.003	0	1
52		min	-.635	3	.002	15	0	1
53	2	max	-.176	16	.001	1	-.002	15
54		min	-.633	3	0	15	-.004	1
55	3	max	-.175	16	0	1	-.003	15
56		min	-.631	3	0	1	-.005	1
57	4	max	-.174	16	0	15	-.002	15
58		min	-.629	3	-.001	3	-.004	1
59	5	max	-.172	16	-.002	15	0	1
60		min	-.626	3	-.003	3	0	1
61	M7	1	max	.633	3	.002	0	1
62		min	.168	15	0	15	0	1
63	2	max	.631	3	0	1	0	15

Envelope Member Section Forces (Continued)

Member	Sec		Axial[k]	LC	Shear[k]	LC	Moment[k-ft]	LC
64		min	.167	15	0	15	-.001	1
65	3	max	.63	3	0	1	-.001	15
66		min	.167	15	0	1	-.002	1
67	4	max	.629	3	0	15	0	15
68		min	.166	15	0	6	-.001	1
69	5	max	.628	3	0	15	0	1
70		min	.165	15	-.002	6	0	1

Envelope Member Section Stresses

Member	Sec		Axial[ksi]	LC	Shear[ksi]	LC	Top Bending[k...]	LC	Bottom Bendin...	LC	
1	M1	1	max	.412	3	.061	3	0	1	0	1
2			min	.113	15	.016	15	0	1	0	1
3		2	max	.389	3	-.003	15	1.339	3	-.353	15
4			min	.107	15	-.011	3	.353	15	-1.339	3
5		3	max	.366	3	-.022	15	-.295	15	1.124	3
6			min	.1	15	-.082	3	-1.124	3	.295	15
7		4	max	.326	3	.025	3	.589	3	-.156	15
8			min	.09	15	.006	15	.156	15	-.589	3
9		5	max	.303	3	-.012	15	0	1	0	1
10			min	.084	15	-.047	3	0	1	0	1
11	M2	1	max	.303	3	.047	3	0	1	0	1
12			min	.084	15	.012	15	0	1	0	1
13		2	max	.326	3	-.006	15	.589	3	-.156	15
14			min	.09	15	-.025	3	.156	15	-.589	3
15		3	max	.366	3	.082	3	-.295	15	1.124	3
16			min	.1	15	.022	15	-1.124	3	.295	15
17		4	max	.389	3	.011	3	1.339	3	-.353	15
18			min	.107	15	.003	15	.353	15	-1.339	3
19		5	max	.412	3	-.016	15	0	1	0	1
20			min	.113	15	-.061	3	0	1	0	1
21	M3	1	max	-.097	16	0	15	0	1	0	1
22			min	-.353	3	-.002	3	0	1	0	1
23		2	max	-.097	16	0	1	-.022	15	.054	3
24			min	-.353	3	0	15	-.054	3	.022	15
25		3	max	-.062	16	0	1	-.01	15	.042	3
26			min	-.225	3	0	1	-.042	3	.01	15
27		4	max	-.097	16	0	15	-.022	15	.054	3
28			min	-.353	3	0	1	-.054	3	.022	15
29		5	max	-.097	16	.002	3	0	1	0	1
30			min	-.353	3	0	15	0	1	0	1
31	M4	1	max	-.034	16	0	15	0	1	0	1
32			min	-.121	3	0	3	0	1	0	1
33		2	max	-.034	16	0	15	-.009	15	.015	3
34			min	-.121	3	0	3	-.015	3	.009	15
35		3	max	-.033	16	0	1	-.012	15	.02	3
36			min	-.12	3	0	1	-.02	3	.012	15
37		4	max	-.033	16	0	6	-.009	15	.015	3
38			min	-.12	3	0	15	-.015	3	.009	15
39		5	max	-.033	16	0	6	0	1	0	1
40			min	-.119	3	0	15	0	1	0	1
41	M5	1	max	.12	3	0	15	0	1	0	1
42			min	.032	15	0	3	0	1	0	1
43		2	max	.12	3	0	15	-.003	15	.005	3
44			min	.032	15	0	3	-.005	3	.003	15
45		3	max	.12	3	0	1	-.004	15	.007	3

Envelope Member Section Stresses (Continued)

Member	Sec		Axial[ksi]	LC	Shear[ksi]	LC	Top Bending[k...	LC	Bottom Bendin...	LC
46		min	.032	15	0	1	-.007	3	.004	15
47	4	max	.12	3	0	6	-.003	15	.005	3
48		min	.032	15	0	15	-.005	3	.003	15
49	5	max	.12	3	0	6	0	1	0	1
50		min	.031	15	0	15	0	1	0	1
51	M6	1	max	16	0	1	0	1	0	1
52		min	-.121	3	0	15	0	1	0	1
53	2	max	-.034	16	0	1	.015	1	-.009	15
54		min	-.121	3	0	15	.009	15	-.015	1
55	3	max	-.033	16	0	1	.02	1	-.012	15
56		min	-.12	3	0	1	.012	15	-.02	1
57	4	max	-.033	16	0	15	.015	1	-.009	15
58		min	-.12	3	0	3	.009	15	-.015	1
59	5	max	-.033	16	0	15	0	1	0	1
60		min	-.119	3	0	3	0	1	0	1
61	M7	1	max	3	0	1	0	1	0	1
62		min	.032	15	0	15	0	1	0	1
63	2	max	.12	3	0	1	.005	1	-.003	15
64		min	.032	15	0	15	.003	15	-.005	1
65	3	max	.12	3	0	1	.007	1	-.004	15
66		min	.032	15	0	1	.004	15	-.007	1
67	4	max	.12	3	0	15	.005	1	-.003	15
68		min	.032	15	0	6	.003	15	-.005	1
69	5	max	.12	3	0	15	0	1	0	1
70		min	.031	15	0	6	0	1	0	1

Envelope Wood Code Checks

Member	Shape	Code ...	Loc[ft]	LC	Shear ...	Loc[ft]	LC	Fc' [ksi]	Ft' [ksi]	Fb' [ksi]	Fv' [ksi]	RB	CL	CP	Eqn	
1	M1	2X4	.991	8.431	3	.403	8.268	3	2.156	1.11	1.891	.225	17.045	.877	1	3.9-3
2	M2	2X4	.991	7.134	3	.403	7.296	3	2.156	1.11	1.891	.225	17.045	.877	1	3.9-3
3	M3	2X4	.485	23.042	3	.012	9.917	1	.01	.776	1.321	.162	22.862	.613	.005	3.9-1
4	M4	2X4	.107	3.78	3	.005	0	1	.127	1.223	2.083	.162	12.135	.966	.059	3.9-1
5	M5	2X4	.307	0	3	.003	4.41	1	.393	1.247	2.124	.162	9.073	.985	.182	3.6.3
6	M6	2X4	.107	3.78	3	.005	0	1	.127	1.223	2.083	.162	12.135	.966	.059	3.9-1
7	M7	2X4	.307	0	3	.003	0	1	.393	1.247	2.124	.162	9.073	.985	.182	3.6.3