Dealing With Structural Issues for Solar Permitting

Alan Harper
Plan Review Specialist III
City of Madison Building Inspection

Why are we concerned about the structure of solar installations of roofs?

- **There has never been a structural failure of a solar installation.**
- **Solar installers have been doing this for decades.**
- **Municipalities are picking on solar installers.**

Examples of installations we saw when we first started asking for plans

- **Supports for racking systems spaced at 10 feet.**
- **¾" lags screwed through rafters and truss chords.**
- **No site visit by the installer prior to permitting.**

The contractors were not recognizing the need to pay attention to the structure under their installations.

What happened when plans were asked for on all installations?

- Panic
- Confusion
- Fighting back
- Going “overboard” on design

Advantages of plan review and permitting:

- ❖Levels playing field
- ❖Creates a minimum level of expectation
- ❖Helps the installer to be viewed as a professional

Solar ABC's Expedited Solar Permit Process:

- Two criteria
  - 5 lb/ft^2 system dead load

    A typical system runs 3 – 5 lb/ft^2
  - 45 lb / attachment

    For a 3 lb/ft^2 system this translates to an attachment grid of 3.8 feet.

Items to look for on structural submittals:

Item #1: Loads

- Weight of equipment (dead load)
- Snow and wind loads

Two methods recognized for determining snow and wind loads

- Wisconsin UDC code
- ASCE 7-05

Wisconsin code

- **Snow load:**
  30 psf (can be reduced for roofs of 7:12 pitch or greater)

- **Wind load:**
  The code has no language addressing wind load down force

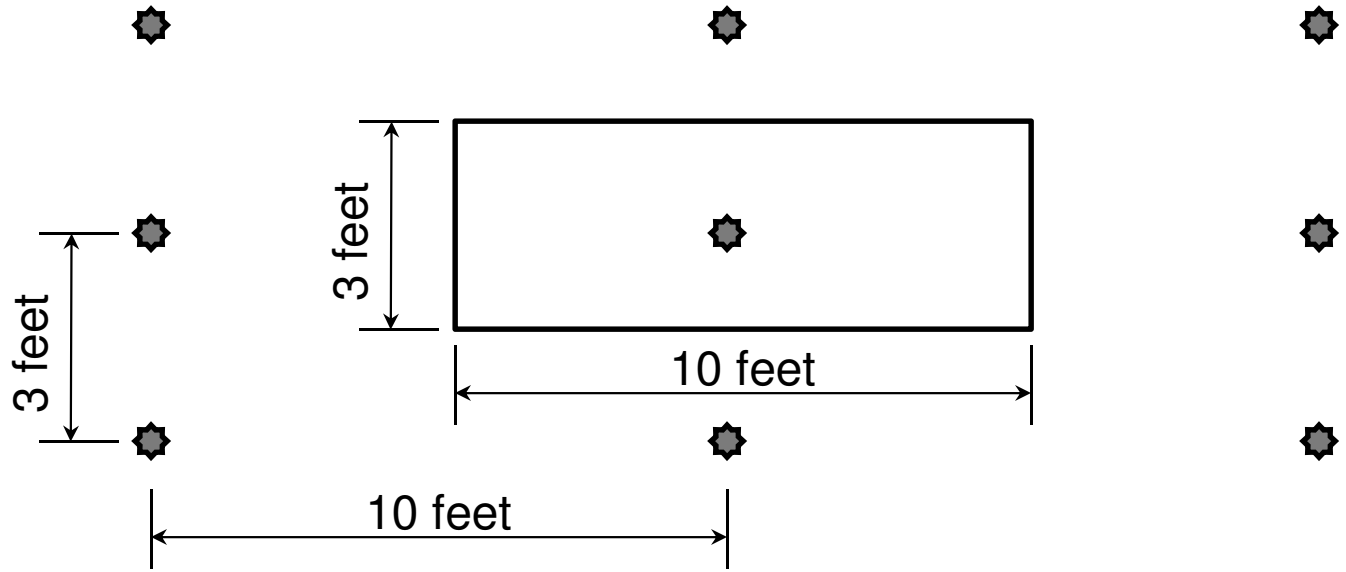
  Roofs shall withstand a pressure of at least 20 pounds per square foot acting upward normal to the roof surface. SPS 321.27 (3)a.

ASCE 7-05

- **Snow load:**
  - **30 psf ground snow load**
  - **Roof snow load = $C_s(0.7C_eC_tIp_g)$**
- **Wind load:**
  - **Two choices**
  1. **Components and cladding**
     $p=q_h[(GC_p) – (Gc_{pi})]$
  2. **Solid signs**
     $p=q_hGC_fA_s$

Items to look for on structural submittals:

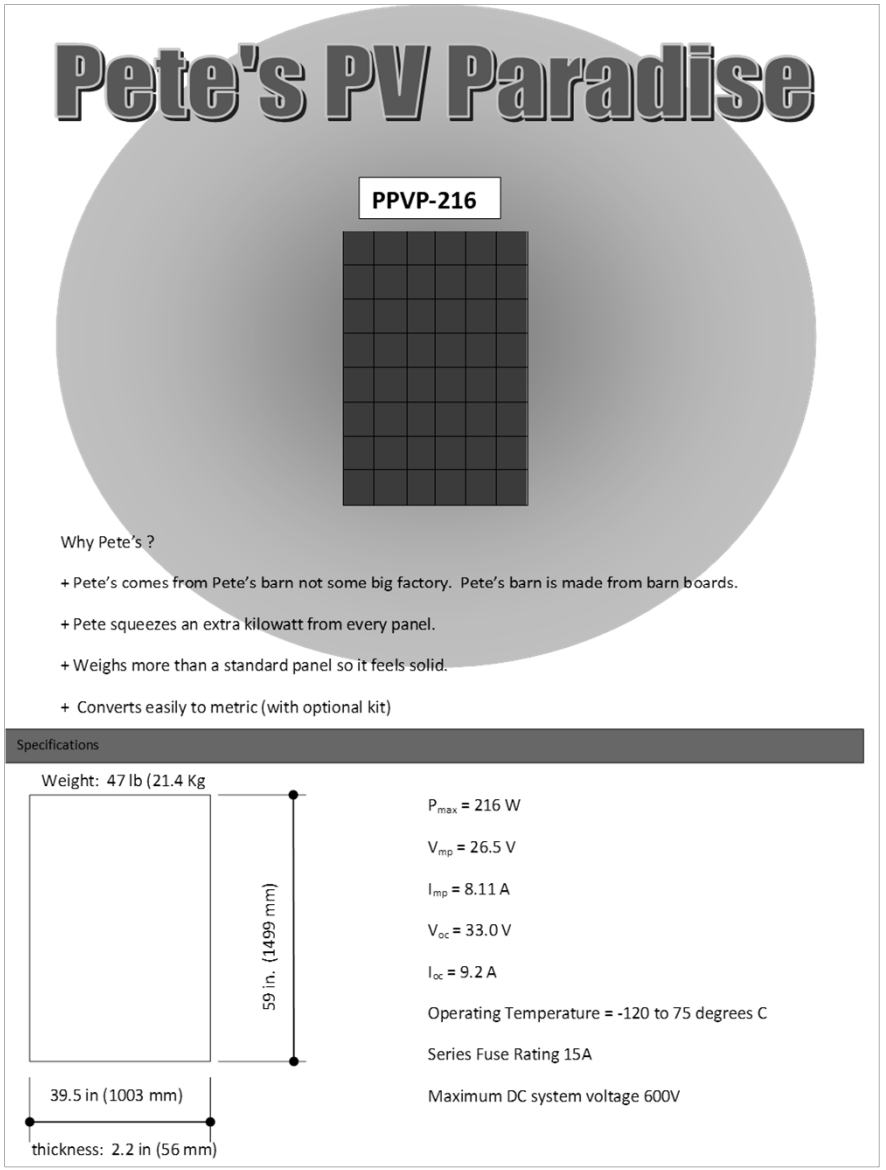
Item #2: Concentrated Loads



ASCE 7-05 section 4.3 “Unless otherwise specified, the indicated concentration shall be assumed to be uniformly distributed over an area 2.5 ft square and shall be located so as to produce the maximum load effects in structural members.”

Wisconsin code example 5:12 pitch roof

- **Dead load:**
  - **The applicant should include a cut sheet for the panel used. This needs to include the size and weight of panels.**



Wisconsin code example 5:12 pitch roof

As the solar panels are tilted up the load to the roof per unit area increases. To get the load per unit area for a panel divide the weight of the panel by the area of the panel then multiple by the proper factor.

Slope	Multiply by
1:12	1.00
2:12	1.01
3:12	1.03
3.5:12	1.04
4:12	1.05
5:12	1.08
6:12	1.12
7:12	1.16
8:12	1.20
9:12	1.25
10:12	1.30
11:12	1.38
12:12	1.41
13:12	1.47
14:12	1.54

For this example:
Area of panel = 39.5 in x 59 in / 144 in/sqft = 16.2 sqft

Load to support = 47 lb / (16.2 sqft x 1.08) = 2.7 lb/sf

Tributary area is 30 sf so load on support is 81 pounds

Weight of the rack adds a small amount to this. The conservative installer will add the rack load.

Wisconsin code example 5:12 pitch roof

- **Snow load:**
  30 psf

The dimension for distances on a roof must be multiplied by the following factors to get the horizontal distance on a rafter or truss.

Slope	Multiply by
1:12	1.00
2:12	0.99
3:12	0.97
3.5:12	0.96
4:12	0.95
5:12	0.92
6:12	0.89
7:12	0.86
8:12	0.83
9:12	0.80
10:12	0.77
11:12	0.74
12:12	0.71
13:12	0.68
14:12	0.65

For this example:
Snow to a support = 10 ft x 3 ft x 0.92 x 30 psf = 828 lb

ASCE 7-05 example 5:12 pitch roof

Figure out all of the factors and go through all of the calculations then submit all of the documentation **or**

Solarstrut V2.1
Load Generator
Horizontal projection 9.5 feet

Project address:
Number and street
14 S. 39th Street
City and state
Madison, WI
Date and time
2/14/2011 13:26

Vertical projection 3.2 feet

Solar array

Tilt angle (degrees) 18.43

1.1 = C_t of roof

Horizontal

Height of one panel =	60	inches
Width of one panel =	39.5	inches
Number of panels in a row =	4	
Number of panels in a column =	2	
Weight of one panel =	44	pounds
Tributary length for support=	28.5	inches
Tributary width for support=	48	inches
Spacing of roof structural members =	24	inches
Height from ground to midpoint of roof =	12	feet
Width of building =	48	feet
Height of midpoint of array above ground =	12.5	feet
Horizontal distance from top of array to roof edge =	13.4	feet
Roof slope =	4 /12 =	18.4 degrees
Design wind velocity	90	mph
Exposure category B or C	B	
Ground snow load p_g =	30	psf

LOADS FROM ARRAY TO STRUCTURAL MEMBER

At support

Snow load (p_s) =	224.5	pounds per support
Wind load (F) =	73.8	pounds per support
Panel Load (D_p) =	26.8	pounds per interior support
Uplift =	80.1	pounds per interior support

Weight of sliding snow

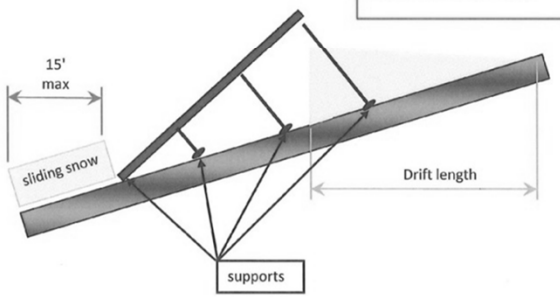
Sliding snow (S) = 121.1 pounds per lineal foot (15 feet max from array)

Drift load

Drift load at array = 0.0 pounds

Drift length = -4.70 feet

Note: Drift and sliding snow loads are added to the base snow loads on the roof. Support loads include snow loads.

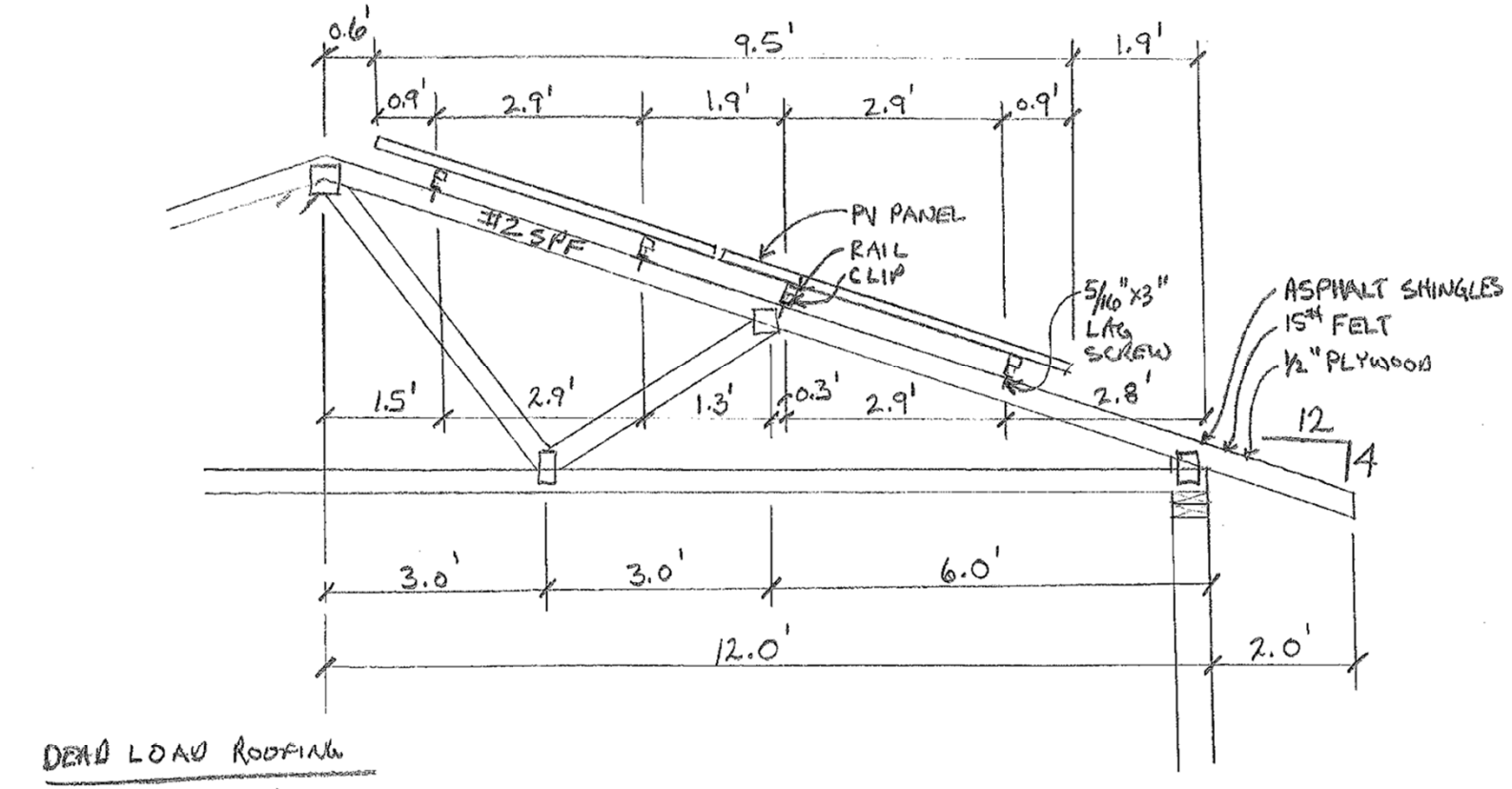


Total Load at Support

Dead + 0.75(wind + snow) =	250	pounds
Dead + wind =	101	pounds
Dead + snow =	251	pounds

Base snow load on roof area not covered by panels = 23.1 pounds per square foot

Items to look for on structural submittals:



DEAD LOAD ROOFING

SHINGLES	=	2.2 PSF
FELT	=	.2 PSF
PLYWOOD	=	1.8 PSF
TOTAL		4.2 PSF

TRUSS SECTION

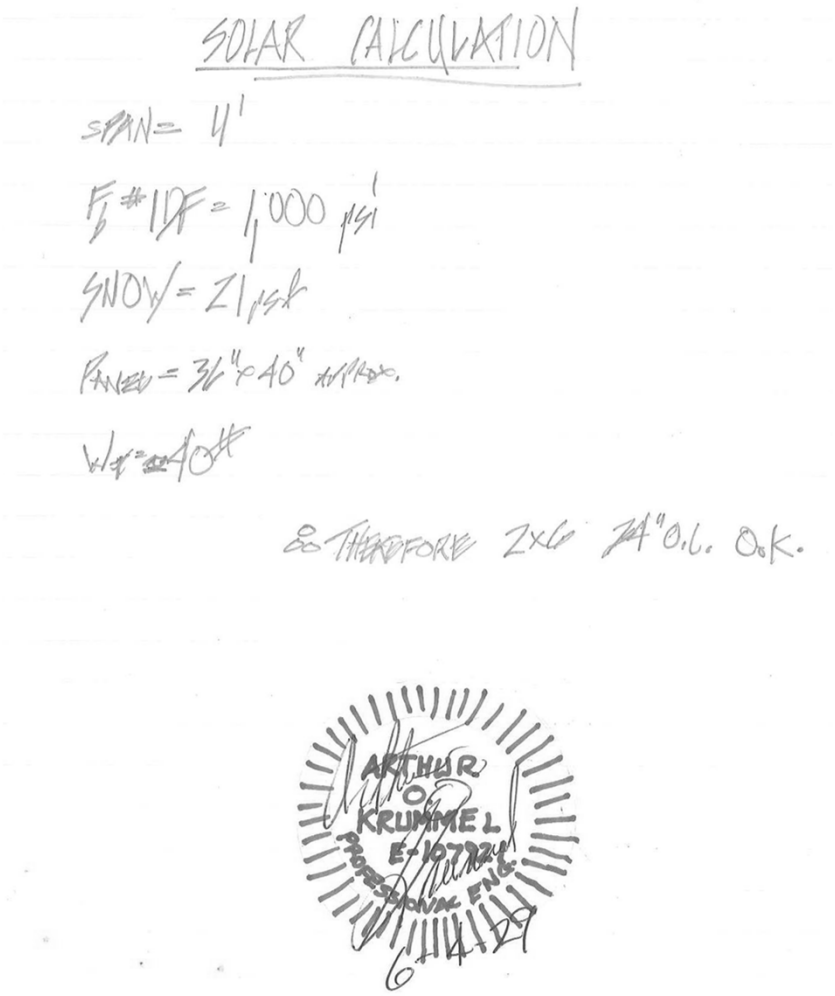
SCALE ½" = 1'-0"

14 S. 39TH ST.

14 S. 39TH ST.

Items to look for on structural submittals:

Item #3: Structural Calculation



SOLAR CALCULATION

SPAN = 4'

F_b #1DF = 1,000 psi

SNOW = 21 psf

PANEL = 36" x 40" max.

Wt = 40#

∴ THEREFORE 2x6 24" O.C. O.K.

ARTHUR O. KRUMMEL E-10732 PROFESSIONAL ENG.

1/2

STRUCTURAL ANALYSIS

ROOFTOP SOLAR @ 14 S. 39TH ST.

PANELS 39.5" × 60" WT = 47#

ROOF SLOPE = 4:12 SLOPE FACTOR = 0.95

HORIZONTAL PANEL AREA = 39.5" × 60" × 0.95 = 2,251 in² = 15.6 ft²

UNIFORM PANEL LOAD = $\frac{47\#}{15.6\,ft^2} = 3.0\#/ft^2$

SNOW = 30#/ft²

TOTAL LOAD ON SUPPORTS = 33#/ft²

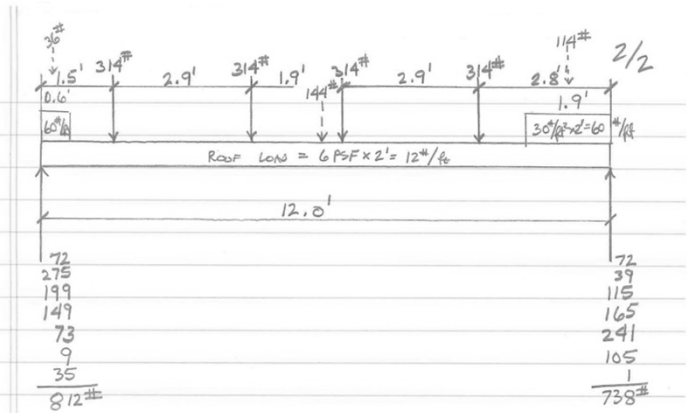
TRIB AREA @ SUPPORT = $4' \times \frac{57"}{(2)(12"/ft)} = 9.5\,ft^2$

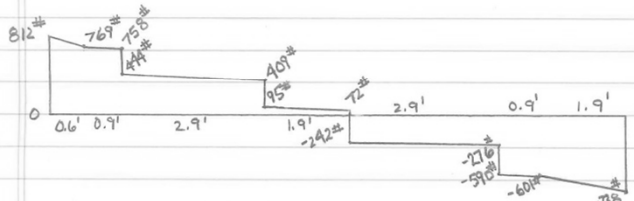
LOAD @ SUPPORT = 33#/ft² × 9.5 ft² = 314#

UPLIFT @ SUPPORT = 9.5 ft² × 20#/ft² = 190#

5/16" Φ LAG WITH 2" PENETRATION = 205#/in × 2 = 410# > 190# ∴ OK

2/2





$$M_{MAX} = \left(\frac{812\# + 769\#}{2}\right) \times 0.6' + \left(\frac{769\# + 758\#}{2}\right) \times 0.9' + \left(\frac{444\# + 409\#}{2}\right) \times 2.9' + \left(\frac{95\# + 72\#}{2}\right) \times 1.9' = 2,560\,ft\cdot lb$$

M_{ALLOW} 2×6 #2 SPF = 717 ft·lbs

2,560 ft·lb / 717 ft·lbs = 3.6 RAFTERS

∴ ADD (3) 2×6 @ EACH SUPPORT RAFTER

Include any modifications needed

Solarstruc V2.1

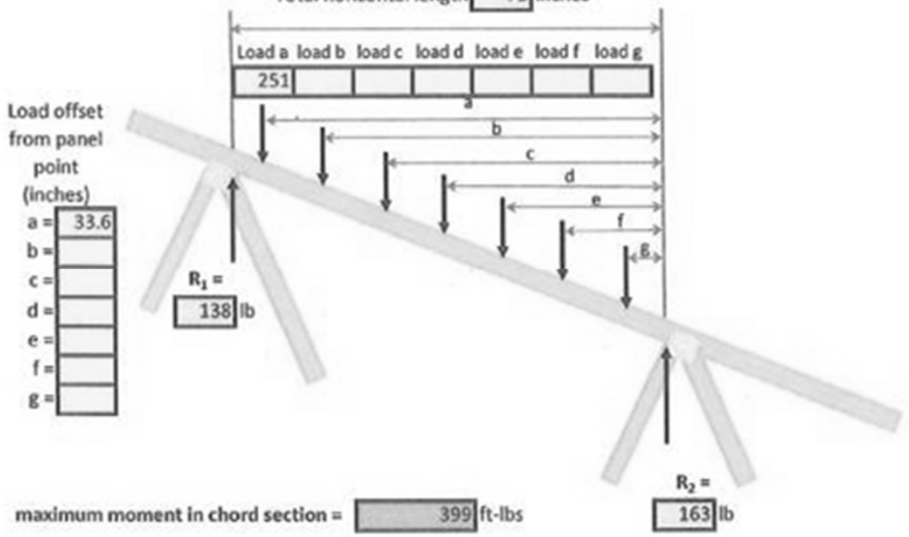
TRUSS CHORD CHECK

(input data in applicable yellow spaces)

Dead load of roofing materials [4.2] pounds per square foot

Spacing of trusses [24] inches

Total horizontal length [72] inches



maximum moment in chord section = [399] ft-lbs

Allowable moments:
#2 SPF 2 x 4 = 442 ft-lbs
2100 msr SPF = 615 ft-lbs

Note: Apply loads from left to right.
Example - If there are three point loads on this section of truss the loads should be under Load a, Load b, and Load c and the distances a, b, and c should be filled in.