

January 11, 2019

Everest Solar Systems, LLC
3809 Ocean Ranch Blvd, Suite 111
Oceanside, CA 92056
Attn: Andy Neshat



RE: *TileHook 3S 5.5 PV Panel Mounting System Evaluation*

To whom it may concern:

Per your request, Moment Engineering + Design has performed a comprehensive structural analysis of the Everest Solar TileHook 3S to determine allowable loads to the roof mount assembly. When installed per the conditions and design criteria described herein, the TileHook 3S is compliant with the applicable sections of the design reference documents noted below.

Design Reference Documents

- *2016 Triennial Edition of Title 24, California Code of Regulations (2016 CBC)*
 - *Based on 2015 International Building Code and 2015 International Residential Code*
- *ASCE/SEI 7-10 – Minimum Design Loads for Buildings and Other Structures*
- *AWC - NDS 2012 – National Design Specification for Wood Construction*
- *ADM1 - 2010 Aluminum Design Manual, by the Aluminum Association*
- *Section and materials data provided by K2 Systems GmbH*
- *Load test data provided by K2 Systems GmbH*

Overview

The TileHook 3S roof mounting system consists of extruded aluminum supports and bases providing points of attachment for a photovoltaic assembly to an existing structure. Fastener withdrawal forces, hook internal stresses, and deflection of the hook assembly limit the allowable loading of the assembly. This analysis outlines recommended allowable loading and bracket spacing for the TileHook 3S based on a set of standardized design parameters.

Methods & Design Parameters

1. TileHook 3S allowable loads

This analysis has included evaluation of hook deflection, internal stresses, and fastener loading to determine allowable limits for the TileHook 3S assembly. Calculated allowable stresses were based on the following data:

- *Analysis of load/deflection test data provided by K2 Systems GmbH*
 - *Observance of 0.25" downward deflection limit state*
 - *Observance of 0.27" upward deflection limit state*
- *Analysis of 2D and 3D finite element models of TileHook 3S*
 - *Observance of material stress limit states per ADM1*
- *Evaluation of lag screw anchorage, per 2012 NDS*

- Calculations based on allowable tension and shear for 5/16" dia. stainless steel lag screws.

An envelope of minimum allowable loads for all limit states was constructed to determine the allowable uplift, shear, and downforce loads for the TileHook 3S assembly.

2. TileHook 3S recommended bracket spacing

Applicable combinations of dead, wind, and snow loads were evaluated in accordance with current code requirements to determine allowable bracket spacing. Maximum spacing of brackets were calculated to ensure loads to and deflections of TileHook 3S remain within defined allowable limits for design configurations noted.

Design wind pressures were determined using Components and Cladding calculations in Chapter 26-30 of ASCE 7-10, using the loading parameters listed below. Configurations not conforming to these parameters will require additional analysis. Calculation of applicable roof snow load should be based upon ground snow load maps and equations and factors of ASCE 7-10, Chapter 7 and applicable sections of the 2016 CBC. For designated Case Study areas noted in the 2016 Triennial Edition of Title 24, California Code of Regulations, refer to local jurisdiction requirements for snow and wind load determination. Seismic criteria were not considered per provisions of ASCE 7-10 Section 13.1.4.

Loading Parameters:

- Roof snow load: 0-30 psf
- Ultimate 3-second gust wind speed (V) = 115-180 mph
- Building roof mean height: 30 ft. or less
- Roof wind pressure region: Zone 1 - Zone 3
- Structural risk category: II
- Wind exposure: B, C, D
- Panel orientation: Portrait or Landscape
- Panel installation angle: Flush with roof slope
- Roof slope (θ): 12 to 45°

Design Results

Allowable loads to the TileHook 3S assembly are as follows:

| <u>Load Type</u> | <u>Load</u> | <u>Deflection</u> |
|------------------|-----------------|-------------------|
| Uplift | -279 lbs | -0.27" |
| Downforce | 267 lbs. | 0.137" |
| Lateral Load | 201 lbs. | 0.25" |

Allowable spacing of the bracket are principally controlled by applicable wind (speed, exposure, pressure zone) and snow loads to the structure. Refer to the TileHook 3S bracket spacing tables in the appendix to this document for maximum recommended spacing based on combinations of these loading parameters. Note that on-center spacing of existing roof framing may impose additional limits on spacing of mounts.

Installation Notes

The following guidelines apply to all installations using the TileHook system:

- TileHook bases require anchorage with two (2) 5/16" diameter stainless steel lag screws set into existing roof rafter. Minimum thread embedment for lag screws shall be eight times the screw diameter (2.5").
- Refer to manufacturer guidelines for installation of panel support rails and connective hardware. The use of hot dipped galvanized or stainless steel fasteners is advised.
- Install TileHook 3S assembly with sufficient clearance under hook to prevent deflection of assembly into roof tile under design loads. 0.25" clearance is recommended.
- Note that withdrawal of fasteners or permanent deformation of hook can occur if recommended values are exceeded.

Summary

This assessment has provided design validation for code-compliant installations of the TileHook 3S mounting system for the hook configurations and applied loads noted previously. For all other configurations, refer to Everest Solar Systems for engineering support. This report does not provide analysis of any existing structures, as may be required by the local authority having jurisdiction.

We appreciate the opportunity to have assisted you with this project. Should you have any further questions regarding this analysis, please feel free to contact us by phone or email.

Best Regards,



Shawn P. Kelley, P.E.

Principal

moment ENGINEERING + DESIGN

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| | | Table 1: Maximum Spacing (in.) - TileHook 3S 5.5 - Wind Exposure B Condition | | | | | | | |
|--------------------|---------------------------|--|------------------------------|----------------------|----|----|----|----|----|
| | | Exposure | Ultimate Wind Speed, V (mph) | Roof Snow Load (psf) | | | | | |
| | | B | | 0 | 5 | 10 | 15 | 20 | 25 |
| Roof Slopes 12-45° | Roof Wind Pressure Zone 1 | 110 | 80 | 70 | 52 | 40 | 32 | 28 | 24 |
| | | 115 | 78 | 68 | 50 | 40 | 32 | 28 | 24 |
| | | 120 | 72 | 64 | 48 | 38 | 32 | 28 | 24 |
| | | 130 | 62 | 58 | 46 | 38 | 30 | 26 | 24 |
| | | 140 | 52 | 52 | 44 | 36 | 30 | 26 | 22 |
| | | 150 | 46 | 46 | 42 | 34 | 28 | 24 | 22 |
| | | 160 | 40 | 40 | 38 | 32 | 28 | 24 | 22 |
| | | 170 | 40 | 40 | 38 | 32 | 28 | 24 | 22 |
| | Roof Wind Pressure Zone 2 | 110 | 56 | 56 | 52 | 40 | 32 | 28 | 24 |
| | | 115 | 50 | 50 | 50 | 40 | 32 | 28 | 24 |
| | | 120 | 46 | 46 | 46 | 38 | 32 | 28 | 24 |
| | | 130 | 40 | 40 | 40 | 38 | 30 | 26 | 24 |
| | | 140 | 34 | 34 | 34 | 34 | 30 | 26 | 22 |
| | | 150 | 30 | 30 | 30 | 30 | 28 | 24 | 22 |
| | | 160 | 26 | 26 | 26 | 26 | 26 | 24 | 22 |
| | Roof Wind Pressure Zone 3 | 110 | 36 | 36 | 36 | 36 | 32 | 28 | 24 |
| | | 115 | 34 | 34 | 34 | 34 | 32 | 28 | 24 |
| | | 120 | 30 | 30 | 30 | 30 | 30 | 28 | 24 |
| | | 130 | 26 | 26 | 26 | 26 | 26 | 26 | 24 |
| | | 140 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| | | 150 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| | | 160 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| | 170 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | |

Notes:

Wind and snow loading based on equations of factors of ASCE 7-10, Chapters 26-30 and 7.

Refer to state building code for determination of applicable wind speeds and snow loads.

Anchorage design assumes 5/16" lag screws with 2.25" thread embedment in Douglas Fir roof framing (SG=0.50). Reference withdrawal and shear values were derived per Chapter 11 of the NDS (W = 266 pli, Z = 210 pli). Calculation of allowable withdrawal force for fasteners includes a load duration factor of 1.6 for wind load cases. Reference lateral loads were not adjusted; design wind loads are assumed to be oriented in the vertical direction relative to TileHook 3S assembly. Bracket spacing governed by fastener withdrawal or hook deflection, unless noted otherwise.

| | | Table 2: Maximum Spacing (in.) - TileHook 3S 5.5 - Wind Exposure C Condition | | | | | | | |
|--------------------|---------------------------|--|------------------------------|----------------------|----|----|----|----|----|
| | | Exposure | Ultimate Wind Speed, V (mph) | Roof Snow Load (psf) | | | | | |
| | | C | | 0 | 5 | 10 | 15 | 20 | 25 |
| Roof Slopes 12-45° | Roof Wind Pressure Zone 1 | 110 | 62 | 58 | 46 | 38 | 30 | 26 | 24 |
| | | 115 | 56 | 56 | 44 | 36 | 30 | 26 | 22 |
| | | 120 | 52 | 52 | 44 | 36 | 30 | 26 | 22 |
| | | 130 | 44 | 44 | 40 | 34 | 28 | 24 | 22 |
| | | 140 | 38 | 38 | 38 | 32 | 28 | 24 | 20 |
| | | 150 | 32 | 32 | 32 | 30 | 26 | 22 | 20 |
| | | 160 | 28 | 28 | 28 | 28 | 24 | 22 | 20 |
| | | 170 | 28 | 28 | 28 | 28 | 24 | 22 | 20 |
| | Roof Wind Pressure Zone 2 | 110 | 38 | 38 | 38 | 38 | 30 | 26 | 24 |
| | | 115 | 36 | 36 | 36 | 36 | 30 | 26 | 22 |
| | | 120 | 32 | 32 | 32 | 32 | 30 | 26 | 22 |
| | | 130 | 28 | 28 | 28 | 28 | 28 | 24 | 22 |
| | | 140 | 24 | 24 | 24 | 24 | 24 | 24 | 20 |
| | | 150 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| | | 160 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| | | 170 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| | Roof Wind Pressure Zone 3 | 110 | 26 | 26 | 26 | 26 | 26 | 26 | 24 |
| | | 115 | 24 | 24 | 24 | 24 | 24 | 24 | 22 |
| | | 120 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| | | 130 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| | | 140 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | | 150 | -- | -- | -- | -- | -- | -- | -- |
| | | 160 | -- | -- | -- | -- | -- | -- | -- |
| | | 170 | -- | -- | -- | -- | -- | -- | -- |

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| | | Table 3: Maximum Spacing (in.) - TileHook 3S 5.5 - Wind Exposure D Condition | | | | | | | |
|--------------------|---------------------------|--|------------------------------|----------------------|----|----|----|----|----|
| | | Exposure | Ultimate Wind Speed, V (mph) | Roof Snow Load (psf) | | | | | |
| | | D | | 0 | 5 | 10 | 15 | 20 | 25 |
| Roof Slopes 12-45° | Roof Wind Pressure Zone 1 | 110 | 52 | 52 | 44 | 36 | 30 | 26 | 22 |
| | | 115 | 48 | 48 | 42 | 34 | 28 | 24 | 22 |
| | | 120 | 44 | 44 | 40 | 34 | 28 | 24 | 22 |
| | | 130 | 36 | 36 | 36 | 32 | 26 | 24 | 20 |
| | | 140 | 32 | 32 | 32 | 30 | 26 | 22 | 20 |
| | | 150 | 28 | 28 | 28 | 28 | 24 | 22 | 20 |
| | | 160 | 24 | 24 | 24 | 24 | 24 | 20 | 18 |
| | | 170 | 24 | 24 | 24 | 24 | 24 | 24 | 20 |
| | Roof Wind Pressure Zone 2 | 110 | 32 | 32 | 32 | 32 | 30 | 26 | 22 |
| | | 115 | 30 | 30 | 30 | 30 | 28 | 24 | 22 |
| | | 120 | 28 | 28 | 28 | 28 | 28 | 24 | 22 |
| | | 130 | 24 | 24 | 24 | 24 | 24 | 24 | 20 |
| | | 140 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| | | 150 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| | | 160 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | | 170 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | Roof Wind Pressure Zone 3 | 110 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| | | 115 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| | | 120 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |
| | | 130 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |
| | | 140 | -- | -- | -- | -- | -- | -- | -- |
| | | 150 | -- | -- | -- | -- | -- | -- | -- |
| | | 160 | -- | -- | -- | -- | -- | -- | -- |
| | | 170 | -- | -- | -- | -- | -- | -- | -- |

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