

Attn: Corey Geiger, COO, IronRidge Inc.

Date: October 12th, 2018

Re: Structural Certification for IronRidge *All Tile Hook* Roof Attachment

This letter addresses the structural capacity of IronRidge *All Tile Hook* for use as a tile roof attachment for flush mounted PV solar systems. The *All Tile Hook* assembly consists of a cold formed stainless steel base and arm with an optional aluminum flashing. The All Tile Hook base is attached to an underlying roof rafter using two (2) 5/16" stainless steel lag bolts and the arm component is secured to the base by a 5/16" carriage bolt. Assembly of the arm, base, and accompanying hardware shall be installed in accordance with IronRidge's All Tile Hook installation manual. Full assembly details are shown in Exhibit EX-0016.

The referenced uplift, compression and lateral capacities of All Tile Hook tabulated below are based on mechanical load tests conducted along the four load directions shown in Figure 1, using a Universal Instron Test Unit, conforming to the following standards:

ASTM D1761-12, Standard Test Methods for Mechanical Fasteners in Wood
ASTM A370-13, Standard Test Methods and Definitions for Mechanical Testing of Steel Products
NDS-2015, National Design Specification (NDS) for Wood Construction
ICC-428, Acceptance Criteria for Modular Framing Systems Used to Support Photovoltaic (PV) Modules

The uplift, compression and lateral load testing was performed by installing the All Tile Hook assembly on a sample roof deck composed of 15/32" OSB board over 24" O.C. 2x4 Douglas Fir rafters. The measured rafter average specific gravity and moisture contents are 0.37 and less than 16%, respectively. For each test the arm component was set at the furthest allowable position from the lag bolts and loads were directly applied at the highest slot position along the center line of the arm as shown in Figure 1 in order to perform the tests at the worst configuration.

The ultimate failure mode for uplift testing was pull out of the lag bolts from the rafters and for compression testing the ultimate failure mode was rupture of the OSB board due to compression bearing of the arm. The averages of the peak loads of both directions, which were observed concurrent with the respective ultimate failure point, are documented in Table 1 shown below.

The ultimate failure mode for both lateral directions was pull out of the lag bolts from the rafters. Average peak loads of 2315 lbs. and 619 lbs. were recorded for the direction parallel to rafter and direction perpendicular to rafter respectively. The associated lateral movements at the loading point were observed to be 7" and 10" respectively. To restrict system deformation under lateral loads, a deflection based serviceability limit was applied, which consequently results in a reduced allowable capacity. The serviceability limit determined loads are reported as the allowable capacity for both lateral load directions as tabulated in Table 1. Specifically, based on full scale lateral testing, a 1" lateral arm deflection is confirmed compatible with the full-scale system and presented as the serviceability limit for the load direction parallel to rafter. For the lateral load direction perpendicular to rafter, the Instron recorded proportional limit of 0.75" is presented as the serviceability limit which eliminates permanent deformation of the assembly.

Observed test results and failure modes along with allowable capacities are summarized in the Table 1.

Table 1: IronRidge All Tile Hook Mechanical Load Test Results & Allowable Capacities ⁽¹⁾						
Load Direction	Specimen Quantity	Observed Failure Mode	Average Peak Load at Failure (lbs) ⁽²⁾	Safety Factor ⁽³⁾	Deviation of Test Results ⁽⁴⁾	Allowable Load (lbs)
Uplift	4	Lag Bolt Pull-out	1011	3.0	10.6%	337
Compression	4	OSB Deck Rupture	709	2.54	10.3%	279
Lateral Parallel to Rafter	4	Lag Bolt Pull-out	2315	3.0	5.4%	154 ⁽⁵⁾
Lateral Perpendicular to Rafter	4	Lag Bolt Pull-out	619	3.0	8.0%	75 ⁽⁵⁾

- (1.) Capacities apply to rafter size of 2x4 or greater at 24" O.C. or less, deck thickness 15/32" or greater, and rafters with a Specific Gravity of 0.37 or greater. The specific gravity during testing was measured and recorded per ASTM D2395-14 "Standard Test Methods for Density and Specific Gravity."
- (2.) Values are based on securing lag bolt within center 1/3 of rafter width with a minimum 2.5" end distance.
- (3.) Safety factor is associated with respective failure modes per ASTM 7147-11 and NDS-2015.
- (4.) Deviation refers to the highest or lowest test value to the group average and is based on the ultimate peak load for the tension/compression and serviceability limit load for the lateral directions.
- (5.) The provided allowable loads are controlled by the specified serviceability limit.

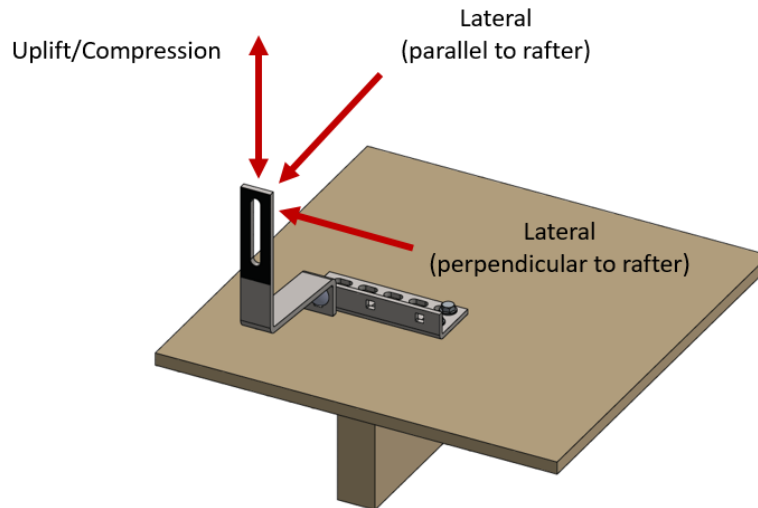


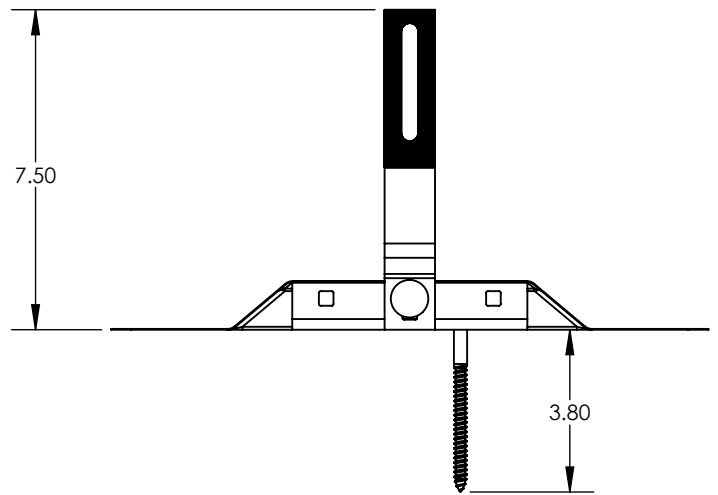
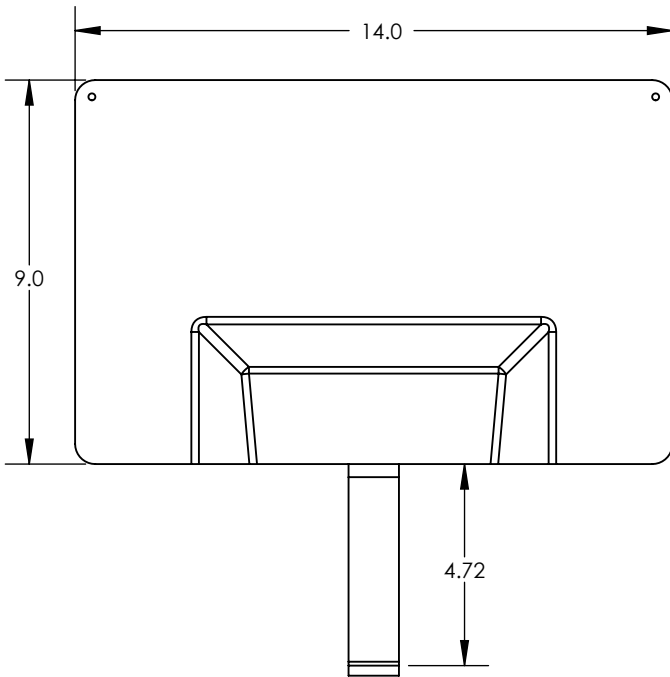
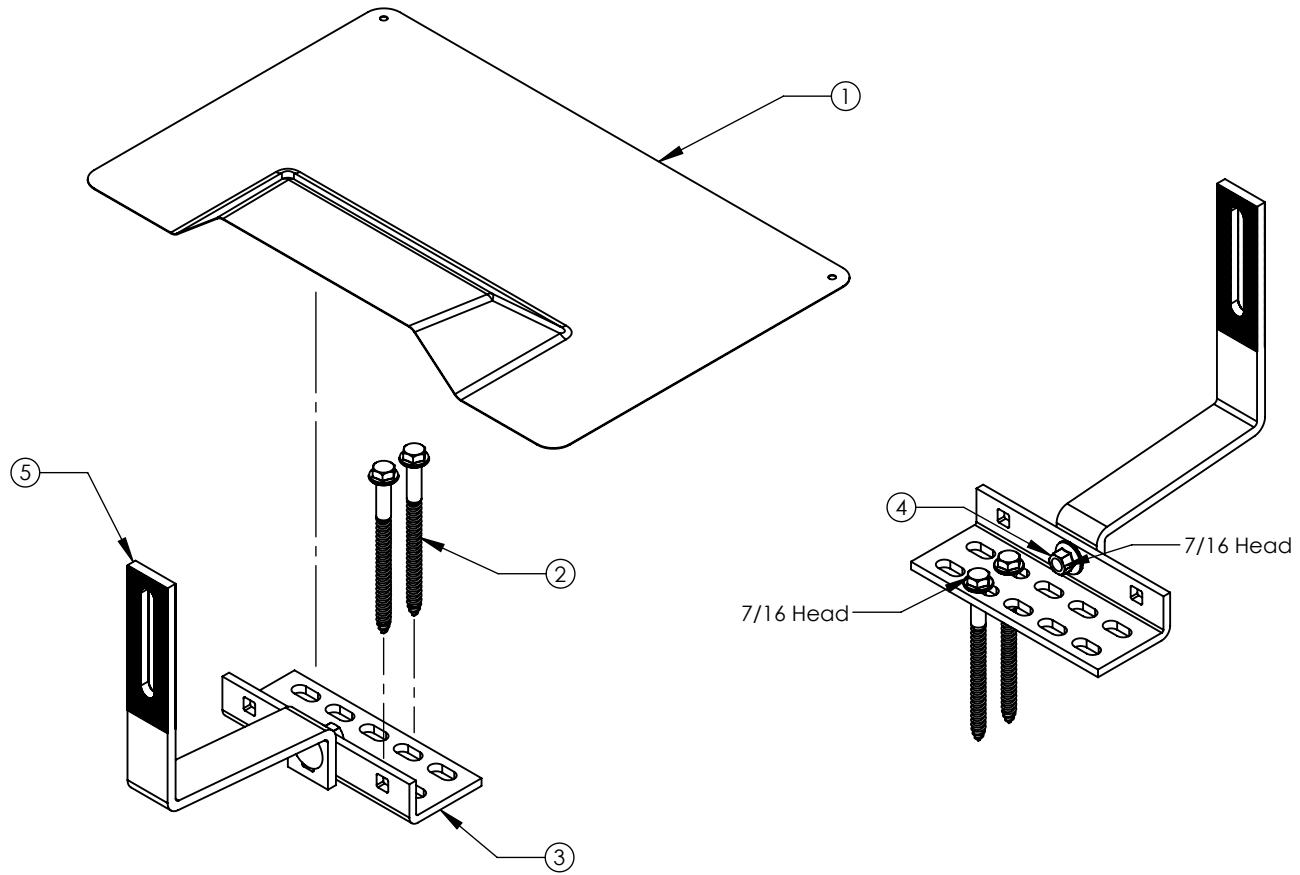
Figure 1

Sincerely,



Gang Xuan, SE
Senior Structural Engineer

EXHIBIT: EX-0016



ITEM NO.	DESCRIPTION
1	ASSY, FLASHING
2	BOLT, LAG 5/16 X 4"
3	ASSY, BASE
4	BOLT, CARRIAGE 5/16 x 1"
5	ASSY, ALL TILE HOOK



IRONRIDGE

ASSY, All Tile Hook
DWG. NO. EX-0016