Structural ENGINUITY INC
Ingenuity in Engineering

August 9, 2019

Attn: Mr. Marshall Green
Quick Mount PV
2700 Mitchell Dr.
Walnut Creek, CA, 94598

RE: Quick Mount PV – QRail Tilt System
PV Module Racking System — SEI Project No.: 18500.00
State of Arizona Certification Letter

Dear Mr. Green:

Structural Enginuity Inc. (SEI) has completed its review of the Quick Mount PV – QRail Tilt System for typical installations in the state of Arizona. The QRail Tilt System is compliant with the sections of the following design references and codes when installed per the conditions and design criteria delineated herein.

Design References and Codes:

- ASCE/7-05, 7-10, & 7-16 – Minimum Design Loads for Buildings and Other Structures
- SEAOC PV2-2012 & PV2-2017
- 2015 Aluminum Design Manual, by the Aluminum Association
- Materials information and section and details provided by Quick Mount PV as appendages to this letter
- 2009, 2012, 2015, & 2018 International Building Code and 2009, 2012, 2015, & 2018 International Residential Code
- AC428, Acceptance Criteria for Modular Framing Systems Used to Support Photovoltaic (PV) Modules, November 2012 by ICC-ES

General Mounting System and Analysis Overview:

The QRail Tilt System consists of solar PV modules mounted at an angle between 2 rows of aluminum rails (either the QRail Standard or QRail Light) and attached to a flat (slope less than 7 degrees) roof using QBase mounts. The rails span between points of attachment to the existing roof structure. The following information summarize the structural analysis performed by SEI in order to certify the QRail Tilt System for the state noted above.

The analysis for certification included the following parameters for the QRail Tilt System.

- Maximum Module Length = 82”
- Maximum Module Angle = 35 degrees
- Portrait & Landscape orientation of photovoltaic modules
- Maximum Height Above Roof of Low Edge of Module = 2’
- Maximum Height Above Roof of High Edge of Module = 4’
- Minimum Gap Between Modules = 0.25”

- Wind Analysis:
  - Wind Category: B, C, and D
  - Wind Directionality Factor (Kd) = 0.85
  - Topographic Factor (Kzt) = 1
- Snow Analysis:
  - Snow Exposure Factor (Ce) = 1.0
  - Thermal Factor (Ct) = 1.2
  - Importance Factor (Is) = 1
- Seismic Analysis:
  - Seismic Design Category E or less
  - Importance Factor (Ip) = 1
  - Amplification Factor (ap) = 1.0 per ICC-AC428
  - Component Response Modification Factor (Rp) = 1.5 per ICC-AC 428

Applicable loading combinations consisting of dead, wind, snow, and seismic loads in accordance with the governing code requirements were used to determine allowable rail span lengths, based on bending stress capacity, shear capacity, axial capacity, and an assumption of a single-span condition with an allowable deflection of L/60. Design wind pressures were determined using Components and Cladding calculations per ASCE in use with SEAOC and in conjunction with the loading parameters noted above. Applicable roof snow load shall be based on ground snow load maps, equations, and factors of ASCE and applicable sections of the International Building Code for the location of the project in combination with the loading parameters noted above.

It should be noted that the analysis was limited to the capacity of the rails and attachments of the QRail Tilt System. Analysis of the roof structure itself shall be the responsibility of the installer, and should be reviewed and approved by a registered design professional where required by the local authority having jurisdiction.

Installation Notes:

The Tilt Mount System shall be installed with the following guidelines to be in compliance with attached span tables:

- Rails shall be continuous and not spliced over a minimum of 2 supports.
- The minimum horizontal clear distance between the modules and the edge of the roof shall be the larger of 2 times the height of the top edge of the modules minus the height of the parapet or 4 ft.
- Maximum end cantilever of aluminum support rail shall not exceed 1/3 of allowable span in the roof wind pressure zone of the cantilever.
- Actual span length resultant loads must be within the structural capacity of the roof members supporting the solar PV array.

Structural ENGINUITY INC
Ingenuity in Engineering

Conclusion and Certification Summary:

Based on the structural analysis performed by SEI in regards to the loading parameters specified above for QRail Tilt System, SEI has provided a QMPV Tilt Calculator. The calculator accounts for the multiple roof and loading conditions and array sizes and may be used to provide span lengths based on the loading conditions listed above. The attached design guide further explains the design process used by the QMPV Tilt Calculator.

This letter is to certify that the loading criteria and design basis used for the structural analysis of the QRail Tilt System is validated and performed in compliance with the governing building codes for the state of Arizona.

Please contact our office if you have any further questions relating to this matter.

Sincerely,

Peter Martin
Engineer III
pmartin@structuralenginuityinc.com

Allan T. Myket, P.E.
President/Founder
amyket@structuralenginuityinc.com

Structural Enginuity Inc.

Registered Professional Engineer (Structural)
CERTIFICATE NO. 59440
ALLAN T. MYKET
Date Signed 8/9/19
ARIZONA U.S.A.

Exp Date: 3/31/2021

Structural ENGINUITY INC
Ingenuity in Engineering

September 6, 2019

Attn: Mr. Marshall Green
Quick Mount PV
2700 Mitchell Dr.
Walnut Creek, CA, 94598

RE: Quick Mount PV – Tilt Mount System
PV Panel Racking System
State of California Certification Letter

SEI Project No.: 18500.00

Dear Mr. Green:

Structural Enginuity Inc. (SEI) has completed its review of the Quick Mount PV – Tilt Mount PV Panel Racking System for typical installations in the United States. The Tilt Mount System is compliant with the sections of the following design references and codes when installed per the conditions and design criteria delineated herein.

Design References and Codes:

- ASCE/7-05, 7-10, & 7-16 – Minimum Design Loads for Buildings and Other Structures
- SEAOC PV2-2012 & PV2-2017
- 2015 Aluminum Design Manual, by the Aluminum Association
- Materials information and section and details provided by Quick Mount PV as appendages to this letter
- 2015 International Building Code and 2015 International Residential Code
- AC428, Acceptance Criteria for Modular Framing Systems Used to Support Photovoltaic (PV) Modules, November 2012 by ICC-ES

Furthermore, SEI has provided a QMPV Tilt Calculator to generate custom span and attachment spacing values, as well as attachment reaction forces, for various location and building specific cases. The following is a design guide for the QMPV Tilt Tool, explaining the required inputs and the procedure used to calculate the tool outputs. Please note that this Design Guide references ASCE 7-10 and SEAOC PV2-2012. The tool can also be used with ASCE 7-05, ASCE 7-16, and SEAOC PV2-2017 codes. Please use the equivalent chapters and equations to the ASCE 7-10 and SEAOC PV2-2012 references shown in the following guide for these codes.

1815 W. Diehl Rd, Suite 100, Naperville, IL 60563
630-219-1997 (P)
www.structuralenginuityinc.com

Structural ENGINUITY INC
Ingenuity in Engineering

System Requirements:

The QMPV Tilt System is designed to meet the requirements set forth in SEAOC PV2 and ASCE 7-16 for Rooftop Solar Panels on Buildings with Flat Roofs with Slopes Less Than 7 Degrees. As such, when designing an array with the QMPV Tilt Tool, the following conditions shall be met:

- Maximum Roof Slope = 7 Degrees
- Maximum Module Length = 80.4" (When in Portrait orientation only)
- Maximum Module Angle = 35 degrees
- Maximum Height Above Roof of Low Edge of Module = 2'
- Maximum Height Above Roof of High Edge of Module = 4'
- Minimum Gap Between Panels = 0.25"

Required Information and Inputs:

The QMPV Tilt System can be used in a large variety of conditions. In order to properly calculate loads on the system, the following information is needed specific to the array being analyzed.

Building Information

- Mean Roof Height: For buildings with multiple roof heights, the roof on which the array is located shall be used.
- Building Length and Width: The overall plan dimensions of the building are needed. It does not matter which is set as length or width as long as both dimensions are entered.
- Parapet height: For buildings with multiple roofs, the parapet for the roof on which the array is located shall be used.

Module Information

- Module Length, Width, and Weight
- Module Orientation: Portrait or Landscape

Array Information

- Spacing between array rows and spacing between individual modules
- Number of rows and columns for each array
- Spacing between rows and modules
- Module tilt angle
- Edge distances from the array to each building edge

Racking Information

- Rail type
- Attachment type

Loading Information

- The applied loads are dependent on the project location and building code
- Snow load – The ground snow load of the project location is needed
- Wind Load – The applicable wind speed determined based on location and exposure category is need
- Seismic loads – The S_{DS} value for the project location is needed

Load Determination

Once the required information has been acquired, loads are determined per the applicable code. The below descriptions correspond to the ASCE 7-10 code. The equivalent sections and equations should be followed if ASCE 7-05 or ASCE 7-16 are being used.

Dead Loads

The dead load of the system is conservatively assumed to be 4 psf. This accounts for all components of the system including the PV modules, rail system, and attachments. This value may be modified in circumstances where a particularly light weight or heavy PV module are being used.

Snow Loads

The applied snow loads are calculated from equation 7.3-1 of ASCE 7-10. The snow load always acts downwards vertically.

$$p_f = 0.7 C_e C_t I_s p_g \qquad (7.3\text{-}1)$$

- C_e = 1.0 per Table 7-2 of ASCE 7-10
- C_t = 1.2 per Table 7-3 of ASCE 7-10
- I_s = 1.0 per Table 1.5-2 of ASCE 7-10
- p_g is a required input based on the project location and can be determined using Figure 7-1 of ASCE 7-10

Wind Loads

The applied wind load is determined using a combination of ASCE and SEAOC PV-2. Wind always acts perpendicular to the PV modules. The Wind Velocity Pressure (q_h) must first be calculated per Equation 30.3-1 of ASCE 7-10.

$$q_z = 0.00256\ K_z K_{zt} K_d V^2\ (\text{lb/ft}^2) \qquad (30.3\text{-}1)$$

- K_z is determined based on the mean building roof height per Table 30.3-1 of ASCE 7-10
- K_{zt} = 1.0 per section 26.8.2 of ASCE 7-10, this value may need to be updated if the building the array is being installed on is location on or near an isolated hill or ridge
- K_d = 0.85 per Table 26.6-1 of ASCE 7-10

Once the Wind Velocity Pressure has been determined using ASCE 7-10, SEAOC PV2 is used to determine the Design Wind Pressure (p_h). The below descritions correspond with the SEAOC PV-2 2012 document. The equivalent sections and equations should be followed for SEAOC PV2-2017.

The Design Wind Pressure is calculated using equation 29.9-1 of SEAOC PV2-12

$$p = q_h\,(GC_{rn}) \quad (lb/ft^2)\ (N/m^2) \qquad (29.9\text{-}1)$$

- q_h was calculated previously using ASCE 7-10 equation 30.3-1
- GC_{rn} is determined using SEAOC PV2-2012 Figure 29.9-1

(GC_{rn}): Net pressure coefficient, equal to $\gamma_p E[(GC_{rn})_{nom}(\gamma_c)]$

The value of GC_{rn} will vary for each rail section. It is recommended to use software such as the QMPV Tilt Calculator to determine this value for each section of rail in order to simplify large amounts of calculations and ensure an efficient design. And explanation of the factors used is described below:

- γ_p is determined using the height of the building parapet.
- E is an edge factor. It is determined using the height of the panel and the distance to the nearest building edge. This factor is only applied to panels on an edge of the array and varies depending on the direction the module is facing in respect to the building edge.
- $(GC_{rn})_{nom}$ is determined using figures in SEAOC PV-2. The value changes based on the module tilt angle, the location of the array on the building, and the Normalized Wind Area affecting the rail. This normalized area is determined using the module dimensions, the distance the rail spans between attachments, and the overall dimensions of the building.
- γ_c is determined based on the module dimensions.

The QMPV Tile Calculator is capable of quickly determining the GCrn value for each section of rail within the array in order to calculate accurate design values and ensure the rail and attachment system are optimized on a project specific basis.

Seismic Loads

The design seismic loads include both a lateral and vertical component. The lateral component is determined using equations 13.3-1, 13.3-2, & 13.3-3 of ASCE 7-10.

$$F_P = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)}\left(1 + 2\frac{z}{h}\right) \qquad (13.3\text{-}1)$$

F_p is not required to be taken as greater than

$$F_p = 1.6 S_{DS} I_p W_p \qquad (13.3\text{-}2)$$

and F_p shall not be taken as less than

$$F_p = 0.3 S_{DS} I_p W_p \qquad (13.3\text{-}3)$$

- S_{DS} is a required input based on the project location
- W_p is determined based on the weight of system
- R_p = 1.5 per ICC-AC 428
- A_p = 1.0 per ICC-AC 428
- I_p = 1.0

Structural ENGINUITY INC
Ingenuity in Engineering

Applying Loads to the Racking System

Once the design loads have been calculated they must be applied to the rail system. The loads are combined per section 2.4.1 of ASCE 7-10.

1. D
2. $D + L$
3. $D + (L_r \text{ or } S \text{ or } R)$
4. $D + 0.75L + 0.75(L_r \text{ or } S \text{ or } R)$
5. $D + (0.6W \text{ or } 0.7E)$

6a. $D + 0.75L + 0.75(0.6W) + 0.75(L_r \text{ or } S \text{ or } R)$

6b. $D + 0.75L + 0.75(0.7E) + 0.75S$

7. $0.6D + 0.6W$
8. $0.6D + 0.7E$

Combinations 2 and 4 will not control for the rail system, but all other load combinations must be analyzed.

Once the loads have been determined and combined per the ASCE provisions, the rails must be checked for bending stress capacity, shear capacity, axial capacity, and an allowable deflection of L/60. This analysis is based on code provisions of the 2015 Aluminum Design Manual. The QMPV Tilt calculator automates this analysis and determines the optimal rail length to the nearest inch.

The rail attachments can be analyzed once the rail length has been determined. The allowable capacities of the attachments are based on lab testing and is specific to each attachment product. The loads from the rails must be applied to the attachments, if the loads exceed the capacities of the attachments the rail spans must be reduced. The QMPV Tilt calculator analyzes the attachments at both the high and low rails and reduces spans where necessary. In addition, attachment reactions are provided to be used by the Structural Engineer responsible for determining the capacities of the existing building supporting the PV array.

Conclusion:

As described above, the analysis and design of a rail mounted solar PV array can become complicated and time consuming, especially for more unique shapes and sizes of arrays. SEI has provided the QMPV Tilt Calculator in order to automate this process. In all cases, the QMPV Tilt Calculator outputs shall be verified by a licensed design professional. Depending on the project jurisdiction, additional code provisions may apply. In addition, the QMPV Tilt Calculator does not determine the capacity of the structure supporting the solar PV arrays.

Please contact our office if you have any further questions relating to this matter.

Sincerely,

Peter Martin
Engineer III
pmartin@structuralenginuityinc.com

Mark A. Tryon, P.E.
Vice President/Founder
mtryon@structuralenginuityinc.com

Structural Enginuity Inc.