**Product Bulletin:**

## Thermal Expansion Consideration for Solar Structures

### Overview

Thermal expansion is one of many important structural design considerations. In fact virtually all materials exhibit some linear dimensional change as a function of temperature change and accordingly, a Coefficient of Thermal Expansion is a material property that is typically determined by empirical methods. The Coefficient of Thermal Expansion (CTE) is often expressed in terms of a constant per length (ft) per degree F.

- The CTE for Steel is .0000065 / Ft-degree F
- The CTE for Aluminum is .000013 / Ft-degree F

### Application

Anticipating the field considerations and understanding the consequences of thermal expansion is the key to effectively using CTE's as a design factor.

For example, railroad rails are long and experience a wide range of temperature changes. Unless there are provisions for thermal expansion, it is possible that rails may actually lift and or buckle under extreme conditions. Bridge design is similar in that the ends of the span are fixed and accordingly, thermal expansion (or contraction) will cause the bridge to either increase or decrease in length and thus expansion joints need to be designed to accommodate the change in dimension. Otherwise, damage to the pavement or structure could occur.

Solar Canopies on the other hand are unlike bridges or rails in that the ends are "not fixed' but permitted to expand or contract without effective restriction. In other words, while the columns are bolted to foundations which are certainly pinned, the roof elastically (freely) expands and contracts as temperature changes and therefore effectively relieves much or all of the induced stresses within the structure.

Figure 1 below is a schematic of a structure that can and will expand accordingly as the temperature increases. Using the Coefficient of Thermal Expansion for steel, the change in length to a 150' long canopy from a 40 degree F temperature change can be calculated:

Delta L = .0000065 x 12 x 150 x 40 = .468" or about ½" overall. Since the structure is not restricted on either end, it's reasonable to conclude the structure will expand uniformly expanding the canopy length at the roof line by about .25", well within the expected and allowable deflection limits. Additionally, each bay has slotted purlin connections that would allow the racking, modules and overall solar array to float over the structural frame. That detail is shown in Figure 1B below.

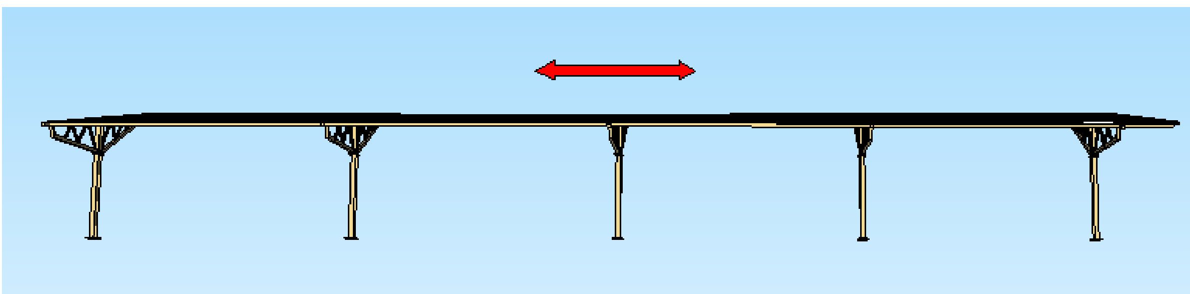

Figure 1

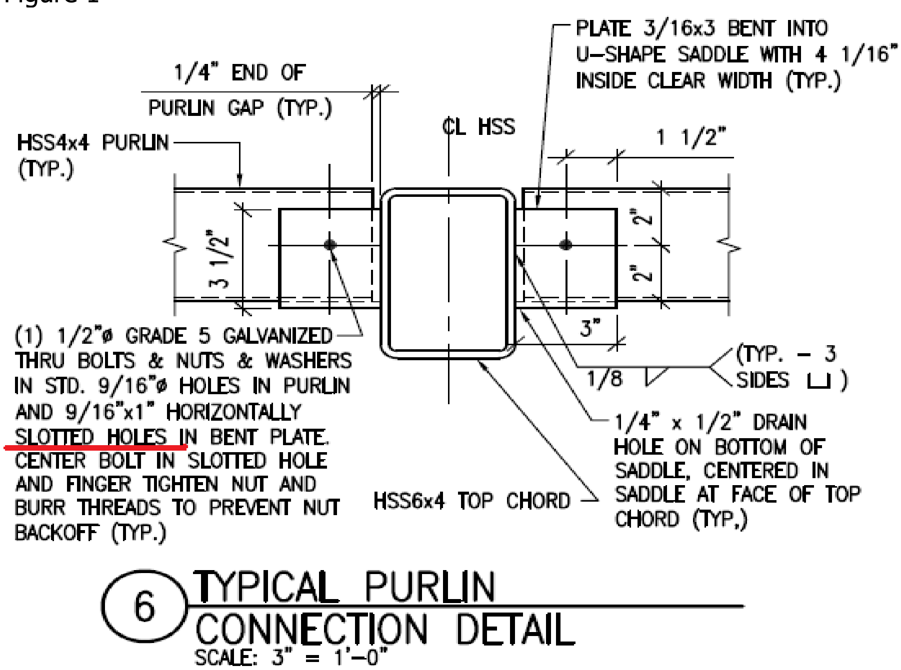


Figure 1B

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## Racking Systems, Modules and Attachment to Steel Structure

Unlike some other canopy designs with modules connected directly to purlins, Structural Solar LLC utilizes an engineered aluminum racking system that attaches to the steel structure via L-Foot connections. While attached to the steel, the racking system acts somewhat independently when connected to the solar modules. As Aluminum and Steel have different coefficients of thermal expansion, this transition allows the two systems to expand or contract at slightly different rates.

Figures 2, 3 and 4 below show how the modules sit / mount on the aluminum rail (turquoise) and how the aluminum rail attaches to the steel purlin (gold) via an L-foot connection.

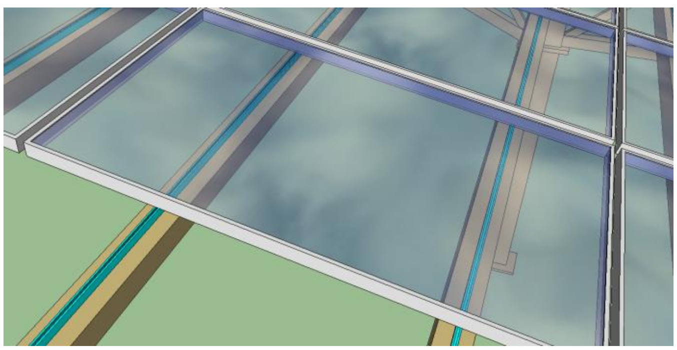

Figure 2

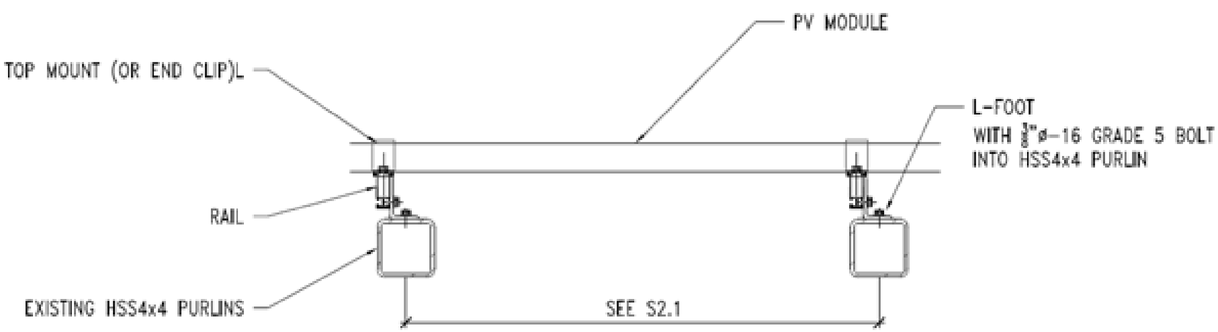


Figure 3

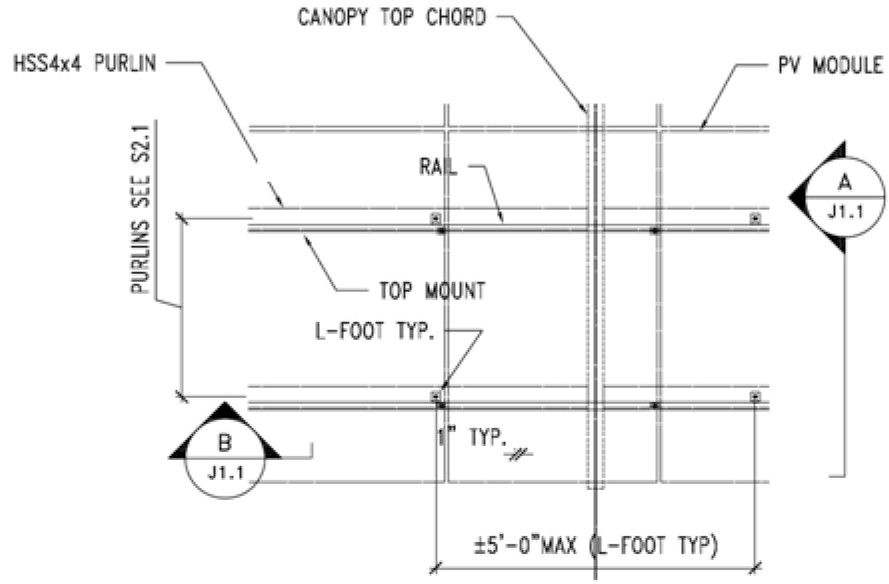


Figure 4

From Figures 2 and 4, the aluminum rail is shown to run directly on top of the steel purlin and connected via an L foot on 5′ (60″) centers. Using the same example of a 40 degree F increase in temperature of the rail, the differential expansion (between the aluminum and steel) over a 60″ length is 0.0156″. That means the aluminum rail will expand or increase in length by about 1/64″ over the 5′ length which is insignificant and incapable of causing damage to any structural component, fastener or fastened connection.

## Solar Module and Racking System Connection

The analysis thus far has dealt with the structure and racking system connection to the structure and its behavior as a function of temperature change. And essentially, all of these components are under the solar panel where temperature change will be driven more by gradual ambient changes in temperature. The same is not true of solar panels which are by design, exposed to the most direct and intense sunlight (radiation) possible. As a result, the potential thermal impact directly on the module surface by the sun is significant. Since panel efficiency decreases with increasing temperature, all leading solar panel manufacturers design the module to dissipate heat quickly. In fact the aluminum frame is typically designed with a rear "fin" that acts to dissipate the heat directly and also provides air space beneath the module and provides for convective losses, a situation which is far more severe on a roof mount versus an open canopy. In fact, most module manufacturers address Normal Operating Cell Temperature (NOCT) as a key design feature of the product.

Figure 5 below shows a typical rail mounted (clamped) according to good solar installation practices at four (4) points along the long side of the panel.

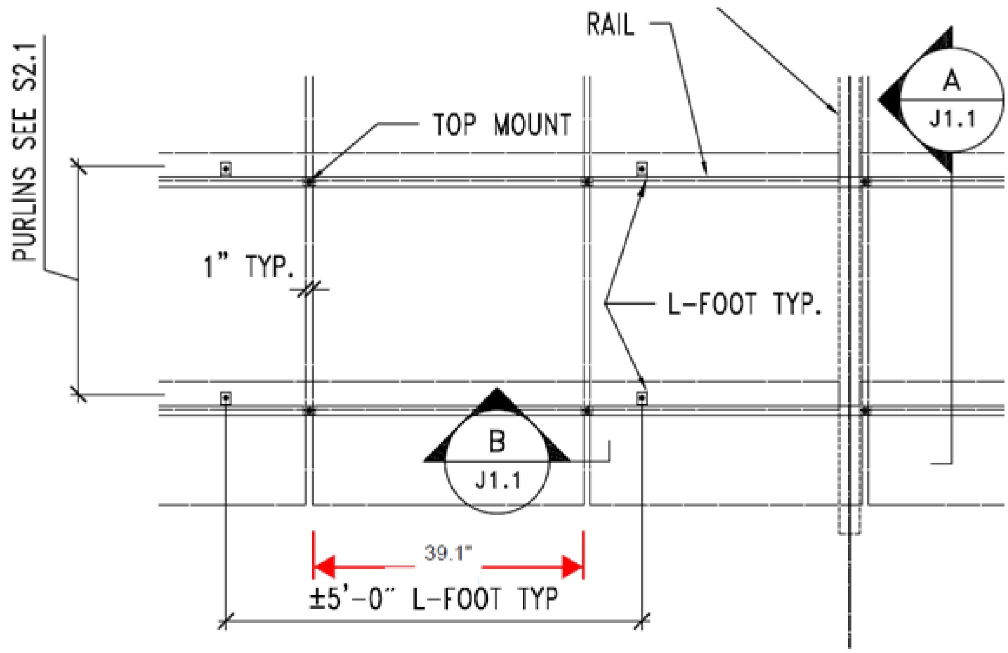


Figure 5

Consider the following extreme situation:

The solar module is 39.1" wide and the temperature of the top surface of the module (i.e. glass) is 180 degrees F while the aluminum rail is lower, approximately at 140 Degrees F.

The aluminum rail that the module is effectively clamped to is shaded by the module and it is 90 degrees F for a temperature differential of 50 degrees.

Relative to the rail, the module (frame) will try to expand by 39.1 x 50 x 0.000013 = 0.025" or about 25 thousands of an inch and exert force against the clip (and adjacent module) that effectively restricts its expansion. Accordingly, the module must either flex within its pinned connections or compress within its mount. Under extreme cold conditions, the module will want to contract from its pinned connection.

In both cases, solar modules are designed to absorb this expansion or contraction. Figure 6 below is the cross sectional view of a Sharp Solar module and shows a typical side seal which not only seals the edge of the laminated solar cell / tempered glass with polyimide sheet and back-sheet but allows for absorption of minor dimensional changes due to temperature induced and/or other external forces. The frame also serves as a thin section "fin" that allows heat to dissipate from the solar cell and provides an "air space" when modules are installed on a roof.

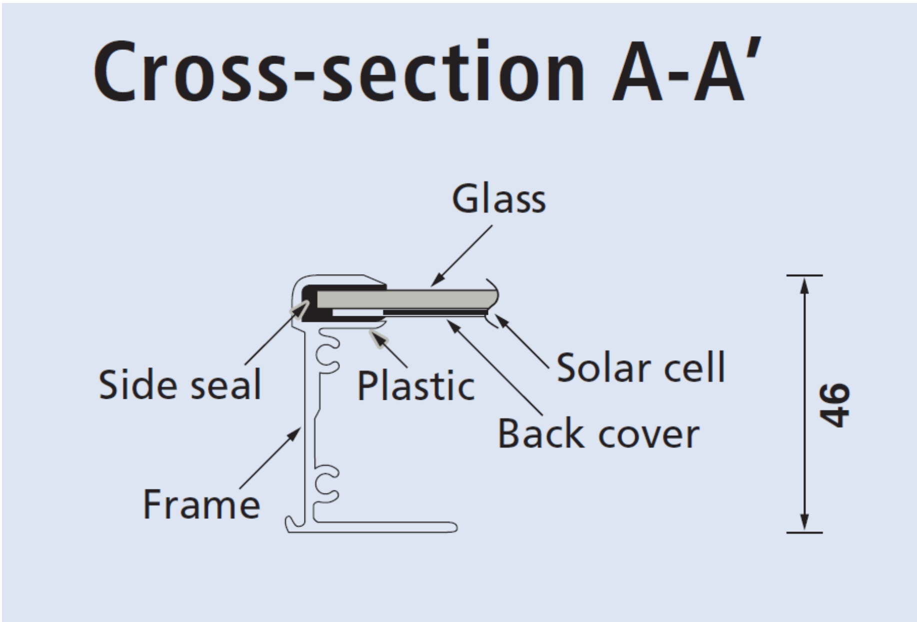


Figure 6

## Conclusions

1. Solar Canopies, designed as stand-alone structures typically do not require expansion joint since they can freely expand and contract on their own (not fixed between two points)

2. Structural Design may provide for expansion joints in building structures that exceed 300’ in length

3. Canopy length aside, Structural Solar LLC provides for expansion / contraction with slotted holes in the purlins that extend between truss frames. Aluminum rails are connected to the purlins via an L-Foot connection which provides the aluminum rail / purlins to incrementally expand and contract over the length of the canopy

4. Solar Modules are designed to absorb and dissipate large amounts of radiated sunlight / heat. Unlike “direct connected” solar panels to a steel purlin, solar modules with aluminum frames that are fastened (clamped) to aluminum rails, will have similar thermal expansion and will expand and contract together. To the extent there is a differential in temperatures between the module and racking, the change in length over the short span of a solar panel (39.1”) is negligible and easily absorbed by the side seal / design of the solar module.

5. The stresses created between the aluminum framed module and the aluminum rail due to different temperatures (Delta T) is not impacted or improved by providing expansion joints on the rails.