Product Bulletin:

Design Criteria for Structural Solar Supports for Parking Canopies Installations

Overview

Effective Solar Canopy design for parking lot installations must / should meet certain reasonable standards for durability, functionality, attractiveness and affordability. Failure to address all four (4) criteria typically results in a project that either does not pencil out economically or worse, does not provide years of trouble free performance.

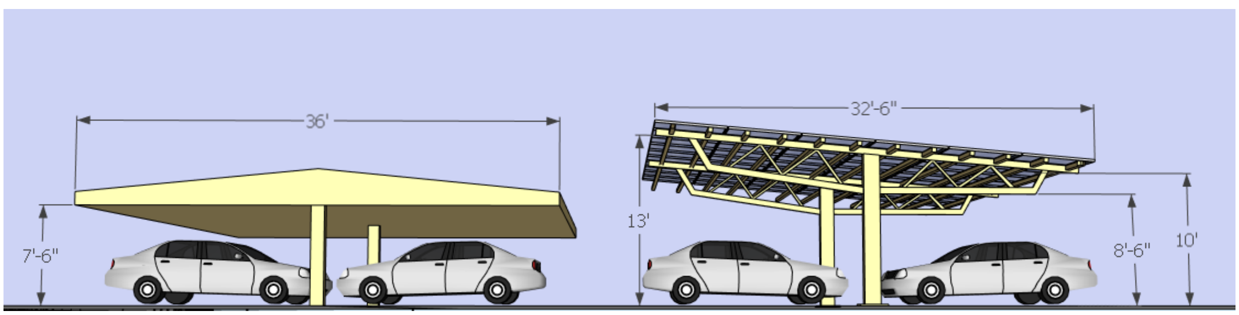
- **Durability**: Simply defined, the ability of the structure to be low or no maintenance for 20 to 25 years.
- **Functionality**: Once installed, the ability to provide adequate structural framework for solar modules while also providing for vehicular traffic and logistics under and around the canopy. Canopy columns and trusses should not interfere with parked cars, car doors, snow plows or emergency vehicle traffic around the site.
- **Attractiveness**: Aesthetic appeal is a subjective quality but consistent clean design lines, scale and proportion, long lasting coatings and quality workmanship will create a sustainable and inspirational image.
- **Affordability**: Solar canopies are simply an alternative to roof and ground mounted solar and effective design is also economical design which is competitive with other installation methods. In fact, as its primary purpose is that of a solar support, it is Structural Solar LLC's opinion that solar canopies qualify as part of the Investment Tax Credit.

In effect, Solar Canopies are <u>elevated structural solar supports</u> with tremendous benefit to Solar Developers who need a cost effective and durable structural solution for large solar arrays. When installed in parking lots, canopies can be sized and favorably oriented to accommodate large solar arrays as an alternative to rooftop solar installations. But there is a distinction between covered parking and structural solar supports and this Product Bulletin examines the critical differences and design considerations for each.

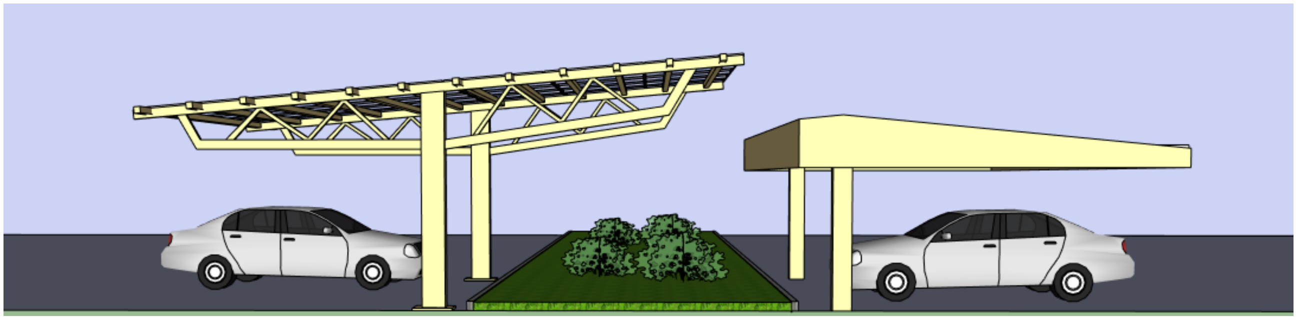
Design – Structural Dimensions

Parking spaces may be diagonal or perpendicular to the drive aisle and the spaces may be "one space deep" along the perimeter of a property or "head-to-head parking (two deep) along interior aisle parking areas. Typical parking spaces are 9' wide by 18' deep. Since solar canopies require foundations and columns on periodic centers (e.g. every 18' or 27'), longer and wider canopies generally result in more favorable economics.

With covered parking canopies, the intent is to provide "asset protection" against hail, sun, ice and snow. Typically, parking structures are as low as possible, symmetrical and are designed to cover the entire space whereas solar canopies are elevated, provide additional eave clearance, have a tilted roof and provide coverage only to the extent of the solar module coverage. Additionally, for most commercially available solar modules, (6) rows of modules in portrait orientation will result in a canopy between 32'-33' (out-to-out) width which is safely inside the parking area and away from the drive aisle. And even a modest tilt of 5 degrees results in the higher eave clearance on the order of 13'. Clearly, "asset protection" or protection for vehicles is not a design consideration for structural solar supports.



Solar canopies should only be installed to the extent they are required to support the solar array. Typically, successful developers will select the surface lot/s which have the most favorable solar orientation and are also nearest to the point of electrical connection. The longest and widest solar canopies will result in the most favorable economics. Trenching generally occurs from one canopy to the other but only at one point as conduit runs within each canopy is typically along the truss and purlins. Moreover, wider canopies are often installed along perimeter parking areas as shown below reinforcing the notion that efficient solar design seeks only to establish the lowest cost footprint.



Eave Height: for Emergency Vehicles and Snow Plows

There is no perfect answer to the question of eave height required for oversize vehicles. The legal street limit for vehicles is 13’-6” so designing for 14’ nominal clearance is the only way to prevent the possibility of contact with the canopy. Unfortunately, depending on the tilt, the upper eave height will be at least 19’ / 20’ (or higher) and drive structural / foundation costs higher by nearly 50%. Accordingly, “affordability” is severely impacted. The more rational approach is to exercise risk management. By slightly elevating the eave clearance and maintaining the eave well within the parking area and away from the drive aisle, there is less chance of contact by a snow plow operator. Likewise, standard height canopies will be more “visible” and obvious to a snow plow operator. Well placed bollards or clearance signs will further discourage operators from passing too close to the canopies. Finally, solar canopies without a metal deck will act much like an overhead heated sidewalk, melting snow and clearing the array without mechanical intervention and without icicle formation. From that perspective, the lower the canopy, the less likely that drifting snow will occur underneath. There is ample experience (and evidence) with standard height solar canopies (in the snow-belt) to suggest that excessively elevated structures are unnecessary, costly and architecturally unsightly.

5 degree slope, (standard) 8’-6” clearance structures 1 day after 22” snowfall

Design – Loading and Construction

Solar Canopies (or Elevated Structural Supports) are designed to site-specific snow, wind and seismic loads and take into consideration the dead loads of the rail and modules as well as other live loads. Since vehicles park under the structure, efficiently designed systems will have a single line of columns placed between (and not in front of) the parking spaces. Cantilevered structures will utilize a drilled pier foundation or spread footer to resist the turn-over force. Columns are typically placed every 18' feet or 27' (2 or 3 parking spaces) apart.

Design – Solar Modules as the Roof

One of the most significant differences between solar canopies and parking canopies is the roof itself. Solar canopies use the solar modules connected to the racking system as the roof. There is typically one inch around each of the modules so there is no attempt to "waterproof" the structures. Once again, there is distinction between asset protection provided by parking canopies versus solar canopies with primary intended purpose as a structural solar support (Investment Tax Credit). And there are notable additional advantages and benefits as a result.

- Solar Canopies (Structural Solar Supports) have a lower installed cost if the metal deck and labor to install it is eliminated

- Solar Canopies (Structural Solar Supports) are a "green" solution to large unproductive paved parking areas. Instead of having a massive heat sink, solar canopies provide shade while allowing filtered light and water to pass through. Accordingly, an existing surface lot is not negatively impacted whereas a metal roof generally necessitates gutters, downspouts and underground culverts to carry the rainwater away to a detention basin.

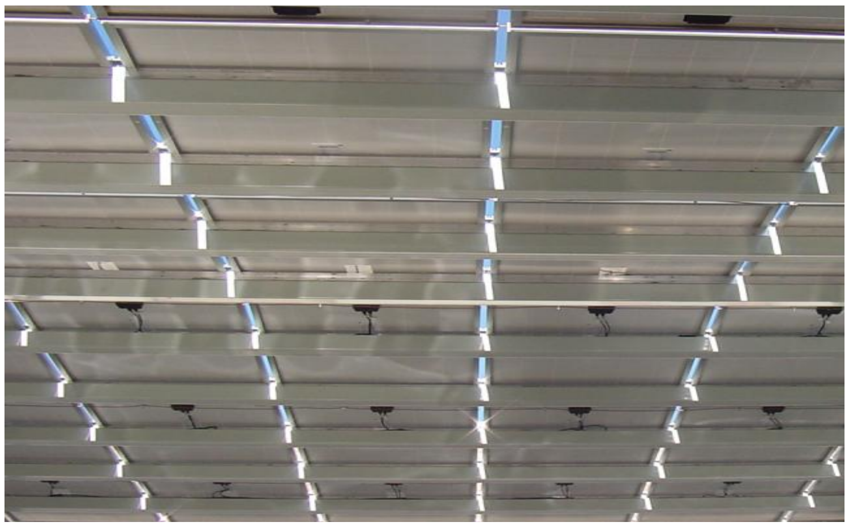
- Solar Canopies (Structural Solar Supports) send a strong, highly visible and inspirational message to customers, shareholders, students and employees about the commitment to clean renewable solar energy.

- Solar Canopies (Structural Solar Supports) provide the framework for future installed electric charging station hardware. With columns on 18' centers, mounted charging stations will always be adjacent to the parking space.

- Solar Canopies (Structural Solar Supports) will stay cooler and operate more efficiently in the summer than roof mounted PV modules. With roof mounted solar, rails must be elevated to provide for air circulation between the modules and metal roof systems.

- Solar Canopies (Structural Solar Supports) will clear snow easily and quickly in the winter. Empirical evidence suggests that solar arrays without an underlying metal deck will clear quickly when the sun comes out and the modules warm. The watery interface between the module surface and the snow allows the snow to slide off, melt harmlessly and clear between the modules. Metal decks on the other hand provide an area underneath the array where snow can

Be mechanically lodged and refreeze. Accordingly, snow and ice are less likely to clear and icicle formation can occur.



Notwithstanding the above discussion regarding snow, a snow or ice rail can be added to the lower eave as a means to temporarily block sheeting ice or snow should it be a concern. Details of the ice rails construction is the subject of a separate product bulletin.

Optional Bolt-On Ice Rail