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Design Guide for Rooftop Solar

INTRODUCTION

Climate change and an increasing awareness on the economics and sustainability of solar energy has brought the use of solar power to the forefront of the building industry. Industry professionals and building owners are increasingly considering solar power as an alternate or supplemental form of energy to their buildings. To remain at the leading edge of sustainability, RJC must provide industry leading information to our clients on the structural impact of solar panels on existing construction, new construction and future installations. The following white paper provides recommendations on the structural design of roofing systems when considering solar panels.

BACKGROUND

Solar power is produced by converting sunlight into electricity. The two major methods of converting sunlight into electricity are photovoltaics (PV) and concentrated solar power (CSP). CSPs utilize mirrors and tracking systems to concentrate sunlight onto a small heat collector. The concentrated heat is then used in conventional power plants [1]. CSPs are typically used for large scale power production plants and are not commonly used in the building industry [2]. PVs are more common in the building industry and utilize the photovoltaic effect to create voltage through certain materials (i.e. silicon, arsenide, etc.) when exposed to light. Essentially, photons of light excite the surface of a semiconductor, knocking electrons loose to become part of a charged electrical field. This field generates an electromotive force that can be tapped by wires into a useable form of electricity. This electricity is typically created and supplied from the roof using solar panels and distributed to the building using electrical wiring [3].

Solar power has both benefits and limitations. Once installed, solar power installations have very low operation and maintenance costs. They do not produce air pollutants or carbon dioxide and have a minimal impact on the environment when located on buildings. It is considered a renewable and fairly sustainable source of energy [6]. However, the sun is not available at all times of the day and during the nights buildings must rely on other forms of energy that come from a power grid. Also, a large surface area is also often required to effectively capture solar energy [2].

Critics of solar power have brought into question the material and energy used to produce PV panels. The production of Solar PVs involves many materials that can be hazards to the environment and to producers through accidental or fugitive emissions especially in regions where low environmental regulations exist. For example, Gallium Arsenide, an important material used in high-efficiency solar cells, is considered a known carcinogen and is listed in The California Environmental Protection Agencies' list of chemicals known to cause cancer. Silicon tetrachloride, a by-product of the production process, is also an extremely toxic substance and can be an extreme environmental hazard. Furthermore, the purification of silicon requires high temperatures which are achieved by highly energy intensive and expensive processes. This process also results in up to 80% of the initial metallurgical grade silicon being lost in the production process. It is imperative that technological innovation lead to safer and more efficient means of producing solar panels. Excessive waste, environmental hazards and potential health hazards resulting from the production process can significantly undermine the environmental gains realized by using solar power [4].

DEVELOPMENT

As with any form of energy conversion, solar conversion has an efficiency rate. Ongoing advances in manufacturing and materials have resulted in current efficiencies of up to 22% for silicon based panels. Cells in the R&D phase have been known to reach up to a 40% efficiency [5]. These advancements in solar technology and improvements in efficiencies are decreasing costs for the use of solar power. Building owners and industry professionals are increasingly considering and using solar panels as a preferred method of energy production in their buildings as efficiencies increase. Designers must design roofing systems for the structural impact of existing, new and future solar panel installations.

TYPES OF SOLAR PANELS

Roof mounted PV Solar Panels are typically supported by racking systems which come in two basic forms. The first is a mechanically fastened system and the second, the more common of the two, is a ballast restrained system. The mechanically fastened system penetrates through the roofing membrane and can be used in pitched roofs and flat roofs. A complete mechanically fastened PV system, including the panels and the racking, weighs between .1 kPa to .24 kPa [7]. The more common systems are restrained on the roof by ballast weights and has no roof penetrations. These systems are typically low profile and are installed on flat roofs. They can be easily installed on the roof surface and are usually more economical. The average weight of a ballast system can range from .17 kPa to .34 kPa which includes the racking, the panels, and the average weight of the ballasts over the surface area of the PV system. The distribution of the ballasts on a roof is typically not uniform and usually has more weight concentrated along the edges and corners of a building, where wind loads are higher. In high seismic zones and post-disaster buildings, special consideration may also be required to prevent sliding of the PV system.

Part of the limitations of solar panels is that the sun is not available at all times of the day and a large surface area is required to capture a usable amount of the suns energy. The larger the surface area required to support the PV system, the greater the potential impact on the building structure.

STRUCTURAL IMPACT (ECONOMICS)

The use of rooftop solar panels increases the superimposed dead load (SDL) of the roofing system and can have varying impact on a building depending on what material is being used for the structural system. For concrete buildings, which intrinsically have a higher structural self-weight, the relative additional weight of the solar panels will generally prove to be an insignificant portion of the building's total structural costs. For a steel or wood low rise building, the relative additional weight from rooftop solar panels can add approximately 10% to the total factored design load of the roof structure. However, when considered in light of the total building costs, this additional costs may prove to be minimal. Unlike new construction, upgrading for solar panels on an existing steel or wood roof can lead to significant renovation costs. In new construction projects, the designer should always consider alerting the owner and design team to the long-term savings that potentially result from designing new roofs for future a PV installation, considering the anticipated rise in the use of solar energy in the future.

STRUCTURAL IMPACT (ECONOMICS) - *continued*

It is also important to note that the installation of solar panels supported by low profile racking systems will typically not increase the snow loading on a structure. The apex of the solar panels is usually designed to be just below that of basic snow depth on a flat roof. The designer should confirm this with the solar panel supplier. Higher profile stand mounted PV arrays can have a greater impact on roof snow loads and wind loads and should be individually investigated. As well, solar panel installations on sloped roofs can act to trap snow that otherwise may have been considered to slide off the roof structure.

Finally, roofing systems installed in new buildings are typically designed to outlast or at least match the average life of the new solar PV system which is about 25 years. Depending on the type of panel installation used this will allow for synergies to be realized in replacement cost.

CONCLUSION

Solar power as an alternative source of energy is coming to the forefront of the building industry. Owners are becoming more aware of the benefits and potential cost savings from the use of PV solar panels. Although solar panels have significant cost savings throughout the life of the building, upgrading existing buildings for solar panels can prove to be a costly undertaking. Considering making buildings solar ready early in the design process of new building projects can save building owners and operators significant future upgrading costs. The design and construction of solar ready buildings will add additional costs to the structural, mechanical and electrical systems and should therefore be discussed with the design team as to the impact on all building systems.

In anticipation of future solar installations, we recommend that new buildings be designed with reserve capacity. An additional superimposed dead load allowance of 0.25 kPa should be used in the design of the roofing structure for future installations. It is important to note that the distribution of ballast weight is not uniform and may, in future, still require localized upgrades to the structure. For this reason, consideration should be given to increasing the superimposed dead load allowance for individual roof members for wood or steel joist systems to 0.50 kPa. This increased allowance would be for the individual joist members only and would not impact the design loading of roof beams, building columns, and supporting foundations.

The owners of solar ready buildings should be advised to work with the solar panel supplier to attempt to stay within the load allowance when designing PV systems to be installed on solar ready buildings.

For assessment of existing buildings and solar panel installations on new buildings, we recommend that designers obtain system specific information on weights from the PV supplier. The information contained in this paper may be used for preliminary design.

To find out more about rooftop solar design, visit: www.rjc.ca or contact **Jeff Rabinovitch** directly.

REFERENCES

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ADDITIONAL RESOURCES

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