

Chapter 2

Structural Loading

Installing PV panels onto roofs introduces hazards that can affect the structural integrity of the roof. Not only does the roof support the dead load of the PV system itself, but also external forces introduce structural loading. Outside installations exposes the PV system and roof assembly to hazardous elements such as wind, hail, snow, debris, and extreme temperatures. These elements introduce substantial loads to the panels and the roof through wind up-lift, thermal expansion, and debris build-up. Substantial loads can lead to the destruction of rooftops and PV systems. “Structural engineers must consider each of these loads separately and in combination to identify the worst-case loading situation” (O’Brien and Banks 2012). There are guidelines on the installation, maintenance, and testing of PV systems that can help prevent failure of the system due to extreme external forces.

Guidelines depend on what type of mounting is used to attach the PV systems to the roof. There are three different methods of mounting PV systems to a roof structure: ballast-only, attached roof-bearing, and structurally attached. Ballast-only PV systems are weighed down by heavy materials such as concrete to keep them located in the same position. Ballast-only systems are not attached to the roof structure. An attached roof-bearing system uses friction clips to secure PV modules to the beams of the framing system. Structurally attached PV systems are attached to the roof structure such that the load path is the same for both upward and downward forces (SEAOC 2012a). The three types of methods: ballast-only, modular, and structurally attached are shown in Figs. 2.1, 2.2 and 2.3 respectively. Each method has advantages and disadvantages with cost and how different hazards will interact with the system.

There is also another method of attachment, which is BIPV (Building Integrated), these systems are in more green buildings and are becoming more popular. This attachment method is most similar to the attached roof bearing system. Because this attachment method is dependent on the building that the PV system is attached to, diverse building designs leads to diverse BIPV systems. The uniqueness of these systems are displayed in Figs. 2.4 and 2.5.

Fig. 2.1 Ballast-only PV system ASCE (2013)

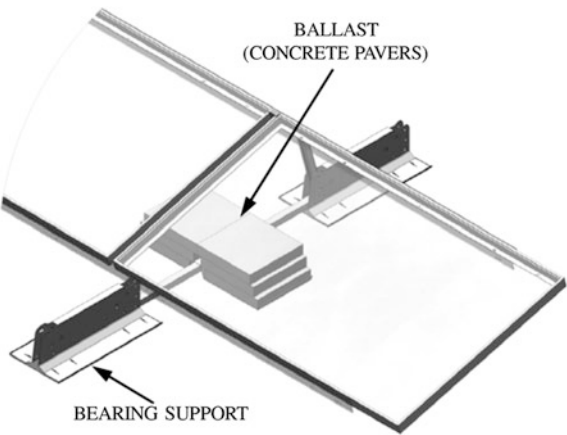


Fig. 2.2 Attached roof-bearing PV system ASCE (2013)

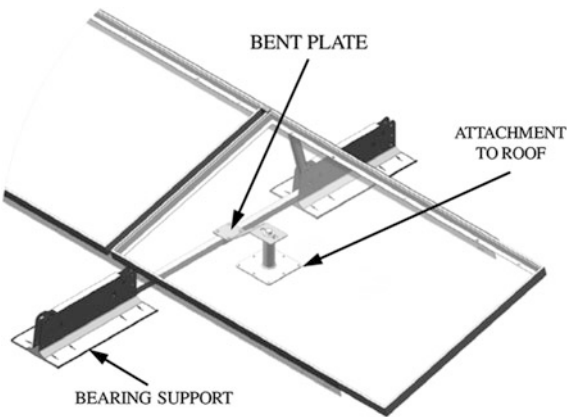


Fig. 2.3 Structurally attached PV system ASCE 2013

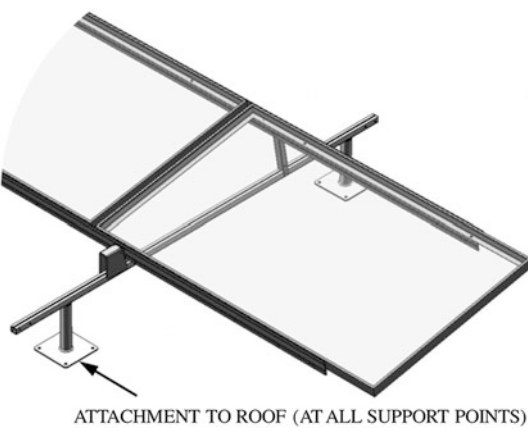




Fig. 2.4 BIPV mounted system (NREL image gallery)



Fig. 2.5 BIPV mounted system (NREL image gallery)

Although these two examples are both BIPV systems they look and behave completely differently. “Building-integrated systems are integral with the roof or lay flat on the roof surface such that they do not affect the roof profile. They may consist of sheets of photovoltaic material attached to the roof membrane by adhesive, for example” (Maffei 2014). The attachment method can significantly affect the loads that are being applied to the structure and how it is being handled. “The roofing industry has learned from experience that ballast-only rooftop equipment does not necessarily remain stationary. Structurally attached equipment is more reliable in this regard” (Kirby 2011). An engineer using calculations found in codes and standards can evaluate structurally attached equipment.

Even though structurally attached equipment can be evaluated by an engineer, the ballast-only systems are difficult to evaluate. There are advantages for ballast-only systems. “Ballast-only systems avoid the cost and increased water intrusion risk caused by the roofing penetrations needed for attached systems” Ward (2013). Ballast-only systems do not puncture the roofing membrane in order to keep them stable, which avoids the issue of water leaking through the holes created by structurally attached equipment. Another aspect of the ballast-only PV systems that creates a hazard for the roofing structure is all the added weight of the ballasting. A roof needs to be able to support not only the PV systems, but also the heavy ballasts that are used to hold down the PV systems. As stated before, the structural loading of the PV systems can be significantly increased when combined with external forces such as wind.

Modular systems are even more difficult to evaluate than ballast-only systems. They are attached to the building by screws, clips, or adhesives. A variation of the attached roof-bearing type is one in which an anchor is used to secure the pedestals of the solar panels to the roof deck as opposed to the roof framing. In that case, the designers should consider the load path for the wind uplift load transferring from the anchor through the deck into the secondary structural framing supporting the deck.

Structural loading is difficult to be calculated for these attachment methods. This method is often used for smaller buildings like residential buildings; therefore this report will focus on ballast-only systems and structurally attached systems.

“It is important that designers and engineers determine loads on modules, fasteners, all components within the racking system and the applied loads to the roof. Loads must ultimately be transferred from the modules to the fasteners and racking system, and ultimately through the roof deck and building structure to the ground. This is common knowledge for most structural engineers. Remember that this likely involves the use of different effective wind areas based on the load-sharing capability of the component under analysis. The wind load rating of the module should not be exceeded. Once wind loads are determined, structural engineers must apply appropriate safety factors and combine loads as required in ASCE 7-05 Section 2. ‘ASCE Standard 7-05 is the standard for evaluating wind forces on structures.’ The ASCE Standard 7-05 “provides requirements for general structural design and includes means for determining dead, live, soil, flood, wind, snow, rain, atmospheric ice, and earthquake loads, and their combinations that are suitable for inclusion in building codes and other documents” (Thomson Reuters 2013).

“In addition to wind loads, other loads such as snow, seismic and gravity (dead load) must be taken into account” (O’Brien and Banks 2012). The load that is provided by the weight of the PV systems themselves is only a portion of the loads that is going to be imposed on the roofing structure.

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