

WHITE PAPER ROOFTOP EQUIPMENT ATTACHMENT

**Rooftop Equipment Attachment- SPRI Task Group on Rooftop Equipment Attachment with Anchors
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ABSTRACT

Without proper attachment, rooftop equipment can become displaced during wind and seismic events. Displaced rooftop equipment can puncture and tear roof membranes allowing water direct access into buildings, causing interior finish damage, operational outages, loss of stored product and proliferation of biological growth. The likelihood of fire is increased if rooftop-mounted equipment, tethered by electrical or gas lines, becomes damaged from movement. Displaced rooftop equipment can also be blown from a roof and injure people on the ground below. This paper will discuss the code-related requirements for rooftop equipment attachment and review historical and current practices.

BACKGROUND

Rooftop equipment often forms an integral part of the building envelope, and therefore, proper attachment of rooftop equipment and utilities is paramount to long-term roof performance. Frequently, rooftop equipment becomes detached and displaced during wind and seismic events. Historically, equipment displacement occurs at forces lower than wind speed from storms classified as hurricanes, tornados, derechos or other major events. When dislodged, windblown equipment can tear roof membranes allowing water to saturate underlying components and enter the building. If that equipment is blown from the roof, it will act as wind-borne debris that can damage buildings, other property and injure people. Additionally, the resilience of a building is compromised as the damaged equipment may no longer function and any active gas or electrically-connected parts can increase fire risk.

Several significant wind events have prompted increased scrutiny of buildings, building enclosures and roofing performance. Hurricane Katrina, a Category 5 Atlantic hurricane, caused over 1,800 fatalities and \$125 billion in damage in late August 2005, heavily impacting the city of New Orleans and the surrounding areas. After initial recovery efforts, the Federal Emergency Management Agency (FEMA) issued "Attachment of Rooftop Equipment in High-Wind Regions" (Hurricane Katrina Recovery Advisory) in May 2006 and later revised it in July 2006. FEMA issued a second advisory specifying attachment of rooftop equipment in high-wind regions in March 2018 following Hurricane Irma, an extremely powerful Cape Verde hurricane and Hurricane Maria, a deadly Category 5 hurricane that devastated the northeastern Caribbean in September 2017. These documents jumpstarted revisions of the building code to include language concerning proper installation of rooftop equipment.

In addition to the focus on proper attachment during high-wind events, several organizations have also issued guidelines and advisories regarding the potential danger from earthquakes. According to the U.S. Geological Survey, more than 143 million Americans living in the 48 contiguous states are exposed to potentially damaging ground shaking from earthquakes. With so many people living and working in a seismic zone, code and design officials have included rooftop equipment attachment requirements for earthquake prone areas. This paper will discuss rooftop equipment attachment for slopes less than 2:12 but has implications for all roofing types.

CODE REQUIREMENTS

The International Building Code (IBC), a model building code developed by the International Code Council (ICC), is an essential tool to preserve public health and safety. The IBC is in use or adopted in all 50 states, the District of Columbia, Guam, Northern Marianas Islands, New York City, the U.S. Virgin Islands and Puerto Rico. Although these codes have given some guidance on rooftop attachment, more is needed to help outline best practices and eventually standardize the installation of attachment systems.

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As early as the 2015 IBC, Chapter 28 Mechanical Systems, Section 2801.1 Scope, references that “Mechanical appliances, equipment and systems shall be constructed, installed and maintained in accordance with the International Mechanical Code (IMC).” Chapter 3 General Regulations, Section 301.15 Wind Resistance, of the 2015 IMC, states “Mechanical equipment, appliances and supports that are exposed to winds shall be designed and installed to resist the wind pressures determined in accordance with the International Building Code.” Chapter 16 of the IBC, Structural Design, Section 1609.1 Wind Loads Applications, states that “Buildings, structures and part thereof shall be designed to withstand the minimum wind loads prescribed herein.” Chapter 16, Section 1609.1.1 Determination of Wind Loads, states that “Wind loads on every building or structure shall be determined in accordance with Chapters 26 and 30 of ASCE 7 or provisions of the alternate all-height method in Section 1609.6.”

In the 2018 IBC, the ICC revised and clarified the requirements of Chapter 28 Mechanical Systems, Section 2801.1 Scope, to read: “The provisions of this chapter, The International Mechanical Code and the International Fuel Gas Code, shall govern the design, construction, erection and installation of mechanical appliances, equipment and systems used in buildings and structures covered by this code.” And like in the 2015 IBC Chapter 16 Structural Design, Section 1609.1 Wind Loads Applications, states that “Buildings, structures and part thereof shall be designed to withstand the minimum wind loads prescribed herein.” But, in Chapter 16 Section 1609.1.1 Determination of Wind Loads, it states that “Wind loads on every building or structure shall be determined in accordance with Chapters 26 and 30 of ASCE 7.” Chapter 35 of the 2018 IBC references the American Society of Civil Engineers / Structural Engineering Institute ASCE 7-16.

Like in 2018, the 2021 IBC and IMC have similar language regarding the design, construction, erection and installation of mechanical appliances, equipment and systems used in buildings and structures. Chapter 16, Section 1609.1.1 Determination of Wind Loads of the 2021 IBC, states that “Wind loads on every building or structure shall be determined in accordance with Chapters 26 and 30 of ASCE 7.” Chapter 35 of the 2021 IBC again references the ASCE 7-16.

Regarding earthquake (seismic) loads in the 2015 IBC Chapter 16 Structural Design, Section 1613.1 Earthquake Loads Scope, “Every structure, and portion thereof, including nonstructural components that are permanently attached to structure and their supports and attachments shall be designed and constructed to resist the effects of earthquake motions in accordance with ASCE 7.” In the 2018 IBC, clarification was added to the code by including “in accordance with Chapters 11, 12, 13, 15, 17 and 18 of ASCE 7 as applicable.” The 2021 IBC has similar language as the 2018 code.

Chapter 29 of ASCE 7-10 does provide some guidance for determination of wind loads on building appurtenances (such as rooftop structures and rooftop equipment) and other structures of all heights (such as solid freestanding walls and freestanding solid signs, chimneys, tanks, open signs, lattice frameworks and trussed towers) using the directional procedure. However, in ASCE 7-16 Chapter 29, step-by-step directions are provided for the determination of wind loads on building appurtenances and other structures in Table 29.1-1. Additionally, there are several equations provided for calculating wind force (F), or pressure (p) on various rooftop equipment and utilities.

- Eq. (29.3-1) for signs and walls
- Eqs. (29.4-2) and (29.4-3) for rooftop structures and equipment
- Eq. (29.4-1) for other structures
- Eq. (29.4-5) or (29.4-7) for rooftop solar panels

In ASCE 7-10 Chapter 13 Seismic Design Requirements For Nonstructural Components, paragraph 13.4 Nonstructural Component Anchorage, it reads that “Nonstructural components and their supports shall be attached (or anchored) to the structure in accordance with the requirements of this section” and “Component attachments shall be bolted, welded or otherwise positively fastened without consideration of frictional resistance produced by the effects of gravity. A continuous load path of sufficient strength and stiffness between the component and the supporting structure shall be provided.” Additional requirements

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include that “The design documents shall include sufficient information relating to the attachments to verify compliance with the requirements of this section.” Paragraph 13.4 of ASCE 7-16 has similar requirements as ASCE 7-10.

The 2022 edition of ASCE 7 now includes a chapter on tornado loads. Wind and its interaction with structures in tornadic storms are vastly different from traditional winds. Therefore, additional considerations for building design and rooftop equipment anchorage are required in areas prone to tornados and for essential facilities (buildings with Risk Categories III or IV). Chapter 32 of ASCE 7-22 outlines the necessary requirements for tornado wind loads, along with relevant tornado resistant design standards and methodologies.

In the 2020 Florida Building Code (FBC) Chapter 15 Roof Assemblies and Rooftop Structures, Section 1522.1 High-Velocity Hurricane Zones - Rooftop Structures and Components, states that “Rooftop structures shall be designed and constructed in accordance with the Florida Building Code” and in 1522.2 Rooftop-Mounted Equipment, “All rooftop equipment shall be secured to the structure in compliance with the loading requirements of Chapter 16 (High Velocity Hurricane Zones). Typically, wood blocks commonly referred to as wood “sleepers” are used to support rooftop equipment or utilities. They are placed between the roof membrane and equipment or utilities. The use of such wood “sleepers” is not permitted based on language in the IBC. Also in the 2020 Florida Building Code, Mechanical Section 305.3 Piping Support, Structural Attachment, states that “Hangers and anchors shall be attached to the building construction in an approved manner.”

TRADITIONAL METHODS of INSTALLATION

Traditional rooftop equipment installation methods include three categories: ballasted, adhered and positively attached. In many cases, these traditional methods of installation are field fabricated, labor intensive and rely on sealants for long-term watertightness. Field fabrication requires the installer to determine the proper design, installation method and compatibility of the material, which can vary significantly based on the application. Many of the traditional attachment methods require regular maintenance to ensure performance, watertight protection and the continuation of the roofing warranty. Table 1 outlines the differences among the five main categories:

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Table 1

Traditional Attachment Method		Challenges
Self-Ballasted	<ul style="list-style-type: none"> Relies on the weight of equipment alone Requires sacrificial layer to protect roof For example: Large HVAC, ducting, plumbing, conduit etc. 	<ul style="list-style-type: none"> Low load resistance for lightweight equipment Highest potential for loss/ damage Not for mechanically attached roofs due to flutter
Ballasted	<ul style="list-style-type: none"> Requires the application of additional weight to increase the frictional resistance Need sacrificial layer to protect roof For example: solar, antennas, satellites, etc. 	<ul style="list-style-type: none"> Does not meet “positively fastened” requirement of ASCE 7 Long-term durability of ballasted materials (sandbags, concrete masonry units (CMU), others) do not match roof service life requirements Cyclic loading could affect the ability of the substrate to withstand loads without damage Not for mechanically attached roofs due to flutter
Adhered	<ul style="list-style-type: none"> Adhered to existing roof membrane with mastics, sealants or other appropriate bonding agents For example: lighting protection, electric conduit, etc. 	<ul style="list-style-type: none"> Material compatibility/long-term performance depends on the stability of the adhesive, including UV-exposure and heat aging Material compatibility varies with every roofing type and brand Typically, lower load resistance due to adhesion being a function of a small force over a large area Not for mechanically attached roofs due to flutter effects acting as a bond-breaker
Structurally Attached	<ul style="list-style-type: none"> Mechanical attachment to roof structure, needs to cut into roof system (membrane, insulation, deck, etc.), then waterproof For example: fall restraint, washing davits, etc. 	<ul style="list-style-type: none"> Removing over square foot of roof assembly is invasive and has potential for leaks with a direct water path into the building Many supports are connected from the underside which is expensive and difficult for occupied spaces Substantial thermal bridging occurs at the support
Roof-deck Attached	<ul style="list-style-type: none"> Mechanical attachment to the roof deck or supporting structure through the roof assembly For example: HVAC, ducting, solar, piping, satellites, guy wires, etc. 	<ul style="list-style-type: none"> Due to component shapes and irregularities, the watertight seal between the membrane cover and equipment support could be problematic Long-term performance generally relies on the flexibility of the sealant, the ability to maintain the sealants condition and the watertightness between the cover, tie-down and equipment support

MARKET OVERVIEW of ENGINEERED ATTACHMENT METHODS

Until recently, rooftop equipment attachment methods have been overlooked and used the traditional methods above. However, some engineered solutions have emerged as effective alternatives to traditional solutions in the industry. These engineered approaches offer several advantages over the traditional methods of installation, including:

- No on-the-roof fabrication
- Specifically designed as anchoring components
- Virtually no added weight to the roof
- Manufacturer-supplied warranties (both component and roofing manufacturer)
- Testing data to verify functionality in handling roof loads
- Standardized connection points and mount

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These engineered solutions can be divided based on attachment method to the roof assembly and waterproofing method as shown in Table 2:

Table 2.

Engineered Attachment Method		Waterproofing
Mechanically Attached	Mechanically attached to roof deck with proper fasteners	Compression seal
		Same flashing system as existing roof
		Compression seal and membrane flashing
		Manufacturer approved liquid flashing products
Heat Welded	Heat welded to existing roof membrane	Non-applicable, zero-roof fastener penetrations

Each category offers a unique approach to addressing the challenges of mounting rooftop equipment. It is critical to evaluate the overall project requirements, including code, wind and seismic loads (tensile, shear and compression) and differential movement when determining the attachment type and functionality. These engineered solutions are in alignment with the current code requirements of:

- Nonstructural components and their supports shall be attached (or anchored) to the structure
- Component attachments shall be bolted, welded or otherwise positively fastened without consideration of frictional resistance produced by the effects of gravity
- A continuous load path of sufficient strength and stiffness between the component and the supporting structure shall be provided
- The use of wood “sleepers” shall not be permitted
- Can be installed using typical traditional roofing methods by experienced professional roofing contractors

BEST PRACTICES

Best practices for rooftop equipment attachment vary by attachment methodology and roof system type. Refer to the manufacturer’s installation instructions and the specified roofing material the manufacturer requires before installing. Also, consider material and component compatibility and its impact on the manufacturer’s warranty. All installation work should be performed by a professional roofing contractor familiar and experienced with installation of the attachment components. Verify the engineered solution is suited to handle the proper loads (i.e., tensile, shear and compression) and ensure proper fastener selection.

CONCLUSIONS

Due to damage caused by rooftop equipment displaced by wind or seismic events, code professionals have included specific design and attachment criteria in the International Building Code and International Mechanical Code. These criteria provide roofing professionals and designers guidance in the calculation of wind and seismic forces and, in some cases, specific attachment criteria. Attachment methods on the market today are engineered to be minimally invasive to the roof system and provide a continuous load path of sufficient strength and stiffness between the component and the supporting structure. The engineered attachment methods address code requirements, minimize potential for property loss and life safety concerns, offering several advantages over the traditional methods of installation:

- No on-the-roof fabrication

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- Intentional design philosophy
- Lower labor cost to install
- Manufacturer supplied warranties
- Testing data to verify functionality in handling roof loads
- Standardized connection points and mounts

The following checklist highlights the key topics to consider for rooftop equipment attachment:

- Research appropriate building codes
- Determine anticipated wind and seismic forces
- Evaluate existing roof system
- Investigate existing roof components for compressive strength and adhesion
- Evaluate fire risk from displaced units or utilities
- Investigate roof warranty terms
- Consult attachment and roof manufacturer's instructions
- Research membrane compatibility with sealant and/or bonding agent
- Analyze attachment system for possible thermal bridging
- Develop loading, travel and protection plan to protect membrane
- Clean, dry and prepare membrane prior to attachment
- Develop final review plan of completed project