

# Rooftop Equipment Maintenance and Attachment in High-Wind Regions



FEMA

HURRICANES IRMA AND MARIA IN PUERTO RICO

Recovery Advisory 1, April 2018

## Purpose and Intended Audience

Observations after the 2017 hurricanes have once again shown that rooftop equipment is often damaged during high winds. Damaged equipment can impair the operation of the facility, and the equipment can detach and become damaging wind-borne debris. In addition, water can enter the facility where equipment was displaced or damaged. The most common problems typically relate to inadequate equipment anchorage, inadequate strength of the equipment itself, and corrosion of equipment and connectors.

The purpose of this Recovery Advisory is to recommend practices that will increase the wind resistance of rooftop equipment in high-wind regions<sup>1</sup> such as Puerto Rico. This guidance is intended for architects, engineers, contractors, building officials, and building owners. Additional detailed criteria can be found in FEMA's *Design Guide for Improving School Safety in Earthquakes, Floods and High Winds*, December 2010 (FEMA P-424, 2010).

## Key Issues

- 1. Facilities in the planning stage:** Designers should calculate wind loads on rooftop equipment and specify equipment that has sufficient strength to resist the calculated loads. Equipment attachments must be well-detailed and capable of resisting the high wind loads. During construction, contractors should implement quality control and quality assurance procedures to ensure that the design intent is met. In high-wind areas that also have moderate or high seismic loads, designers should specify and detail equipment attachment that has sufficient strength to resist the wind and seismic design loads. Further references are provided in this document.
- 2. Existing rooftop equipment:** It is recommended that the building owner hire a qualified architect or engineer to perform a wind vulnerability assessment. If significant vulnerabilities are identified, corrective action to mitigate the vulnerabilities is recommended.
- 3. Preparations prior to hurricane landfall:** It is recommended that the building owner have maintenance staff or a contractor perform the following:
  - Remove debris from roof drains, scuppers, and gutters.
  - Remove loose objects such as buckets, lumber, and sheet metal from the roof.
  - Install truck cargo straps around heating, ventilation, and air conditioning (HVAC) units. A best practice is to use 3 inch or greater truck cargo straps with 2 or 3 straps around each unit, depending upon unit height, and straps over and under the unit where it projects beyond the curb.
  - If there is sufficient time, check the attachment of all rooftop equipment to its curbs or other mountings, and add anchors if the existing attachment is inadequate. When performing emergency attachment of fans, relief air hoods, and small HVAC units to wood or sheet metal curbs, space the screws (#12 stainless steel, if available) at approximately 5 inches on center (o.c.) at each side of the equipment.
- 4. After a high-wind event:** A post-event assessment of the building should be done by qualified inspectors to determine any damage to rooftop equipment. If there is damage, the repair process could provide an opportunity to enhance the wind resistance described in this Recovery Advisory.

### Public Assistance Program and Policy Guide (FEMA PAPPG, 2018)

According to the PAPPG, additional grant funding may be available on eligible repairs to provide hazard mitigation against future events. For more information, see PAPPG Appendix J, Section III, B. Roof-Mounted Equipment: "Secure to roof top via a continuous load path, using tie-downs, straps, or other anchoring systems that will resist expected wind forces."

<sup>1</sup> In this advisory, a high-wind region means an area where the basic (design) wind speed is greater than 115 miles per hour (mph) for a Risk Category II building, as defined in the 2016 edition of the American Society of Civil Engineers (ASCE) Standard 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE 7-16, 2017). Using this criterion, all of Puerto Rico is considered a high-wind region.

Table 1 is the minimum attachment schedule provided in FEMA P-424. This table represents an engineered solution for equipment attachment. Note that although the table uses wind speed conversions from American Society of Civil Engineers Standard 7, *Minimum Design Loads for Buildings and Other Structures* (ASCE 7-05, 2005) to ASCE 7-10 (2010), the conversion to ASCE 7-16 would be the same.

### This Recovery Advisory Addresses

- Existing facilities and those in the planning or post-event repair stage, including residential, commercial/industrial buildings, and critical facilities.
- Attachment of HVAC units, exhaust fans, air conditioning (AC) condensers, boiler and exhaust stacks, rooftop ductwork, relief air hoods, gas and condensate drain lines, electrical conduits, electrical service masts, satellite dishes, roof-mounted communications antennae, and lightning protection systems (LPSs).
- Seismic considerations in attaching rooftop equipment.
- Corrosion of attachments.
- Maintenance of rooftop equipment.

### Design and Construction Mitigation Guidance

This section provides examples of various types of rooftop equipment problems that were observed after the 2017 hurricanes. Unless noted otherwise, all photos are from FEMA Mitigation Assessment Team (MAT) observations in Puerto Rico after Hurricanes Irma and Maria. This section also provides design and construction mitigation guidance based on FEMA P-424, Sections 6.3.4 and 6.4.3, along with recommendations based on professional judgment.

As an initial step in the design process or post-event repairs, it is recommended that designers calculate wind loads on rooftop equipment in accordance with ASCE 7-16 or the local building code, using whichever procedure results in the highest loads. However, ASCE 7-16 does not provide wind load criteria for all types of rooftop equipment. For example, LPSs are not addressed by ASCE 7-16; guidance is presented below to address this shortcoming.

#### HVAC Units

HVAC units and other rooftop equipment being blown off its curbs, stands, or other mountings (Figure 1) was a commonly observed problem. To anchor small HVAC units, exhaust fans, and relief air hoods, the minimum attachment schedule provided in Table 1 is recommended. For HVAC units that are larger than the units listed in Table 1, unit-specific wind loads should be calculated and appropriate connections specified. The attachment of the curb or other mounting to the roof deck also needs to be designed and constructed to resist wind loads.



**Figure 1.** HVAC unit moved by wind. The unit was inadequately attached to the plastic pedestal (red circle).

**Table 1: Number of #12 screws for base case attachment of rooftop equipment. From FEMA P-424 (Table 6-1).**

| Case No. | Curb Size and Equipment Type   | Equipment Attachment  | Fastener Factor for Each Side of Curb or Flange |
|----------|--|---|---|
| 1        | 12 in. x 12 in. Curb with Gooseneck Relief Air Hood                          | Hood Screwed to Curb  | 1.6   |
| 2        | 12 in. x 12 in. Gooseneck Relief Air Hood with Flange                        | Flange Screwed to 22 Gauge Steel Roof Deck                  | 2.8   |
| 3        | 12 in. x 12 in. Gooseneck Relief Air Hood with Flange                        | Flange Screwed to $1\frac{5}{32}$ in. Gauge Steel Roof Deck | 2.9   |
| 4        | 24 in. x 24 in. Curb with Gooseneck Relief Air Hood                          | Hood Screwed to Curb  | 4.6   |
| 5        | 24 in. x 24 in. Gooseneck Relief Air Hood with Flange                        | Flange Screwed to 22 Gauge Steel Roof Deck                  | 8.1   |
| 6        | 24 in. x 24 in. Gooseneck Relief Air Hood with Flange                        | Flange Screwed to $1\frac{5}{32}$ in. OSB Roof Deck         | 8.2   |
| 7        | 24 in. x 24 in. Curb with Exhaust Fan  | Fan Screwed to Curb   | 2.5   |
| 8        | 36 in. x 36 in. Curb with Exhaust Fan  | Fan Screwed to Curb   | 3.3   |
| 9        | 5 ft., 9 in. x 3 ft., 8 in. Curb with 2 ft., 8 in. High HVAC Unit            | HVAC Unit Screwed to Curb                                   | 4.5*  |
| 10       | 5 ft., 9 in. x 3 ft., 8 in. Curb with 2 ft., 8 in. High Relief Air Hood Unit | Hood Screwed to Curb  | 35.6*   |

Notes on Table 1:

- The loads are based on ASCE 7-05. The resistance includes equipment weight. When using ASCE 7-10, convert the 7-10 Category III/IV basic wind speed to a 7-05 basic wind speed as follows: 7-10 wind speed divided by the square root of  $(1.15 \times 1.6) = 7-05$  speed.
  - The Base Case for the tabulated numbers of #12 screws (or  $\frac{1}{4}$  pan-head screws for flange-attachment) is a 90-mph basic wind speed, 1.15 importance factor, 30 foot building height, Exposure C, using a safety factor of 3. The 7-05 Base Case is equivalent to 120 mph for 7-10 Risk Category III and IV buildings.
  - For other basic wind speeds, multiply the tabulated number of #12 screws by  $(\frac{V_D}{90})^2$  to determine the required number of #12 screws (or  $\frac{1}{4}$  pan-head screws) required for the desired basic wind speed,  $V_D$  (mph).
  - For other roof heights up to 200 ft., multiply the tabulated number of #12 screws by  $(1.00 + 0.003 [h - 30])$  to determine the required number of #12 screws or  $\frac{1}{4}$  pan-head screws for buildings between 30 feet and 200 feet.
- Example A: 24 in. x 24 in. exhaust fan screwed to curb (table row 7), Base Case conditions (see Note 1): 2.5 screws per side; therefore, round up and specify 3 screws per side.
- Example B: 24 in. x 24 in. exhaust fan screwed to curb (table row 7), Base Case conditions, except 120 mph:  $120^2 \times 1 \div 90^2 = 1.78 \times 2.5$  screws per side = 4.44 screws per side; therefore, round down and specify 4 screws per side.
- Example C: 24 in. x 24 in. exhaust fan screwed to curb (table row 7), Base Case conditions, except 150 ft. roof height:  $1.00 + 0.003 (150 \text{ ft.} - 30 \text{ ft.}) = 1.00 + 0.36 = 1.36 \times 2.5$  screws per side = 3.4 screws per side; therefore, round down and specify 3 screws per side.

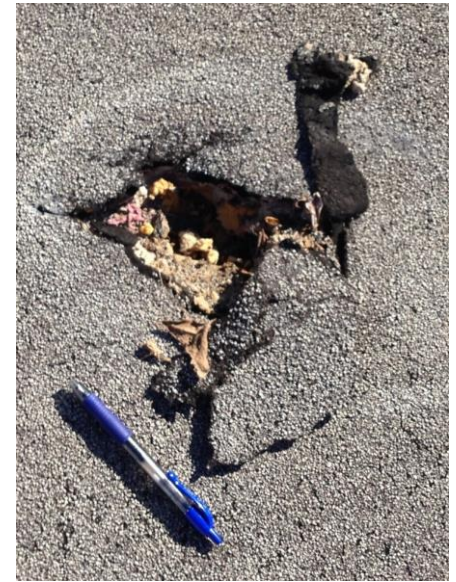
\* This factor only applies to the long sides. At the short sides, use the fastener spacing used at the long sides.



**Figure 2. HVAC unit blown off a roof.**



**Figure 3. Rooftop AC condenser damaged by impact.**



**Figure 4. Left, HVAC unit with blown-off access panel; right, a blown-off filter access panel.**

**Figure 5. Punctured roof, pen for scale.**

At the commercial facility shown in Figure 2, an HVAC unit blew off the roof. Blown-off equipment can injure people or damage lower roofs, adjacent buildings, vehicles, or other rooftop equipment (Figure 3). Although people are normally not outdoors during a hurricane, it is not uncommon for people to go to a hurricane-evacuation shelter or hospital during a hurricane.

Another common HVAC unit is blow-off of access panels (Figure 4). Blown-off panels commonly puncture and tear roof membranes and become airborne debris. Unless the equipment manufacturer specifically engineers the panel attachment to resist the design wind load, the following from problem FEMA P-424, Chapter 6 is recommended:

*Job-site modifications, including attaching hasps and locking devices like carabiners, are recommended. The modification details need to be customized. Detailed design may be needed after the equipment has been delivered to the job site. Modification details should be approved by the equipment manufacturer (FEMA P-424, 2010 6.101).*

The sheet metal unit enclosure (cabinet) may also be blown away. Access panels and cabinets, along with other rooftop equipment and components, can puncture roofs (Figure 5) and tear roof membranes (Figure 6). At the medical clinic in the U.S. Virgin Islands pictured in Figure 6, a tear several feet long was observed near HVAC equipment from which the enclosure had been blown off. Smaller tears and punctures can be difficult to see.



**Figure 6. A tear several feet long in a roof membrane. Hurricanes Irma and Maria, U.S. Virgin Islands.**

### ASCE 7-16 Changes Related to Rooftop Equipment

**No Height Limit for Load Criteria:** Editions of ASCE 7 before 2010 did not provide load criteria for equipment on roofs greater than 60 feet above grade. The 60 foot limit was eliminated in subsequent editions. The criteria in Sections 29.4.1 and 30.10 now apply to all roof heights.

**Wind Loads on Screens:** Equipment screens may be used to hide rooftop equipment from view. According to a new recommendation in ASCE 7-16 Section C29.4.1, wind loads on screens, equipment behind screens, and their support and attachments are to be calculated according to Section 29.4.1, with no reduction to the wind load of the screen unless the reduction is supported by data obtained from the Wind Tunnel Procedure.



**Figure 7. Blown off fan cowl resting on the roof membrane at a hospital.**

New HVAC units should be designed and fabricated by the equipment manufacturer to resist the design wind and seismic loads at the location where the units are installed. Documentation should be provided by the equipment manufacturer to the designer, contractor, and local officials showing that the unit has sufficient strength to meet the design loads. For existing units for which the strength of the unit enclosure is unknown, installation of truck cargo straps around and over units prior to hurricane landfall is recommended to avoid enclosure blow-off.

#### Exhaust fans

Exhaust fans and fan cowlings were frequently blown off their curbs because they were inadequately secured (Figure 7). Table 1 provides an attachment schedule to adequately secure fans and other equipment. Blown-off fans and cowlings can tear roof membranes. Unless the fan manufacturer specifically engineered the cowling attachment to resist the design wind load, FEMA P-424 recommends job-site installation of cable tie-downs, although metal straps can also be used. The cable used should be  $\frac{1}{8}$  inch for cowlings less than four feet in diameter and  $\frac{3}{16}$  inch otherwise. Two cables are recommended where basic design wind speeds are less than 165 mph and four cables otherwise; however, using four cables or straps is a best practice for reducing the chance of equipment blow-off for all design wind speeds. Cables should be anchored to the curb rather than the roof to avoid leakage, and the attachment of the curb should be designed and specified.

Although it is often impractical to place all equipment (including fans) in penthouses, FEMA P-424 recommends doing, so to the extent possible, to avoid debris damage.

#### AC Condensers

In lieu of placing rooftop-mounted condensers on wood sleepers resting on the roof, condensers should be anchored to metal equipment stands or curbs made of concrete, sheet metal, or wood to avoid blow-off (Figure 8). Additionally, it is recommended that mechanical fasteners be used to attach the condensers rather than adhesive. At a school in the U.S. Virgin Islands, several condensers were attached with adhesive to plastic pedestals (Figure 9); all the condensers were blown over, and some were blown off the roof.

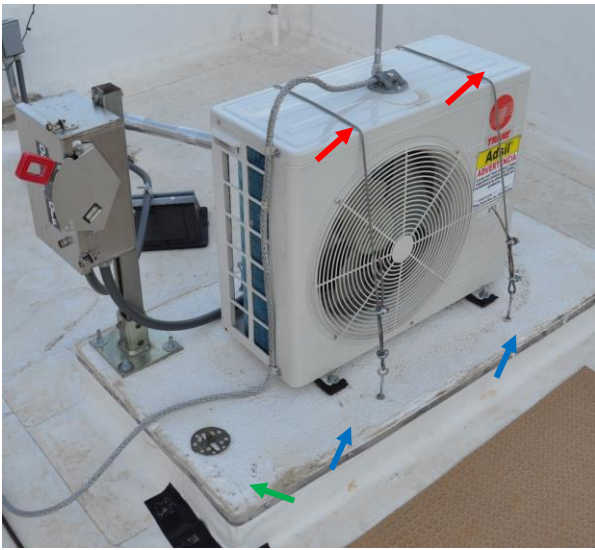
In addition to anchoring the base of the condenser to the stand or curb, FEMA P-424 recommends installation of tie-down straps (cables may also



**Figure 8. The condenser at this hotel simply rested on the curb. Hurricanes Irma and Maria, U.S. Virgin Islands.**



**Figure 9. This condenser was blown off the plastic pedestals to which it was attached. One of the pedestals was broken (red arrow).**



**Figure 10.** This condenser was bolted to a curb (blue arrows) and had tie-down cables (red arrows). The LPS conductor is no longer secured by its connector (green arrow).



**Figure 11.** Toppled exhaust stack at a high school in Loíza.

be used). Figure 10 shows a condenser with enhanced attachment, similar to the guidance in FEMA P-424. Grade-mounted condensers should also be mechanically attached to their support slab or platform.

### Boiler and Exhaust Stacks

Toppled stacks (Figures 11) can allow water to enter the building at the stack penetration, damage the roof membrane, and become wind-borne debris. FEMA P-424 recommends that wind loads on stacks be calculated and guy wires designed and constructed to resist the loads. Additionally, it recommends that the building owner have guy wires inspected annually to confirm that they are taut.

### Rooftop Ductwork

FEMA P-424 recommends that ductwork not be installed on the roof. If ductwork is installed on the roof, it recommends that the ducts' gauge and the method of attachment be able to resist the design wind loads.

For existing ductwork, recommendations are provided regarding flexible connectors between the ducts and fans. Additionally, it is recommended that a wind vulnerability assessment of rooftop ducts be performed.

### Natural Gas Lines, Condensate Drain Lines, and Conduits.

Rooftop natural gas lines, condensate drain lines, and conduit supports often do not provide lateral or uplift resistance (Figure 12). FEMA P-424 provides an example of a gas line support detail that provides lateral and uplift resistance (Figure 13). In this example, at periodic gas line supports, a steel angle was welded to a pipe that was anchored to the roof deck. A strap was looped over the gas line and bolted to the support angle. This detail is also applicable to anchorage of condensate drain lines and conduits. As much as possible, the conduit should be run



**Figure 12.** This conduit carried conductors from a rooftop solar array on the roof of a hospital in Vieques. It was inadequately secured to the roof and failed.



**Figure 13.** Enhanced gas line support detail. From FEMA P-424 (Figure 6-100).

below the deck rather than above the roof membrane.

### Electrical Service Mast

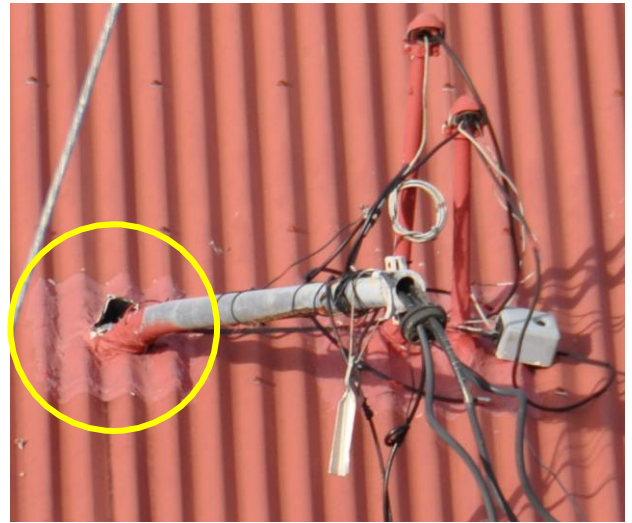
At the electrical service mast shown in Figure 14, the overhead power line collapsed and pulled on the service mast, which resulted in rupture of the mast flashing. FEMA P-424 recommends using underground service. Where overhead service is provided, it recommends that the owner seek the services of an architect or engineer for locating and designing the mast. The following are recommended:

1. A best practice is to anchor the service mast to a concrete or CMU pylon as shown in Figure 15. The overhead service line runs to the mast and underground to the house. With this type of installation, a collapse of the overhead line will not result in property damage. This configuration will also reduce the risk of fire damage in case the power line breaks.
2. For concrete roofs, the mast may be installed on the roof with proper design and detailing.
3. For light gage roofs, such as corrugated metal roofs, the mast should be side-mounted on an exterior wall with proper design and detailing. If the mast is to be roof mounted, it should not penetrate the roof so as to prevent water leakage at the ruptured flashing. It is recommended to have the mast supported on an equipment stand or concrete curb with proper flashing and sealant detailing.

In all cases, a sag in the power line is recommended to reduce tension on the mast during a hurricane.

### Satellite Dishes

As shown in Figure 16, the base plates of the satellite dish support legs were ballasted with solid CMUs, which provided inadequate wind resistance. Displaced dishes can rupture roof membranes and cause other damage or injury. FEMA P-424 recommends that ballast not be used to anchor satellite dishes in high-wind areas. Rather, the dish wind load should be calculated, and a suitable mechanical attachment to the roof deck or structure should be designed.



**Figure 14. A collapsed overhead power line pulled over this service mast, which caused flashing rupture. Hurricanes Irma and Maria, U.S. Virgin Islands.**



**Figure 15. Power delivery pylon for the electrical service mast for a house under construction. The FEMA MAT frequently observed this installation method in Puerto Rico.**

## Roof-Mounted Communication Towers and Antennae

Collapse of communication towers and antennae mounted on the roof or penthouse walls is common during high-wind events (Figure 17). These failures often result in complete loss of communication capabilities. In addition to the disruption of communications, collapsed towers can puncture roof membranes. FEMA P-424 provides guidance on determining design wind loads and determining wind resistance of existing towers.

## Lightning Protection Systems (LPSs)

LPSs frequently become disconnected from rooftops during hurricanes (Figure 18). Displaced LPS components can puncture and tear roof coverings, allowing water to leak into buildings. Prolonged and repeated slashing of the roof membrane by loose conductors (“cables”) and puncturing by air terminals (“lightning rods”) can result in lifting and peeling of the membrane. When displaced, the LPS is no longer capable of providing lightning protection to the area around the displaced conductors and air terminals.

Current LPS standards do not require enhanced attachment of LPSs in high wind regions. FEMA P-424 provides enhanced attachment guidance for several types of roof systems, including parapet attachment methods and the use of membrane flashing strips (Figure 19).

## Seismic Considerations

Seismic hazard is also an important consideration for Puerto Rico. Three FEMA publications address mitigating seismic hazard to rooftop equipment: *Installing Seismic Restraints for Mechanical Equipment* (FEMA 412, 2002); *Installing Seismic Restraints for Duct and Pipe* (FEMA 414, 2004a); and *Installing Seismic Restraints for Electrical Equipment* (FEMA 413, 2004b). Links are given in the references. The following attachment methods are fully detailed in these documents:

### Mechanical and Electrical Equipment on Roofs (FEMA 412 and FEMA 413)

- Leveling stanchions—also called post and beam
- Seismic built-up or seismic pre-manufactured curb
- Wood frame
- Pre-manufactured seismic vibration isolation curb or leveling stanchions with an equipment support frame
- Restrained springs on leveling stanchion



**Figure 16.** The satellite dish at this hospital was nearly blown off the roof. Hurricane Harvey, Texas.



**Figure 17.** Collapsed roof-mounted antennae which had been inadequately secured to the roof using CMUS as ballast.



**Figure 18.** Detached LPS conductor that had been inadequately attached using adhesive.



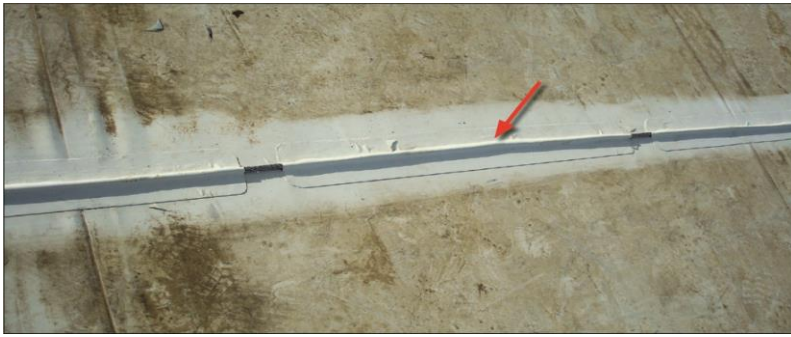


Figure 19. Enhanced LPS attachment, using intermittent roof membrane flashing strips from FEMA P-424 (Figure 6-114).

Figure 20. This corroded turnbuckle failed, allowing the boiler stacks shown in Figure 11 to topple.

### Ducts on Roofs (FEMA 414)

- Pre-manufactured seismic duct brace
- Angle support with cross bracing attached to a roof curb
- Angle support attached directly to the roof in a pitch pocket to seal the roof
- Angle support for round or oval duct

### Piping on Roofs (FEMA 414)

- Single pipe support
- Wood blocking support
- Trapeze support

## Corrosion

Corroded rooftop equipment was frequently observed to have failed in Puerto Rico following Hurricanes Irma and Maria (Figure 20). FEMA P-424 recommends that equipment bodies, stands, anchors, and fasteners be made of “nonferrous metals, stainless steel, or steel with minimum G-90 hot-dip galvanized coating” (FEMA P-424 6.97). The *Building Performance Assessment Team (BPAT) Report - Hurricane Georges in Puerto Rico* (FEMA 339, 1999) noted that an aluminum-zinc alloy coating greatly enhanced corrosion protection for galvanized metal, particularly near salt water. Attachment failure and resulting building damage in a high-wind event can be reduced by using materials that are less susceptible to corrosion.

## Maintenance of Rooftop Equipment

Regular maintenance is important to reduce the likelihood of roof damage during a high-wind event such as a hurricane. Regular maintenance is especially critical when corrosion-resistant equipment following FEMA P-424 was not originally used.

- Schedule regular maintenance for the roof and roof-mounted equipment.
- Carry out maintenance before and after a high-wind event.
- Have the building inspected by a licensed professional inspector after an event.

### Maintenance Tasks

- Remove any debris from roof drains, scuppers and gutters.
- Remove any loose objects (such as buckets, lumber and sheet metal) from the roof.
- Clear vents, screens, and louvers of debris, and make sure they are firmly fastened.
- Check for any corroded parts in the equipment and repair with the appropriate protective coating. Replace them if necessary.
- Check equipment fasteners and make sure all are in good condition.
  - Tighten loose fasteners. Replace them if necessary.
  - Check for corroded fasteners by looking for an intact protective coating. Replace any fasteners on which the

coating has worn away. Corroded fasteners can fail in a high-wind event (Figure 20).

- Use nonferrous metal fasteners where corrosion is an issue. If these are not available, or in areas where corrosion is less of an issue, use stainless steel or steel with at minimum G-90 hot-dip galvanized coating.
- Check for rust on curbs or metal flashing. Apply a protective coating or replace the curbs or flashing if necessary.
- If straps are used to secure equipment to the roof, make sure the straps are taut and in good condition.
- Check for areas of potential roof leakage and seal them. If signs of previous leakage are noticed, check for rotting, and make repairs if necessary.

## References and Resources

### References

American Society of Civil Engineers (ASCE). 2017. *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. ASCE 7-16. <https://www.asce.org/structural-engineering/asce-7-and-sei-standards/>

FEMA. 2010. *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds, Second Ed.* FEMA P-424. <http://www.fema.gov/library/viewRecord.do?id=1986>.

FEMA. 2002. *Installing Seismic Restraints for Mechanical Equipment*. FEMA 412. <https://www.fema.gov/media-library/assets/documents/2142>.

FEMA 2004a. *Installing Seismic Restraints for Duct and Pipe*. FEMA 414. <https://www.fema.gov/media-library/assets/documents/848>.

FEMA. 2004b. *Installing Seismic Restraints for Electrical Equipment*. FEMA 413. <https://www.fema.gov/media-library/assets/documents/843>.

FEMA. 2018. *FEMA Public Assistance Program and Policy Guide*. FEMA PAPPG. <https://www.fema.gov/media-library/assets/documents/111781>.

### Resources

American National Standards Institute (ANSI), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). 2017. *Method of Testing for Rating Seismic and Wind Restraints*. ANSI/ASHRAE 171-2017. <https://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2FASHRAE+Standard+171-2017>.

FEMA. "FEMA Puerto Rico." <https://www.facebook.com/FEMAPuertoRico>. Note, this Facebook page was created for the Hurricanes Irma and Maria recovery process and is regularly updated with useful information.

FEMA. 2017. *Safer, Stronger, Smarter: A Guide to Improving School Natural Hazard Safety*. FEMA P-1000. <https://www.fema.gov/media-library/assets/documents/132592>.

*Note, the following publications have guidance similar to that presented in FEPA P-424 regarding rooftop equipment. FEMA P-424 is cited in this Recovery Advisory because it is a more recent publication.*

FEMA 2007a. *Design Guide for Improving Critical Facility Safety from Flooding and High Winds*. FEMA 543. <http://www.fema.gov/library/viewRecord.do?id=2441>.

FEMA 2007b. *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds*. FEMA 577. <http://www.fema.gov/library/viewRecord.do?id=2739>.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at <https://www.fema.gov/frequently-asked-questions-building-science>.

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