Mitigating Wind Damage to Existing Critical Facilities

In October 2018, high winds and localized flooding impacted critical facilities in the Commonwealth of the Northern Mariana Islands during Super Typhoon Yutu. Several facilities were unable to continue operations during the storm and were delayed from resuming full functionality after the storm, impeding local response and recovery efforts. Specifically, several critical facilities lacked emergency power. While many facilities had backup power in the form of generators, they often did not work because they had not been maintained, were improperly sized, or could not be connected to the facility. Damage from high winds and flooding also impacted critical facility operations.

What are Critical Facilities?

Critical facilities commonly include all public and private facilities that a community considers essential for the delivery of vital services and for the protection of the community. This generally includes emergency response facilities (fire stations, police stations, rescue squads, and emergency operations centers), custodial facilities (jails and other detention centers, long-term care facilities, hospitals, and other health care facilities), schools, emergency shelters, utilities (water supply, wastewater treatment facilities, and power), communications facilities and any other assets determined by the community to be of critical importance for the protection of the health and safety of the population.

This Recovery Advisory provides information to reduce critical facility vulnerability to damage from high wind, including suggestions for assessing the vulnerability of a critical facility to future hazards. The information in this advisory is most useful for retrofits of existing buildings, but also references design guidance appropriate for new construction. Although the focus of this document is on critical facilities, many of the recommendations can be applied to other types of facilities. The audience for this recovery advisory is critical facility owners and operators, engineers, and architects.

Key Issues Addressed by this Recovery Advisory

1. Maintaining Critical Facility Functionality for Community Resilience: Critical facilities provide essential services for the community during and after disasters. Keeping the facility operational means these services can continue without interruption.
2. Vulnerability Assessments: Owners must regularly assess the vulnerability of their facilities and systems to wind and flood hazards. This helps to prioritize improvements and plan regular maintenance activities.
3. Improving Wind Resistance: The most commonly observed wind damage was to the building envelope and exterior equipment, including emergency power. Recommendations to avoid these damages are provided.

Maintaining Critical Facility Functionality for Community Resilience

The services and functions provided by critical facilities are essential to a community, especially during and after disasters. For a critical facility to function as needed, its building structure, building systems, and equipment must be maintained in working order in preparation for emergencies. Regular maintenance is critical, and reliable supply of essential utilities is necessary, including power, water, waste disposal and communication systems.

To avoid interruptions in services, it is important for critical facility operators to identify and mitigate vulnerabilities. Operators can do this by improving the building and building systems to reduce the likelihood of future damage and by establishing redundancies so that there is no single point of failure that could adversely affect the facility functionality. Securing rooftop equipment to protect against wind damage is an example of reducing the likelihood of future damage. Providing an alternate or emergency power source is an example of redundancy. Redundancies should be planned for and documented in a facility's disaster plan, and they should be appropriate to meet the demands of the system they would replace in an emergency.

Critical facility owners also should consider regular maintenance, which helps the structure and building systems that make up the facility better withstand disasters. Owners and operators of critical facilities should create a capital improvement plan with five-year projections to plan for major repairs, and then establish a schedule for upgrades to help plan for and secure the necessary funding. In addition, to save on costs, owners and operators can create a program to standardize materials used for routine maintenance. Purchasing materials in bulk reduces costs and makes routine maintenance activities faster and more efficient. Refer to Super Typhoon Yutu Fact Sheets 1 and 2 for guidance on regular maintenance.

Vulnerability Assessments

This section describes the importance of preparing vulnerability assessments for existing facilities and provides a high-level overview of how to perform these assessments. Publications with more details are referenced in the Details and Useful Links section. A thorough vulnerability assessment identifies significant vulnerabilities that could adversely affect the structure and building operations. The assessments should be conducted by knowledgeable personnel, such as a team of design professionals, designated maintenance staff, architects, or an engineer working closely with facility managers, operators, and maintenance staff. Findings from the assessment lay the groundwork for planning and budgeting capital improvements, identifying mitigation opportunities, and developing contingency plans that address risks. The results of a thorough assessment can be used by facility owners, design professionals, entities that award mitigation grants, and Territorial government agencies.

- **Facility owners** will become aware of the vulnerability of their facilities to potential damage. The owner can identify and budget for renovation measures or construction of a new facility (if the vulnerabilities are significant). Awareness of vulnerabilities informs contingency plans to address potential interruption of facility operations.

- **Design professionals** involved in building renovations can use the information to guide discussions with the building owner about mitigation options. Design professionals also can use the guidelines after damage occurs.

For example, if a portion of a wall or roof is damaged, the undamaged areas can be assessed to determine whether they are vulnerable to future damage, and, if they are, the areas could be mitigated.

- **Entities that award grants for mitigating damage to existing buildings** need thorough assessments before awarding funds to ensure that the proposed mitigation is technically feasible and effective, and that the mitigation benefits equal or exceed their costs.

- **Territorial government agencies** can use vulnerability assessments to identify and prioritize critical facilities for retrofit and include proposed mitigation in their plans.

Preparation of vulnerability assessments is recommended for all existing critical facilities in the CNMI. If a facility owner has several facilities (such as a school district or a large hospital complex), budget constraints may prohibit timely evaluation of all facilities. In this case, the owner should set up an evaluation program or plan and prioritize assessments based on the owner's needs and perceived facility vulnerabilities. For example, schools that will be used as recovery centers after disasters, and facilities constructed before the early 1990s, normally would be evaluated first.

Best Practice: Vulnerability Assessments

Facility owners should assign a specific person or role within the organization to coordinate vulnerability assessments. If possible, identify a second person or entity to review the outcomes of an assessment and act on the recommendations. **Detailed guidance on performing vulnerability assessments for wind hazards is found in FEMA P-2062, *Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities*.** If it is not feasible to conduct a full vulnerability assessment, facility owners should assign a building maintenance or operations staff member to regularly inspect the facility for potential issues. Then, a qualified architect or engineer could be brought in to assess these issues and make recommendations to reduce vulnerability.

At existing facilities, especially when a vulnerability assessment is not feasible, visual inspections should be conducted periodically to identify changing building conditions as a result of exposure to the elements, and thorough inspections should be conducted following winds of 70 mph or greater. The building envelope and exterior-mounted equipment should be inspected once a year by individuals with knowledge of the systems and materials they are inspecting. Items that require maintenance, repair, or replacement should be documented and scheduled for work. To be effective, inspections must cover all building elements and building systems whose failure is likely to cause significant damage or interruption of facility operations.

As part of the planning process for new facilities, all possible natural hazards (flood, wind, seismic, and wildfire) should be considered. If a building design does not ensure continuity of operations, contingency plans that address facility disruption should be developed. FEMA's Risk Management Series provides design guidance and best practices for new facilities (see Resources and Useful Links, below).

Improving Wind Resistance

This section describes key high-wind considerations for existing critical facilities. The building elements most commonly damaged by high winds are the building envelope and exterior equipment. Common wind damage includes roof covering damage (most commonly damaged), roof structure damage or collapse (typically in buildings constructed before 1990 or buildings struck by a tornado), collapse of fire station apparatus bay doors (typically in fire stations constructed before 2000), broken glazing (windows, sky lights) from wind-borne debris and blow-off of rooftop equipment leaving openings or punctures in the roof covering.

Building Envelope

The building envelope consists of exterior doors, glazing, non-load-bearing walls, wall coverings, soffits, and roof systems. This Recovery Advisory includes recommendations for improving the performance of exterior doors, exterior glazing and shutters, and roof systems. Elements of the building envelope not discussed here are covered in the Risk Management Series publications referenced below in Resources and Useful Links.

EXTERIOR DOORS

During Super Typhoon Yutu, wind forces and wind-borne debris damaged large sectional and rolling doors that were intended to protect apparatus bays and vehicles at several fire stations. The doors were damaged, resulting in failures that left doors unusable, preventing equipment from being deployed. In other locations, the failure of large doors resulted in damage to buildings and the vehicles parked inside (Figure 1). A breach in the building envelope increases internal wind pressures and allows entrance of wind-driven rain.

Figure 1. Airport Fire and Incident Response Apparatus Bay—Oshkosh Striker response unit with broken windshield.

To mitigate this type of damage, facilities should have large doors that are tested for wind loads and wind-borne debris impact associated with the design criteria for the site. For wind loads, manufacturers commonly label doors with the pressure rating. If the label is not present, an assessment should be made per FEMA P-2062 to determine if a new assembly is needed. Florida and Texas maintain a database of wind load tested and rated door designs. See Product Approval page at https://www.floridabuilding.org /pr/pr_app_srch.aspx for Florida and www.tdi.texas.gov/wind/prod/ for Texas. If a door has been tested for resistance to wind-borne debris and cyclical air pressure, the sectional and rolling door industry typically cites test method ANSI/DASMA 115 on the label. (Florida and Texas have similar high-wind building requirements, and this takes advantage of their certification and research activities.)

Installing doors that have been tested for wind loads will help protect the integrity of the building envelope. As an additional layer of protection, owners can install open lattice or grates at large openings to keep large debris from damaging the door.

Facility owners also should consider protecting other exterior doors, such as personnel doors. Entrances can be protected by foyers and enclosed entries with two sets of doors at main entry points. Figure 2 shows the entrance to the CNMI Emergency Operations Center, with a partially enclosed entry point. Similar to large doors, installing a personnel door tested for wind loads will help protect the integrity of the building envelope.

Figure 2. Entrance to CNMI Emergency Operations Center.

EXTERIOR GLAZING AND SHUTTERS

Exterior glazing and shutters protect building openings. They are commonly damaged in high-wind events. Glazing should be rated to resist wind loads and wind-borne debris. **One way to verify the level of protection provided by windows is to ensure that they are certified and labeled with performance data** (see Figure 3). The American Architectural Manufacturers Association (AAMA) sponsors a window certification program that requires a label on every window[1]. Additionally, the Miami-Dade Product Control[2] and Florida Building Commission[3] have product approval programs and product information can be obtained from them. If there is no label on the window, sometimes hardware items have logos to indicate the manufacturer. Manufacturers may be able to provide information about whether specific windows are rated.

Impact protective systems (shutters) installed should be rated for the “test missile E” specified in ASTM E1996 and tested in accordance with ASTM E1886. Observations in the field indicate that shutters with multiple points of contact to the frame and a low-profile locking mechanism sustained less damage and remained operable after storms.

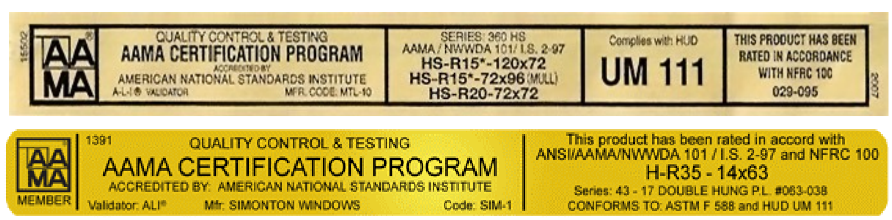

Figure 3. Typical AAMA labels

Best Practice: Maintenance of Operable Openings

Maintaining weatherstripping, sealants, and hardware on openings can extend the useful life and provide for better long-term performance. Facility owners and operators should keep records of maintenance and repair. See CNMI Fact Sheet 1 for detailed information on maintaining openings.

- Regularly maintain shutter assemblies.

[1] AAMA certification program information is available at https://aamanet.org.

[2] More information is available at http://www.miamidade.gov/building/product-control.asp.

[3] More information is available at https://www.floridabuilding.org.

- Remove debris from tracks.
- Lubricate the tracks annually.
- Wash with a cleaner to remove buildup.
- Operate on a regular basis.

ROOF SYSTEMS

Regularly assess, maintain, and repair or replace roofs when needed. Facility owners and operators should develop maintenance programs for building exteriors, specifically for roof systems. Damage and loss of function to critical facilities that occurred during Super Typhoon Yutu could have been limited if more roof systems were properly installed, maintained, and replaced before the end of their effective service life. Maintenance plans should include a section to address repairs when damage occurs, such as repairing punctures in the roof covering. FEMA P-2062 includes guidance to determine whether building elements or systems are at or near the end of their useful service life. If a vulnerability assessment reveals that a building element or system is at or near the end of its useful service life, it should be scheduled for replacement as soon as possible.

Exterior Equipment

Exterior equipment includes roof- and ground-mounted equipment, including mechanical equipment, lightning protection systems, and emergency power systems (if not located in enclosed spaces).

MECHANICAL EQUIPMENT

Failure of mechanical equipment commonly takes two forms: equipment fails to operate or equipment blow-off or damage occurs that subsequently causes water intrusion and interior damage. This section includes recommendations for retrofit, operation, and maintenance of mechanical equipment.

Design and install mechanical equipment and equipment enclosures for critical facilities to resist high winds, in accordance with American Society of Civil Engineers (ASCE) 7-16, or retrofit as appropriate. Evaluate exterior doors for rooftop access to mechanical systems and equipment rooms.

Figure 4. Well-anchored mechanical equipment at Saipan Airport using beams and tie rods.

Adequately anchor Heating, Ventilation and Air Conditioning (HVAC) systems and other equipment to roofs or walls (see Figure 4). New, existing, and replacement equipment should be anchored to resist high wind loads. U.S. Virgin Islands (USVI) Recovery Advisory 2: *Attachment of Rooftop Equipment in High-Wind Regions* and FEMA P-424 provide specific guidance for anchoring HVAC and other equipment to the roof, roof structure, or parapets. If equipment cannot be adequately mounted on a roof, owners should consider moving the equipment elsewhere on-site, where it can be adequately anchored.

Design mechanical systems to be common, simple, modular, and interchangeable. Island conditions mean that mechanical equipment is exposed to harsh elements, increasing the rate of deterioration. By using common, simple, modular, and interchangeable systems, the equipment is easily maintained by local technicians using readily available parts and can be easily repaired or replaced component by component without having to replace entire units.

Install quick connects, switch gears, and electrical panels to facilitate the connection of backup power to mechanical and electrical components if they are damaged. The addition of quick connects and switch gears to critical facilities and public buildings with essential functions post-event can reduce down time and makes it easier for equipment to be maintained or replaced. These connections can be added for a lower cost when electrical repairs are performed.

Mechanical equipment should be maintained regularly to increase resistance to wind damage. See CNMI Fact Sheets 1 and 2 for more details on maintenance of mechanical equipment.

LIGHTNING PROTECTION

Lightning protection systems frequently become disconnected from rooftops during high wind events. Displaced lightning protection systems or components can puncture and tear roof membranes, allowing water intrusion. **To enhance the wind performance of lightning protection systems, consider the following elements of the system** (see FEMA P-424 for additional detail):

- **Parapet attachment**
- **Attachment to built-up, modified bitumen, and single-ply roof membranes**
- **Mechanically attached single-ply membranes**
- **Standing seam metal roofs** (see Figure 5 for an example of a well-attached system)
- **Conductor splice connectors**

Figure 5. Well-attached lightning protection system at Saipan Airport.

EMERGENCY POWER

FEMA P-1019, *Emergency Power for Critical Facilities: A Best Practice Approach to Improving Reliability,* contains guidance on identifying and providing emergency power for critical facilities. FEMA P-1019 suggests considering three levels of operation. The levels—described as Level I, Level II and Level III—are determined primarily by how long the facility may need to operate under emergency power and whether the emergency power system must be sized to supply air conditioning equipment.

Emergency power system requirements can vary based on the code requirements and expected facility use during or after a disaster event. While detailed code requirements are based on the occupancy classification and size of the facility, the basic requirements for each system consist of protecting facility equipment, critical functions, and life-safety systems. For basic functions where a generator is needed to satisfy code requirements, the minimum load acceptable by code should operate life safety equipment, including fire alarm and annunciation systems, smoke control systems, emergency and egress lighting, and conveyance systems that are required for egress. Facility systems and critical functions include ventilation and communication devices that can be required by code based on the length the facility is using emergency power. For post-disaster response facilities, consider the length of time the facility will need to remain functional. If the expectation is several days or weeks, additional power supply planning for ventilation and food preparation equipment would be needed.

Facilities critical to operations, such as hospitals and emergency operations centers (EOCs) designed for disaster response, often provide emergency power sufficient for full operation of the entire facility with onsite fuel capacity, allowing full-scale operations for a week or more. The duration typically is not code mandated for more than 90 minutes, with exceptions being critical healthcare facilities that are required to store enough fuel onsite to maintain generators for a total of 96 hours, but additional levels of redundancy and future mitigation steps should be implemented to sustain the facility after a disaster event.

Additionally, carefully consider the potential for failure, even in an emergency power system. Critical facilities such as hospitals are required by code to maintain parallel utility feeds into the main switch gear, but these still have the potential to fail. Additional back up to emergency power using the N+1 strategy can be applied to each component of the system that exceeds code requirements. For example, the use of two or more smaller fuel tanks in parallel or filter sets allow the components to be maintained without interruption of service. If the critical facility does not meet or exceed current codes, important considerations include defining the critical electrical loads, with exceptions being EOCs where the backup generator should be able to carry the entire load. Review and implementation of updated code requirements specific to the facility use can increase the ability of a facility to remain operational without unnecessary downtime during the critical response-and-recovery period of a disaster.

Given the Commonwealth's harsh environment, emergency and temporary power systems need to be commissioned before events and removed (decommissioned) after they are used. **Similar to mechanical systems, emergency and temporary power systems should be common, simple, modular, and interchangeable. Critical facility owners and operators should maintain emergency power systems on a regular schedule.**

Best Practice: Emergency Power

- Define the emergency power need at your facility, using Super Typhoon Yutu as your reference.
- Make a plan, including activities and resources needed during Super Typhoon Yutu.
- Resource the plan and take action to prepare.
- Maintain the plan in preparation for the next event.

Resources and Useful Links

Design Guidance for New Construction

While the recommendations in this Recovery Advisory focus on existing facilities, several resources are available with design guidance for new facilities. Specifically, designers may reference FEMA's Risk Management Series. Relevant publications from the series are listed below. Wind design guidance is consistent across the three publications, so refer to FEMA P-424 for the most recent guidance.

Risk Management Series:

- FEMA P-424. 2010. Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds.
- FEMA 543. 2007. Design Guide for Improving Critical Facility Safety from Flooding and High Winds.
- FEMA 577. 2007. Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds.

FEMA. 2019a. *Guidelines for Wind Vulnerability Assessments of Existing Critical Facilities.* FEMA P-2062.

FEMA. 2019b. *Successfully Retrofitting Buildings for Wind Resistance.* Hurricane Michael in Florida Recovery Advisory 1 (RA1).

FEMA. 2018. USVI Recovery Advisory 2, *Attachment of Rooftop Equipment in High-Wind Regions.*

FEMA. 2018. USVI Recovery Advisory 4. *Design Installation and Retrofit of Doors, Windows, and Shutters.*

FEMA. 2014. Emergency Power for Critical Facilities: A Best Practice Approach to Improving Reliability. FEMA P-1019.

FEMA. 2009. *Midwest Floods of 2008 in Iowa and Wisconsin.* FEMA P-765.

Super Typhoon Yutu CNMI MAT Fact Sheets and Recovery Advisories:

- Fact Sheet 1: Maintenance for Roof Coverings, Windows/Doors, Shutters, and Exterior Building Elements
- Fact Sheet 2: Maintenance for Critical Building Systems
- Fact Sheet 3: Permitting and Inspection Process for Disaster-Resilient Residential Homes
- Recovery Advisory 1: Code Based Wind-Resistant Roofing for Homes: Reducing Wind Damage in CNMI