Dry Floodproofing: Operational Considerations

FEMA

HURRICANE IRMA IN FLORIDA *Recovery Advisory 1, May 2018*

Purpose and Intended Audience

The purpose of this advisory is to provide guidance on how to effectively implement dry floodproofing mitigation measures for non-residential structures. This Recovery Advisory incorporates observations made by the Federal Emergency Management Agency (FEMA) Mitigation Assessment Teams (MATs) in Texas and Florida after Hurricanes Harvey and Irma. It describes best practices and lessons learned about planning, preparation, and operations of dry floodproofing systems that can make facilities more resistant to disruption in future flood events. The information in this advisory is directed toward existing and new, non-residential facilities.

The guidance in this advisory, along with other FEMA publications related to dry floodproofing, should be used by building owners and design professionals to take action to limit the interruption of building services and flood damage to buildings. It will also be useful to communities and building owners preparing designs and proposals for FEMA Section 404 Hazard Mitigation grants and hazard mitigation elements included in recovery funding available through FEMA Section 406 Public Assistance.

FEMA Public Assistance Program Funding for Dry Floodproofing Projects

In addition to funding for repair and recovery projects, FEMA Public Assistance (PA) Program funding may be available for cost-effective hazard mitigation measures that increase resilience, such as dry floodproofing projects. For more information, refer to Chapter 2 Section VII.C., "Hazard Mitigation" of FEMA's *Public Assistance Program and Policy Guide* (2018).

The primary audience for this advisory includes building owners, operators, and managers; installers; and contractors, but may also be helpful for architects, engineers, various planners, as well as local government and building code officials involved with building planning, design, enforcement, operations, or maintenance. It will also be useful to communities and building owners preparing designs and proposals for FEMA hazard mitigation funding.

Key Issues

- Some dry floodproofing systems were not regularly tested or properly maintained. When the systems were installed prior to the storm, several systems did not provide the intended level of protection.
- Some facilities lacked formal or written documentation on who, how, when, and where to deploy floodproofing systems, which resulted in time and energy wasted on a disorderly or partial deployment prior to the event.

This Recovery Advisory Addresses

- Observations related to dry floodproofing system operations
- Operations, maintenance, and testing plans for dry floodproofing systems
- Deployment considerations for active dry floodproofing
- Floodproofing considerations for a facility Emergency Operations Plan

A companion advisory, titled *Dry Floodproofing: Planning and Design Considerations* (Hurricane Harvey in Texas, TX-RA1, 2018), describes observations of system failures; flood vulnerability assessments; and planning and design considerations for dry floodproofing.

Observations Related to Dry Floodproofing System Operations

The floodwaters of Hurricanes Harvey and Irma tested passive and active dry floodproofing systems. Dry floodproofing involves using passive and active measures to seal a structure or area so floodwater cannot enter (see text box).

With the uncertainty surrounding the tracks of both storms and amount of flooding predicted from rainfall and storm surge, the planning, preparation, and installation of dry floodproofing systems was a timing and logistical challenge.

After Hurricanes Harvey and Irma, the MATs deployed by FEMA to evaluate building performance observed some best practices that enhanced response, such as the use of passive floodproofing systems that operated automatically with the rise of floodwater. However, the MATs observed other active measures that created significant challenges, such as systems that required a sizeable crew with heavy and specialized equipment to mobilize over a period of several days in advance of the storm to properly install the system.

The damage observed by the MATs illustrate that planning for dry floodproofing deployment is inconsistent, installation of dry floodproofing is not always effective, and even when installed, the level of effectiveness of the operation and implementation of dry floodproofing systems is variable.

Dry Floodproofing Systems

Active: Dry floodproofing systems that require human intervention to deploy the physical barrier and are effective only if there is enough warning time to mobilize the labor and equipment necessary to implement them and safely evacuate.

Passive: Dry floodproofing systems that do not require human intervention to deploy the physical barrier.

The image below (from Delaware, 2007) shows an example of an active dry floodproofing barrier installed at a commercial property.

Key Terminology

Flood Barrier: The physical barrier, composed of opening protection, floor slab, and wall system, that separates floodwater from the dry floodproofed portion of the building.

Opening Protection: A cover, shield, or door that covers a window, doorway, loading dock access, or other opening in a building wall or floor. Sometimes called a “closure device.”

Floodwall: A constructed barrier of flood damage-resistant materials to keep water away from or out of a specific area. Floodwalls surround a building and are typically offset from the exterior walls of the building; some floodwalls can be integrated into the building envelope. Floodwalls are considered a component of the overall flood barrier.

Flood Entry Point: Any opening, joint, gap, crack, low point, or other location through or over which floodwater can enter.

Operations, Maintenance, and Testing Plans for Dry Floodproofing Systems

Both the American Society of Civil Engineers, *Standard for Flood Resistant Design and Construction* (ASCE 2014), and the National Flood Insurance Policy (NFIP) guidelines require that the operations, maintenance, and testing[1] plan of a dry floodproofing system be developed during the design of the system and regularly updated throughout the life of the building.

The procedures described in the operations, maintenance, and testing plan should be conducted annually and considered part of the long-term approach to maintaining the effectiveness of the building's flood protection system. The floodproofing components at installation locations should be inspected to evaluate system performance following any flood event and after any construction or demolition project in the building's vicinity. Periodic deployment drills (at least annually) should also be specified in the operations, maintenance, and testing plan. FEMA recommends that the operations, maintenance, and testing plan include the following items:

- A decision tree identifying responsible parties, a sequence and timeline by which various components will be installed, including identified triggers or benchmarks to initiate procedures
- A list of personnel, equipment, and supplies needed to deploy all system components
- A map of the equipment storage location and component deployment locations
- A record of the manufacturer or designer and their contact information for expediting replacement parts and support as needed
- A copy of the NFIP Floodproofing Certificate

In addition to the above-described elements of the operations, maintenance, and testing plan, the following should be considered. These are based on MAT observations of damage and interviews with building owners and managers after Hurricanes Harvey and Irma.

Size and weight. Consider the size and weight of individual dry floodproofing panels when choosing or designing a system and the openings they will cover

1 The terms "testing" and "exercising" are used interchangeably in this advisory although they may have different definitions for design professionals and emergency managers. Regular evaluation of how the dry floodproofing system performs (under practice and design flood conditions) can improve a facility's response to disruption in future flood events.

Applicable Codes

ASCE 24 (Section 6.2.3) describes implementation requirements and restrictions for dry floodproofing new buildings and when Substantial Improvements are made to existing buildings. Owners who want to dry floodproof existing buildings may also benefit from following the guidelines in this standard.

NFIP Floodproofing Certificate

The requirements of the NFIP Floodproofing Certificate are described in FEMA P-936 (1993) and should be understood before starting design. The NFIP Floodproofing Certificate requires compliance with ASCE 24 and is both a design and construction certification. Professional engineers and architects should read the Floodproofing Certificate in its entirety and the applicable sections of ASCE 24, FEMA P-936, and Technical Bulletin 3, "Non-Residential Floodproofing" (FEMA 1993), prior to signing it.

Responsible Parties

Deployment of dry floodproofing systems is a shared responsibility of the building owner or manager, installer (i.e., contracted or on-site staff), and possibly building occupants.

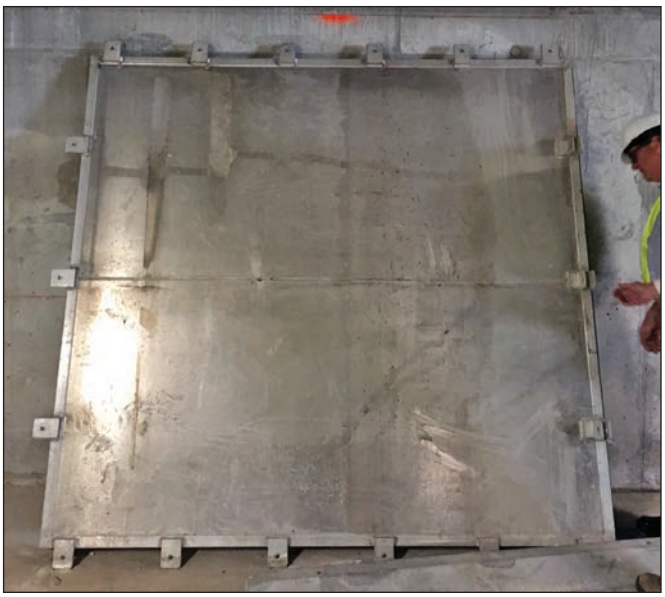


Figure 1: Large (6 feet high x 6 feet wide) metal flood panel requiring special equipment for installation

(Figure 1). If there are difficulties in installing large panels, consider approaches to improve the installation process. This may entail replacing the panel type with a passive floodproofing component or with a component that is easier to install.

System manufacturer. Flood protection systems should come from a reputable manufacturer and be consistent with a testing standard such as ANSI/FM 2510 that includes performance standards for hydrostatic test strength, system leakage, corrosion, and resistance to impact, wear, abrasion, tear, and puncture.

Storage. Determine an appropriate storage location for the dry floodproofing components, supplies, and equipment. Ensure the location is not open to the elements, as ultraviolet radiation and temperature extremes degrade rubber seals, gaskets, and component identification labels (Figure 2). Ensure this location is secure to prevent theft and vandalism, but is also accessible and labeled for the installer in case of deployment. On-site storage of floodproofing components is preferable. A separate location should be provided for spare parts.

All parts should be clearly labelled with permanent marker and a unique identification label that signifies its location when installed.

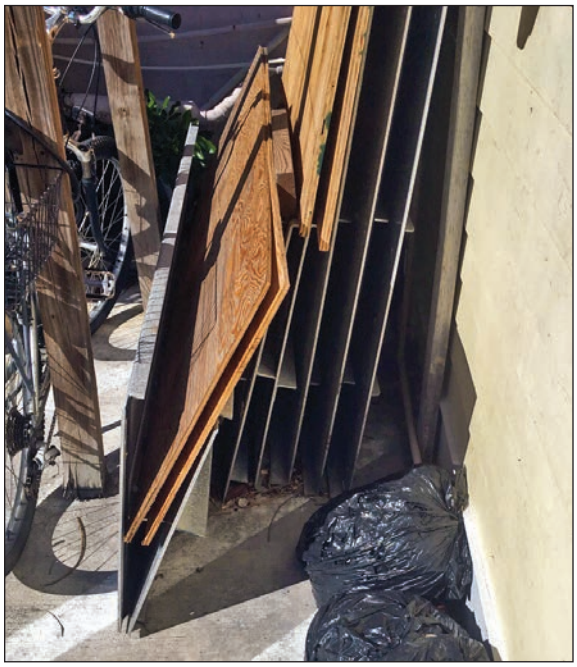


Figure 2: Flood panels (metal) and window shutters (plywood) were stored together outside a building. Panels and rubber gaskets were exposed to the elements; this storage practice is not recommended.

In-house versus contract staff. Assess the pros and cons of using contracted installers versus in-house staff. Ensure sufficient, trained staff will be available to implement the system prior to a flood event. Some dry floodproofing systems are installed by hired contractors who may be responsible for deploying systems at many sites across a city or region. Contract laborers may be limited in availability and timing in the days before an event.

Deployment drills. Conduct a deployment drill of the floodproofing system annually, or more frequently, as prescribed by the operations, maintenance, and testing plan, including testing all valves, sump pumps, power generators, and other drainage measures. An important task is to ensure that all valves or other drainage measures are clear of debris.

During drills and tests, building operators should record the number of workers, the equipment needed, and the time it takes to install part or all of the system, and any perceived system deficiencies should be identified. Ensure that any staff member who may be called upon to install specific floodproofing measures participates in drills and is familiar with and able to implement the floodproofing system. Ensure that the deployment drill considers egress requirements for personnel who remain inside the building.

Figure 3: Torn gasket on metal flood panel after panel was removed. Gasket must be replaced before the next deployment.

Regular inspection. Regularly inspect and maintain shields, doors, gates, pumps, equipment, gaskets, seals, brackets, panels, hardware, etc., and replace immediately if needed, to ensure system performance (Figure 3). Use the equipment list in the operations, maintenance, and testing plan to perform an annual accounting of all component and installation equipment.

Perform a building-wide inspection of all areas below the design flood elevation to check for penetrations in walls, floors, and ceilings, which are common sources of leakage during flood events. If not properly designed with seals able to withstand hydrostatic loads for their given locations, such penetrations can negate flood protection benefits afforded by any floodproofing systems.

Wet-testing. Perform wet-testing of the floodproofing system every 5 years or after gasket replacement.

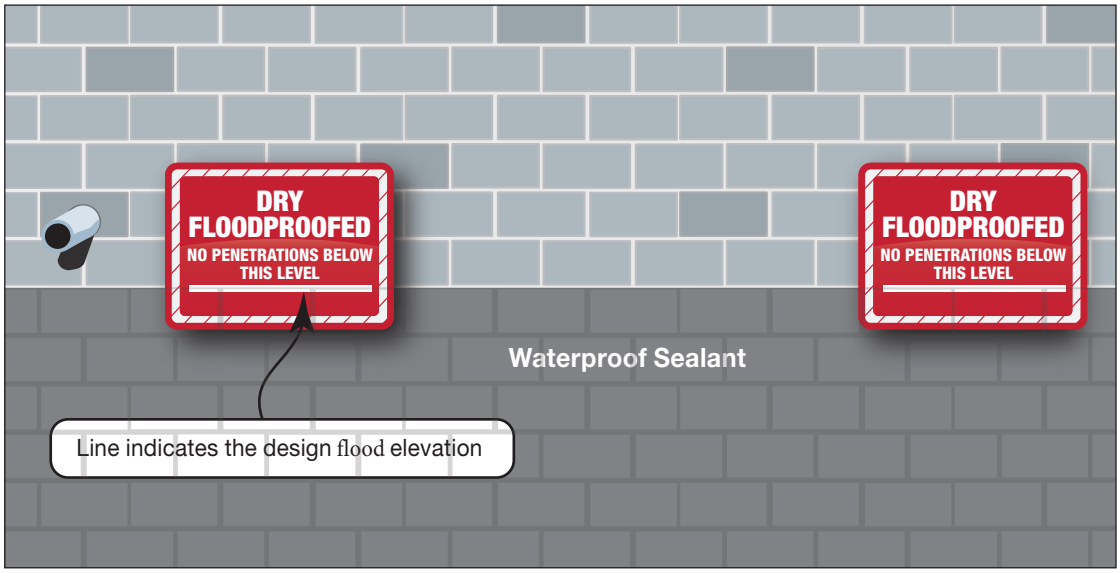
Penetrations Below Design Flood Elevation

If any pipes, conduits, or ducts that penetrate below the design flood elevation cannot resist flood loads, a mitigation solution should be immediately identified and implemented. Refer to Hurricane Harvey Recovery Advisory TX-RA1 for more information about penetrations.

Water leak detection system. Install a water leak detection system behind the dry floodproofing system to allow remote monitoring to determine when passive systems are deployed and whether measures are performing as expected.

Provide labels. To discourage unnecessary penetrations, consider labeling the walls and slabs of a dry floodproofed area, including any flood barriers that are part of a building design (e.g., foundation walls) with "Dry Floodproofed: No Penetrations Below This Level;" the sign should indicate the design flood elevation on the wall (Figure 4). For any existing penetrations that are sealed with watertight components or assemblies, consider a similar marking or designation.

Figure 4: Example signage on a dry floodproofed wall spaced appropriately to maintain awareness



Deployment Considerations for Active Dry Floodproofing

Dry floodproofing measures should be activated once specifically identified triggers or benchmarks occur per the facility Emergency Operations Plan (refer to the following section). The following list includes common considerations to help building owners and operators effectively deploy their active dry floodproofing systems.

- Ensure that the appropriate building operations staff, installer, or municipality officials, if required, have copies of the operations, maintenance, and testing plan and the facility Emergency Operations Plan.
- Deploy all components specified by the operations, maintenance, and testing plan.
- Deploy in the order and at the locations specified in the operations, maintenance, and testing plan. Consider prioritizing locations that are more vulnerable or critical.
- Ensure that the dry floodproofing systems are installed correctly. Failure to install and tighten bolts, or repair/replace gaskets and seals as needed, can lead to leaks or floodproofing system failure.

- Verify that the system components required to install the dry floodproofing systems are stored together, as outlined in the operations, maintenance, and testing plan, with a separate area for spare parts (Figure 5).
- For individual flood components, verify that each component has retained its marking with its unique identification label that signifies its location when installed (Figure 6). Stickers and ink have a tendency to degrade over time, potentially leaving installers unsure of the proper sequence or location of the panels. Some manufacturers make flood panels with installation directions directly on the panel rather than in a separate document.
- The map showing where the dry floodproofing components will be installed should be reviewed and made available, as needed.
- If the flood panel requires a gasket to be inflated with air to ensure a watertight seal, provide redundant methods to maintain inflation, such as a portable air tank or pump (Figure 7).

Figure 5: Enclosed storage space for multiple flood panels, stanchions, and hardware

Figure 6: Installed flood panels. Each flood panel has a unique ID number. Also note the tightener bracket at top.

Figure 7: Flood gate with an air tank and a hand pump as a redundancy measure to inflate gaskets

Floodproofing Considerations for a Facility Emergency Operations Plan

Floodproofing considerations should be included in the facility's Emergency Operations Plan regardless of the size, scope, and complexity of the building(s). The scope and complexity of the floodproofing system and dry floodproofing measures will dictate the level of detail, phasing, and sequencing specified in the Emergency Operations Plan. It will also affect the equipment needed, number of personnel and time needed to install the system, maintenance requirements, appropriate training and exercising, and other issues. Flood-related considerations should address the process and timeline leading up to and during deployment, specific storm conditions that trigger deployment of floodproofing measures, and whether and how the system will be operated during the storm event. Specific additional emergency procedures should be developed for events larger than the design event.

Hurricane Irma Floodproofing Example

A building manager stated that a contractor had installed parts of the dry floodproofing system at one entrance of a building, but had not installed the required components at another building entrance. The result was that the first floor of the building flooded.

Pertinent information from the floodproofing system's operations, maintenance, and testing plan should be included in the floodproofing portion of the facility Emergency Operations Plan, as well as deployment considerations for active dry floodproofing measures (see previous subsections). Refer to Table 1 for details to evaluate when preparing the facility Emergency Operations Plan.

Building owners and operators should review and update the floodproofing portions of their facility Emergency Operations Plan on an annual basis (e.g., after hurricane or rainy season), and after each time the facility's floodproofing system is deployed. Pertinent information related to storm observations, system performance, damage to the floodproofing system, or any perceived system weaknesses or deficiencies should be recorded in both the facility Emergency Operations Plan and the operations, maintenance, and testing plan.

The building owners and operators should ensure that the facility Emergency Operations Plan and operations, maintenance, and testing plan are accessible to appropriate building operations staff, installer, or municipality, if required, and are forwarded as part of any workplace transition to maintain institutional continuity.

Table 1: Floodproofing Considerations to Include in a Facility Emergency Operations Plan

Considerations	Details to Evaluate
Standby Power	• How long will emergency generators supply power for the sump pump system and other building systems without an off-site fuel delivery? • Will emergency generators be accessible during the flood event and equipped to operate during a flood event? • Will fuel delivery be hindered by the implemented dry floodproofing? • Are redundancy measures such as backup connections to other generators needed?
Prior to Event	• Who makes the decision to initiate mobilization and deployment of the floodproofing system? When will it occur based on warning time and expected flood conditions? • Is the facility Emergency Operations Plan permanently posted in at least two conspicuous locations? • What staff or contractors will be needed (e.g., maintenance staff, building engineer, contractors, installers) to retrieve and install active dry floodproofing components? • How many days prior to an event will personnel be mobilized? • How will personnel, equipment, and components be staged or phased? • Where are the storage location(s) and deployment location(s) of all necessary equipment? • How long will it take to deploy or activate the floodproofing system? • What is the system's design flood elevation? What is the expected flood depth?

Table 1: Floodproofing Considerations to Include in a Facility Emergency Operations Plan (concluded)

Considerations	Details to Evaluate
Evacuation*	• Under what conditions will the building be evacuated? • Who will make the decision to evacuate the building in advance of or during a flood event? • Which points are designated as egresses or emergency openings and are they clearly marked? • Does the means of egress allow the floodproofing measures to remain in place? • How does the facility Emergency Operations Plan account for building evacuation timing and sequencing?
Building Occupancy During Event*	• Will the building be occupied during a flood event? If yes, then by whom (e.g., maintenance staff, employees, tenants)? What will their role be, if any, in deploying and operating the dry floodproofing system? • What will the occupants require in the event of an emergency (e.g., food, water, shelter)? How will supplies be stockpiled and how will operations continue during the event? • Will implemented dry floodproofing measures disrupt operations?
After the Event	• What staff or contractors will be needed for cleanup, debris management, removal of floodproofing equipment, and inspection of floodproofing equipment performance? • How long will it take to resume normal operations?

* FEMA recommends evacuating a building before a flood event whenever possible. Building owners and operators should evacuate in accordance with state and local government orders or notices. For unique situations that may require critical personnel to remain behind, advanced coordination and planning should occur with the local government so that emergency and government personnel can plan accordingly for their jurisdictional emergency operations plan.

References and Resources

References

ASCE (American Society of Civil Engineers). 2014. *Standard for Flood Resistant Design and Construction.* ASCE Standard ASCE 24-14.

American National Standards Institute and FM Approvals. 2014. *Approval Standard for Flood Abatement Equipment.* ANSI/FM 2510. http://www.fmapprovals.com/products-we-certify/products-we-certify/flood-mitigation-products.

FEMA (Federal Emergency Management Agency). 1993. *Non-Residential Floodproofing – Requirements and Certification.* Technical Bulletin 3-93. https://www.fema.gov/media-library/assets/documents/3473.

FEMA 2013. *Floodproofing Non-Residential Structures.* FEMA P-936. https://www.fema.gov/media-library/assets/documents/34270.

Resources

ASCE. 2016. *Minimum Design Loads of Buildings and Other Structures.* ASCE Standard ASCE 7-16.

ASFPM (Association of State Floodplain Managers). n.d. "National Flood Barrier Testing & Certification Program." http://www.nationalfloodbarrier.org.

FEMA. 2017. *Protecting Building Utility Systems from Flood Damage.* FEMA P-348. https://www.fema.gov/media-library/assets/documents/3729.

Risk Management Series publications listed below are available at https://www.fema.gov/security-risk-management-series-publications.

- FEMA. 2007. *Design Guide for Improving Critical Facility Safety from Flooding and High Winds.* FEMA P-543.

- FEMA. 2007. *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds.* FEMA P-577.
- FEMA. 2010. *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds.* FEMA P-424.

Technical Bulletins listed below are available at https://www.fema.gov/media-library/collections/4.

- FEMA. 1993. *Non-Residential Floodproofing – Requirements and Certification.* Technical Bulletin 3-93.
- FEMA. 1993. *Wet Floodproofing Requirements.* Technical Bulletin 7-93.
- FEMA. 2008. *Flood Damage-Resistant Materials Requirements.* Technical Bulletin 2.

Recovery Advisories for Hurricane Sandy listed below are available at https://www.fema.gov/media-library/assets/documents/30966.

- FEMA. 2013. *Reducing Flood Effects in Critical Facilities.* Hurricane Sandy RA2.
- FEMA. 2013. *Reducing Interruptions to Mid- and High-Rise Buildings During Floods.* Hurricane Sandy RA4.
- FEMA. 2013. *Designing for Flood Levels Above the BFE After Hurricane Sandy.* Hurricane Sandy RA5.

Recovery Advisories from the 2016 Fall Flooding in Iowa listed below are available at https://www.fema.gov/media-library/assets/documents/130555.

- FEMA. 2017. *Flood Protection for Critical and Essential Facilities.* 2016 Fall Flooding in Iowa RA3.
- FEMA. 2017. *Flood Protection and Elevation of Building Utilities.* 2016 Fall Flooding in Iowa RA4.
- FEMA. 2017. *Flood Protection for Backup and Emergency Power Fuel Systems.* 2016 Fall Flooding in Iowa RA5.

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