



Hurricane Mitigation

A Handbook for Public Facilities

May 2005



FEMA

Hurricane Mitigation

A Handbook for Public Facilities

**Federal Emergency Management Agency
Region 4**

May 2005

TABLE OF CONTENTS

Introduction

Purpose of Handbook

Overview of the Public Assistance Mitigation Program

Mitigation Alternatives for Hurricane Damaged Public Facilities

Hurricane Damage to Public Facilities

<i>I.</i>	<i>SURGE DAMAGE: Mitigation for Category C Facilities – Roads & Bridges</i>	
	A. Inundation	2
	B. Erosion and Scour.....	6
	C. Debris	12
<i>II.</i>	<i>WIND DAMAGE: Mitigation for Category C Facilities – Roads & Bridges</i>	
	A. Light and Traffic Poles	14
	B. Overhead and Roadside Signs	17
	<i>WIND-DRIVEN RAIN DAMAGE: Mitigation for Category C Facilities –Not Applicable</i>	
<i>III.</i>	<i>SURGE DAMAGE: Mitigation for Category D Facilities – Water Control Facilities</i>	
	A. Inundation	20
	B. Erosion and Scour.....	21
	C. Debris	23
	<i>WIND DAMAGE & WIND-DRIVEN RAIN DAMAGE: Mitigation for Category D Facilities – Not Applicable</i>	
<i>IV.</i>	<i>SURGE DAMAGE: Mitigation for Category E Facilities – Buildings & Contents</i>	
	A. Inundation	25
	B. Erosion and Scour.....	38
	C. Corrosion.....	40

V.	<i>WIND DAMAGE: Mitigation for Category E Facilities – Buildings & Contents</i>	
	A. Structural Frame	46
	B. Building Envelope	53
	C. Building Utility Equipment	68
VI.	<i>WIND-DRIVEN RAIN DAMAGE: Mitigation for Category E Facilities – Buildings & Contents</i>	
	A. Building Upgrades	72
	B. Building Utility Equipment	75
VII.	<i>SURGE DAMAGE: Mitigation for Category F Facilities - Utilities</i>	
	A. Inundation	78
	B. Erosion and Scour.....	79
VIII.	<i>WIND DAMAGE: Mitigation for Category F Facilities - Utilities</i>	
	A. Utility Equipment	81
	B. Transmission and Distribution Lines	84
	<i>WIND-DRIVEN RAIN DAMAGE: Mitigation for Category F Facilities– Not Applicable</i>	
IX.	<i>SURGE DAMAGE: Mitigation for Category G Facilities – Parks, Recreational and Other</i>	
	A. Inundation	87
	B. Erosion and Scour.....	90
X.	<i>WIND DAMAGE: Mitigation for Category G Facilities – Parks, Recreational and Other</i>	
	A. Public Beaches and Dunes	94
	B. Docks and Piers	95
	<i>WIND-DRIVEN RAIN DAMAGE: Mitigation for Category G Facilities– Not Applicable</i>	
	<i>Mitigation Best Practices</i>	97
	<i>Appendices</i>	
	A. Regulations & Considerations.....	i
	B. Glossary & Keyword Index.....	v
	C. Acronyms	xiii
	D. References.....	xv
	E. Copy of FEMA Policy 9526.1	xvii

INTRODUCTION

A key strategy in improving delivery of disaster assistance is to reduce the vulnerability of public infrastructure to damages from disaster events such as hurricanes. This *Hurricane Hazard Mitigation Handbook for Public Facilities* (Handbook) assists local jurisdictions affected by hurricanes by suggesting mitigation measures that reduce their vulnerability to hurricane forces including storm surges, high winds, and torrential rains. The mitigation measures in this *Handbook* are provided to help identify potential ideas that local jurisdictions can implement during post-disaster repair and/or rebuilding to reduce future damages.

FEMA provides disaster response and recovery assistance under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act), 42 U.S.C. §§ 5121-5206, as amended. After a disaster, FEMA coordinates recovery efforts through a number of mitigation programs. The opportunities for federal funding of hazard mitigation measures are established in Sections 404 and 406 of the Stafford Act and the Pre-Disaster Mitigation Program.

Section 404 of the Stafford Act provides hazard mitigation grants to States and local governments to implement long term hazard mitigation measures after a major disaster declaration through the Hazard Mitigation Grant Program (HMGP).

Section 406 of the Stafford Act provides for hazard mitigation measures that can be effectively and economically incorporated into public facility and infrastructure repair projects funded under the FEMA Public Assistance (PA) Program.

The Pre-Disaster Mitigation (PDM) Program provides hazard mitigation funds to States and local governments for pre-disaster mitigation planning and the implementation of cost-effective mitigation projects prior to a disaster.

The Challenge: An apparent increase in the frequency and intensity of weather events combined with growth in infrastructure development has escalated disaster response and recovery costs to unsustainable levels. Current estimates indicate the total losses in Florida caused by the four hurricanes

in 2004 are between \$22 and \$23 billion, slightly larger in current dollars than Hurricane Andrew in 1992. Before 2004, declared disasters across the nation have cost over \$50 billion annually.

The Goal: The goal is to reduce excessive losses from disasters through preparedness and mitigation. Three objectives support achieving the goal:

OBJECTIVE 1: Incorporate mitigation betterments into the rebuilding of infrastructure damaged by a disaster so that future disasters will cause less damage.

OBJECTIVE 2: Strengthen existing infrastructure facilities to more effectively withstand extreme weather events such as hurricanes.

OBJECTIVE 3: Ensure that communities address natural hazards through comprehensive plans, which identify all significant hazards and implement steps to eliminate the hazards or incrementally reduce community vulnerability to those hazards.

The Result: Achieving these objectives will substantially enhance community resiliency and economic sustainability in future disasters.

PURPOSE OF HANDBOOK

The *Hurricane Hazard Mitigation Handbook for Public Facilities* (Handbook) is intended to aid local jurisdictions in identifying a variety of feasible mitigation measures that can be implemented during the rebuilding process. The Handbook focuses on projects commonly eligible for hazard mitigation funding under the Public Assistance (PA) program. Frequently, due to the urgency to repair the facility, long-term mitigation opportunities are not fully explored. As a result, hazard mitigation funding opportunities through FEMA's PA program are not fully utilized.

This Handbook provides local jurisdictions with mitigation ideas, many of which have demonstrated success in the past. These mitigation measures should be used as a source of ideas for potential mitigation projects, regardless of whether they will receive FEMA funding.

In addition to the ideas in this Handbook, FEMA's Response & Recovery Policy No. 9526.1, a copy of which is included in Appendix E, can be referenced. This Policy includes an appendix of measures already determined by FEMA to be cost-effective when certain conditions are met, such as when the cost of the mitigation measure does not exceed 100 percent of the eligible cost to repair the damaged element to be mitigated by the measure. However, none of the mitigation measures in this Handbook should be considered "pre-approved" or automatically eligible for FEMA funding.

NOTE: Many of the mitigation measures in this Handbook can be found in the *Flood Mitigation Handbook for Public Facilities* (FMH) previously developed by FEMA Region X (February 28, 2002). These measures are provided in the *Hurricane Mitigation Handbook* in the sections on the pages that follow, along with appropriate page references to the FMH.

OVERVIEW OF THE PUBLIC ASSISTANCE MITIGATION PROGRAM

The FEMA Public Assistance (PA) program authorized by the Stafford Act provides recovery assistance to communities impacted by a declared disaster event. The PA program provides assistance for debris removal, emergency protective measures, and permanent restoration of publicly owned infrastructure. In providing assistance for permanent restoration, there is a required focus on restoring damaged infrastructure to its pre-disaster design. However, Section 406 of the Stafford Act allows FEMA to consider funding mitigation measures that go beyond the scope of work required to return the damaged facility to its pre-disaster design.

The guidelines for requesting PA funding for hazard mitigation measures under Section 406 of the Stafford Act require that:

- Measures can be applied only to the damaged element of the facility.
- Measures must reduce the risk of damage from future similar events; i.e. if damage was caused by hurricane force winds, the mitigation measures must reduce the risk of damage from a similar wind event.
- Measures must be technically feasible and effective in preventing future damage.
- Measures must be cost effective. Cost effectiveness can be determined as follows:
 - Hazard mitigation measures that cost up to 15 percent of the total eligible repair costs on a particular project are considered cost effective.
 - Certain mitigation measures identified in FEMA Policy 9526.1, dated August 13, 1998 (FEMA website: http://www.fema.gov/rrr/pa/9526_1.shtm) may be considered cost effective if the mitigation measure does not exceed the cost of eligible repair work in the project.
 - For mitigation measures that exceed the costs of eligible repair work, an acceptable benefit/cost analysis must be conducted.
- Measures must comply with applicable Federal environmental laws, regulations, and executive orders, such as the National Environmental Policy Act and Executive Order 11988 – Floodplain Management.

In repairing damaged infrastructure to the pre-disaster design, changes required by updated building codes and/or design and construction standards are not considered mitigation measures. Those changes are evaluated for PA funding eligibility using separate criteria applicable to codes and standards changes.

Facilities eligible for mitigation assistance under Section 406 of the Stafford Act include:

- Category C Facilities – Roads and bridges (including culverts) and appurtenant facilities (such as signs and signals).
- Category D Facilities - Water control facilities (such as irrigation canals), channels (provided they are designed and maintained), and sedimentation basins.
- Category E Facilities – Buildings (such as municipal structures), police and fire stations, schools, and hospitals; and equipment (such as vehicles and construction machinery). The contents of buildings (such as furnishings and heating and ventilating equipment) are also eligible.
- Category F Facilities – Utilities (such as storm and sanitary sewers), water treatment and delivery systems, and electrical power generation and distribution systems.
- Category G Facilities - Parks, recreational facilities, marine facilities, and other facilities.

Since the applicant or sub-grantee is responsible for identifying disaster-related damage, the applicant has the primary responsibility for proposing Section 406 mitigation work because Section 406 mitigation must relate directly to the damaged element(s). However, based on experience, FEMA and the State can provide recommendations for mitigation opportunities in consultation with the applicant.

MITIGATION ALTERNATIVES FOR HURRICANE DAMAGED PUBLIC FACILITIES

Organization of mitigation measures in this Handbook:

This Handbook is organized first by type of facility, then by types of damages that are commonly sustained by that facility. Each category of damage lists a selection of mitigation ideas to consider. The general design issues, effectiveness, limitations, and considerations of each mitigation measure are also identified.

Engineering, design and permitting requirements:

The Handbook does not detail site-specific requirements, as the engineering analysis, design, and permitting of each project will vary widely. However, the Handbook does provide some common code and design issues to be considered when implementing a mitigation measure and references to find additional technical details. Repair and mitigation of structural elements most often will require a professional engineer who can provide a detailed analysis of the structure's condition and damage to determine the appropriate repair and mitigation.

Public Assistance eligibility:

As with all agencies that provide federal funding, FEMA requires specific criteria be met regarding eligibility before approval of proposed projects. **ONLY FEMA CAN DETERMINE THE ELIGIBILITY OF AN APPLICANT, THE FACILITY, THE WORK, OR THE COST.** Eligibility criteria are detailed in the *Public Assistance Guide*, FEMA Publication No. 322. Additional information can also be obtained through FEMA's website at www.fema.gov or the FEMA Regional Office.

Regulations and considerations:

The following considerations have been symbolized for their reference in each mitigation measure and are defined in Appendix A - "Regulations & Considerations."



National Environmental Policy Act (NEPA)



Endangered Species Act (ESA)



National Historic Preservation Act (NHPA)



Clean Water Act



Coastal Barrier Resources Act (CBRA)



Floodplain / Wetlands



Right of Way Constraints



Floodplain Effects



Cost



Maintenance



Engineer Needed



Structure's Aesthetics Could be Impacted

Mitigation Keywords:

The “Glossary and Keyword Index,” found in Appendix B, provides a glossary of terms used in the Handbook and identifies mitigation keywords, which are italicized and bolded in the text. A keyword is a mitigation element used in two or more mitigation measures in the Handbook. Keywords are intended to help the reader become familiar with mitigation elements by understanding their application in different measures.

HURRICANE DAMAGE INTRODUCTION

A hurricane is defined as a tropical cyclone, formed in the atmosphere over warm ocean areas, in which sustained wind speeds reach 74 miles per hour or more and circulate in a large spiral around a center or "eye." Hurricanes and other coastal storm events such as tropical storms and Nor'easters (Northeasters) occur along the Atlantic and Gulf Coasts, Puerto Rico and the U.S. Virgin Islands (FEMA Regions I, II, III, IV and VI). Hurricanes and coastal storms known as typhoons occur in Hawaii and the U.S. Pacific Island territories including Guam, American Samoa, and Micronesia (FEMA Region IX). Hurricane intensities are measured using the Saffir-Simpson scale as shown below (<http://www.nhc.noaa.gov/aboutsshs.shtml>).

Intensity	Sustained Wind Speed (mph)*	Gust Wind Speed (mph)**	Pressure (millibars)	Description of Damage
Category 1	74 - 95	90 - 119	> 980	Storm surge generally 4-5 feet above normal. No real damage to building structures. Damage primarily to unanchored mobile homes, shrubs and trees. Some damage to poorly constructed signs. Also, some coastal road flooding and minor pier damage.
Category 2	96 - 110	120 - 139	965 - 979	Storm surge generally 6-8 feet above normal. Some roofing material, door, and window damage of buildings. Considerable damage to shrubs and trees with some trees blown down. Major damage to mobile homes, poorly

				constructed signs, and piers. Coastal and low-lying escape routes flood 2-4 hours before arrival of the hurricane center. Small craft in unprotected anchorages break moorings.
Category 3	111 - 130	140 - 164	945 - 964	

Category 4	131 - 155	165 - 194	920 - 944	Storm surge generally 13-18 feet above normal. More extensive curtain wall failures with some total roof structure failures on small homes. Shrubs, trees, and all signs are blown down. Complete destruction of mobile homes. Extensive damage to doors and windows. Low-lying escape routes may be cut by rising water 3-5 hours before arrival of the center of the hurricane. Major damage to lower floors of structures near the shore. Terrain lower than 10 feet above sea level may be flooded requiring massive evacuation of residential areas as far as 6 miles inland.
Category 5	> 155	> 194	< 920	Storm surge generally greater than 18 feet above normal. Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. All shrubs, trees, and signs blown down. Complete destruction of

				mobile homes. Severe and extensive window and door damage. Low-lying escape routes are cut by rising water 3-5 hours before arrival of the center of the hurricane. Major damage to lower floors of all structures located less than 15 feet above sea level and within 500 yards of the shoreline. Massive evacuation of residential areas on low ground within 5-10 miles of the shoreline may be required.
--	--	--	--	---

* 1-minute sustained over open water

** 3-second peak gust over open water

Hurricane damages to public facilities are typically caused by one or more of the following hazards:

- **Surge** – Coastal storm surge and high tide effects associated with hurricanes can generate inundation and breaking wave forces, coastal erosion and localized scour of soils from moving water, and impact forces from waterborne debris. Surge effects can lead to inundation, damage and/or collapse of coastal facilities.
- **Wind** – Hurricanes can produce high positive (blow-in) and negative (suction) wind pressures and windborne debris impact that can penetrate or blow off the exterior elements of buildings and infrastructure. This loss of exterior elements such as roof coverings, can cause additional interior damage and even structural collapse.
- **Wind-Driven Rain** – Heavy rainfall associated with hurricanes can be driven by the wind into building openings and other facilities. This wind-driven rain can lead to heavy water damage of building interiors and utility equipment.

ASSESSING THE CAUSE OF DAMAGE:

Mitigation measures are designed to reduce or eliminate damage to facilities. Determination of the appropriate mitigation measure depends, in part, on the assessment of the cause of damage. Hurricane damages occur as a result of surge, wind, or wind-driven rain hazards. The damages associated with these hazards are discussed next.

Surge Damage: Coastal storm surge damage associated with hurricanes is typically concentrated along the coastline and in low-lying areas where the hurricane has made landfall. The most common forms of storm surge damage are described below:

- **Inundation** – Damage occurs when coastal storm surge from coastal floodwaters (hydrostatic forces) and high tide effects surround and infiltrate facilities. In areas that are located closest to the shoreline, this damage can be accompanied by high-velocity floodwaters (hydrodynamic forces) and breaking wave forces that can damage or destroy virtually anything in their path. Examples of facilities that may be damaged by inundation include roadside equipment, bridge decks, drainage pipes, pumps, building foundations and load-bearing walls, interior and exterior finishes, ground-level utility equipment, and docks and piers.
- **Erosion and Scour** – Damage occurs when moving floodwaters from coastal storm surge shift or remove sand along the coastline (erosion) and/or undermine foundations that support coastal facilities (scour). In some areas, the effects of erosion and scour can result in severe damage or even collapse of coastal buildings and infrastructure. Examples of facilities that may be damaged by erosion and scour include roadway ditches, embankments, shoulders, pavements, culverts, bridge approaches, piers, abutments, drainage/irrigation ditches, shoreline protective structures, building foundations, ground-level and buried utility equipment, transmission/distribution lines, public beaches, and sand dunes.
- **Debris** – Damage occurs when various natural materials and man-made objects are carried by moving floodwaters or breaking waves and either collide with coastal facilities or clog up drainage structures. At a minimum, floodborne debris impacts can create large holes in structures that allow water and wind inside. In areas of high-velocity flow that are

located close to the shoreline, impact damage from heavier floodborne debris can collapse foundations and destroy coastal facilities. Examples of facilities that may be damaged by floodborne debris include bridge piers, abutments, drainage pipes, building foundations, and utility equipment.

- **Corrosion** – Damage occurs when exposure to salt spray and moisture cause significant weakening of metal connectors and fasteners on coastal buildings and other facilities. Damage sufficient to cause the metal to fail can occur as quickly as 5-10 years after initial installation. In areas located closest to the shoreline, corrosion damage can significantly increase the risk of connection failures and severe structural damage during hurricane events. Examples of facilities that may be damaged by corrosion include metal traffic and light poles, building connectors and fasteners, and straps used to anchor or support outdoor equipment and utilities.

Wind Damage: Wind damage associated with hurricanes originates along the coastline and is most severe in coastal areas immediately northeast of where the hurricane has made landfall. However, unlike flood damage, wind damage associated with hurricanes typically extends further inland and can affect a much wider area. Wind damage at a given location will vary based on the wind speed and the age, material, type and quality of construction. The most common forms of wind damage are described below:

- **Wind Pressures** – Wind pressure is a function of wind speed, height above ground, terrain conditions, and the part of the structure that the wind is impacting. Wind pressure acts both inward creating positive (blow in) pressure and outward creating negative (suction) pressure. Wind is cyclical and thus will tend to cause failures from fatigue of materials. Damage occurs when high wind pressures act on the exterior and interior surfaces of various facilities, which can lead to collapse, and overturning of coastal buildings and other structures. Examples of facilities that may be damaged by wind pressures include light and traffic signal poles, overhead roadside signs, building roofs and wall framing, door and window openings, ancillary structures, overhead utility equipment, docks, and pier signs.

- **Windborne Debris Impact** – Wind can pick up debris, depending on wind speed and debris weight, and propel the debris into structures. The debris can be small such as rocks or stones, or it can be large such as pieces of lumber, lightweight columns, tree limbs, or an HVAC condenser. In areas that experience strong hurricane-force winds, impact damage from heavier windborne debris such as trees can crush roofs, pierce walls, shatter glass, collapse foundations, and snap utility poles. Examples of facilities that may be damaged by windborne debris impact include light and traffic signal poles, building roofs and wall framing, door and window openings, ancillary structures, overhead utility transmission/distribution lines, docks, and pier signs.

Wind-Driven Rain Damage: Wind-driven rain damage associated with hurricanes typically originates along the coastline near where the hurricane makes landfall, and then extends inland over a wide area. Wind-driven rain damage associated with hurricanes is typically concentrated in high wind areas that experience heavy rainfall. Damage occurs when rain is carried by high wind and penetrates various structural openings. Wind-driven rain can lead to heavy water damage of interiors and equipment. Examples of facilities that may be damaged by wind-driven rain include building roofs, interiors, contents, and utility equipment.

Assessing the cause of damage begins with an understanding of the characteristics of the hurricane event. In many cases, hurricane mitigation deals with a combination of flood and wind mitigation measures. In addition, all hurricane mitigation should keep in mind the increased effects of corrosion and wind-driven rain in coastal areas. Specific details on assessing the causes of damage are discussed in the introductions for each facility where appropriate.

This Handbook identifies the types of hurricane damage most typically sustained by the following public facilities:

- *Roads & Bridges*
- *Water Control Facilities*
- *Buildings & Contents*
- *Utilities*
- *Other Facilities*

I. SURGE DAMAGE: Mitigation for Category C Facilities - Roads & Bridges

Basic Causes of Damage

- Storm surge inundation (i.e., coastal flooding and/or breaking wave forces) of roads, culverts and bridges
- Erosion and scour around roads, culverts and bridges
- Floodborne debris impact on bridges

This section discusses mitigation measures for common surge damage to roads, roadside facilities, culverts, and bridges, which are caused by:

- A. Inundation*
- B. Erosion and Scour*
- C. Debris*

A. Inundation

Problem: Inundation causes the following damages to Category C Facilities:

1. Roads and roadside equipment are inundated by floodwaters or storm surge, resulting in damaged or destroyed components.
2. Bridge decks that are not sufficiently elevated to the design flood elevation may be inundated by coastal floodwaters during hurricanes and washed away.

Mitigation Objectives: Prevent inundation of Category C Facilities as follows:

1. Reduce the risk that roads and roadside equipment will be damaged by inundation by elevation or floodproofing.
2. Reduce the risk of inundation on bridge decks by elevating the decks or increasing the capacity of the bridge to pass the design coastal flood event.

Mitigation measures to protect roads and roadside equipment from damage caused by inundation include:

- 1.a. Elevate/floodproof traffic signal control boxes..... p. 3
- 1.b. Replace gravel roads with asphalt or concrete p. 4
- 1.c. Increase roadway elevation See *FMH*, p. 15

Mitigation measures to protect bridges from inundation damage caused by insufficient elevation include:

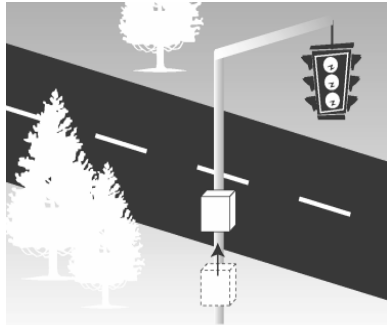
- 2.a. Relocate bridge..... p. 5
- 2.b. Construct bridge wingwalls See *FMH*, p. 49
- 2.c. Elevate the bridge deck See *FMH*, p. 54
- 2.d. Replace a steel truss bridge with an open deck bridge..... See *FMH*, p. 55
- 2.e. Replace multi-spans with a single span bridge..... See *FMH*, p. 56
- 2.f. Increase bridge opening size See *FMH*, p. 57

A.1.a Elevate/Floodproof Traffic Signal Control Boxes

Elevate pole-mounted and grade level traffic signal control boxes above the design flood elevation. If elevation is not feasible, the box may be sealed to prevent intrusion of floodwaters.

Design issues:

- State and local standards for traffic signal construction may apply.
- A pole-mounted box may be attached to the pole at a greater height. The elevation of a grade-level box may be increased by constructing a pad of fill or concrete, provided it does not create a vehicle impact hazard.
- Elevated box must not obstruct sight lines for drivers.
- Grade-level signal control boxes may be elevated and anchored on a concrete or masonry pedestal. Pedestals must be designed to avoid being an impact hazard in the event of a vehicle accident and resist flood-induced erosion and scour.
- For floodproofing, box must be constructed of **flood-resistant materials** and sealed to prevent entry of floodwaters.
- Design mitigated signal control boxes and connections to resist increased forces and corrosion.



Effectiveness:

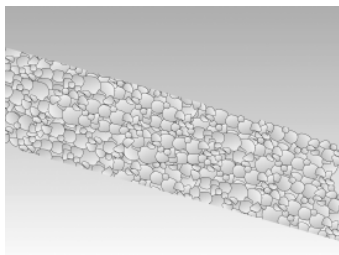
- Elevation is completely effective for the design flood.
- Floodproofing of control box is suitable for flood events of short duration with low-velocity flow.
- Effectiveness may be increased using stronger signal poles or grade level box foundations.

Limitations:

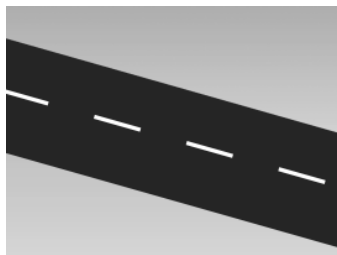
- May not prevent loss of electrical power to the traffic signal.
- May increase maintenance costs due to decreased access.

A.1.b Replace Gravel Roads with Asphalt or Concrete

Replace damaged gravel road surfaces with asphalt or concrete. This measure will prevent damage to gravel roads subject to inundation of floodwaters as well as minimize the potential for floodborne and/or windborne debris.



BEFORE



AFTER

Design issues:

- State and local standards for roadway construction apply.
- Review existing site soil conditions to verify construction feasibility and determine required thickness of pavement.
- Incorporate structures, such as culverts, that facilitate lateral drainage.

Effectiveness:

- Effective at reducing flood damage and floodborne debris, and may provide some resistance to erosion.
- Effective at reducing windborne debris damage in more extreme wind events.
- Effectiveness in areas of increased velocity may be increased by ***elevating*** the roadway surface or adding ***embankment slope protection***.

Limitations:

- Damage repairs to asphalt or concrete roadway surfaces may be more costly.
- May not prevent road damage in locations subject to wave impact forces or severe coastal erosion.

Considerations:



A.2.a Relocate bridge

Relocate the bridge to a location that is less likely to be affected by damaging flows. For example, the crossing could be moved inland so that it is outside the area affected by coastal storm surge and wave action.

Design issues:

- Right-of-way must be available or obtained.
- Will require relocation of roadway.
- Will require engineering analysis and design, to include subsurface investigation to determine soil and bedrock conditions.
- The original facility will likely be abandoned and must be demolished.
- Bridge must be designed to accommodate drainage conditions at the new location.

Effectiveness:

- The most effective mitigation possible, as the bridge will no longer be subject to damaging effects of storm surge.
- May be cost effective in areas where more frequent floods (such as the 10-year flood) overtop the bridge deck, where the flood elevation is above the roadway surface for a short distance, and when right-of-way is available.
- Allows the bridge to remain in service during flood events.

Limitations:

- Must be approved by the FEMA Regional Director, in accordance with 44 CFR §206.226(e).
- May not be feasible in locations where right-of-way is unavailable or expensive to acquire.
- Need to maintain access to properties served by the bridge prior to relocation.

Considerations:



B. Erosion and Scour

Problem: Coastal erosion and scour associated with storm surge causes the following damages to Category C Facilities:

1. Floodwaters or wave action cause scouring of roadway ditch or cause the ditch to be overtopped, resulting in damage to the ditch, roadway embankment, or related facilities such as culverts.
2. Overtopping by floodwaters or waves causes erosion of shoulders, roadway base, or pavement. Wave action may cause impact damage to the pavement. This type of damage may occur when the roadbed is located below the flood elevation in a flood hazard area or in an area subject to wave action.
3. High flows from storm surge or from heavy rains may exceed the capacity of a culvert. Overtopping may cause the embankment through which the culvert passes to be eroded. Turbulence at the culvert inlet and outlet may cause scour and erosion.
4. Coastal erosion and scour cause undermining and failure of bridge approaches, piers, and abutments.

Mitigation Objectives: Prevent erosion and scour of Category C Facilities as follows:

1. Reduce risk of roadway ditch erosion and overtopping by increasing ditch capacity or by hardening erodible areas.
2. Reduce the risk of roadway shoulder overtopping or exposure to wave action by increasing the resistance to these forces.
3. Prevent embankment erosion by increasing culvert efficiency or by increasing resistance to erosion.
4. Reduce the risk of coastal erosion and scour, and floodborne debris impact on bridge approaches, piers, and abutments by protecting or eliminating these elements to increase the resistance to these forces.

Mitigation measures to protect roads from erosion and scour damage to roadway ditches include:

- 1.a. Increase ditch capacity See *FMH*, p. 4
- 1.b. Install lining in the ditch..... See *FMH*, p. 5

Mitigation measures to protect roads from erosion and scour damage to roadway surfaces and shoulders include:

- 2.a. Relocate road p. 8
- 2.b. Soil stabilization/geotextiles p. 9
- 2.c. Replace gravel roads with asphalt or concrete See p. 4
- 2.d. Increase roadway elevation See *FMH*, p. 15
- 2.e. Construct shoulder protection See *FMH*, p. 16

Mitigation measures to protect culverts and embankments from erosion and scour damage include:

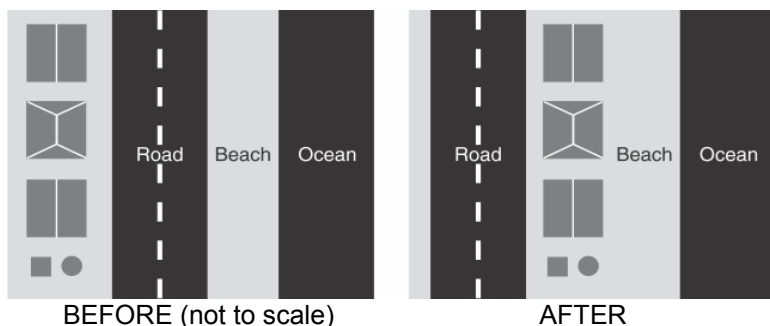
- 3.a. Relocate culvert p. 10
- 3.b. Bio-engineered embankment slope protection See *FMH*, p. 9
- 3.c. Change geometry of roadway section..... See *FMH*, p. 11
- 3.d. Place riprap along eroded slope See *FMH*, p. 13
- 3.e. Shape culvert entrance See *FMH*, p. 35
- 3.f. Install appropriate culvert end sections..... See *FMH*, p. 37
- 3.g. Construct an energy dissipater See *FMH*, p. 38

Mitigation measures to protect bridges from erosion and scour damage include:

- 4.a. Protect approaches and abutments using rip-rap p. 11
- 4.b. Relocate bridge..... See p. 6
- 4.c. Construct bridge wingwalls See *FMH*, p. 49
- 4.d. Replace multi-spans with a single span bridge..... See *FMH*, p. 56

B2 .a Relocate Road

Relocate the roadway away from floodprone areas, or areas subject to wave action. This measure will eliminate the risk of damage by removing the facility from the area of the hazard.



Design issues:

- State and local standards for roadway construction apply.
- Right-of-way must be available or obtained.
- New location must be free of other hazards.
- Incorporate structures (culverts) to facilitate lateral drainage.

Effectiveness:

- The most effective mitigation possible, as the road will no longer be subject to flooding.
- May be cost-effective in areas where more frequent floods (such as the 10-year flood) overtop the road, where the flood elevation is above the roadway surface for a short distance, and when right-of-way is available.
- Allows the roadway to remain in service during flood events.

Limitations:

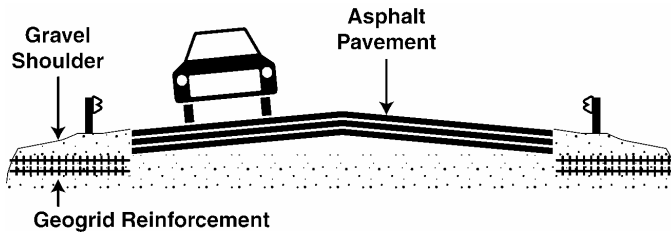
- Must be approved by the FEMA Regional Director, in accordance with 44 CFR §206.226(e).
- May not be feasible in locations where right-of-way is unavailable or expensive to acquire.
- Need to maintain access to properties served by roadway prior to relocation.

Considerations:



B.2.a Soil Stabilization/Geotextiles

Stabilize exposed soils on unpaved roadways and/or shoulders to reduce vulnerability to erosion and scour. This will increase the ability of the roadway and shoulder to withstand hydrodynamic forces caused by overtopping or wave action. Soil stabilization can be accomplished by chemical (lime, cement, fly ash, etc.) or mechanical (geotextile, geogrid, etc.) techniques.



Design issues:

- Chemical stabilization methods require site-specific design analysis and construction methods.
- Critical to develop appropriate mix design for stabilization agents.
- Mechanical stabilization may require combination of designs to provide suitable protection.

Effectiveness:

- Chemical stabilization is reasonably effective in mitigating damage due to erosion caused by low velocity flow, and it is less effective against erosion due to sustained high velocity flow.
- Mechanical stabilization can be effective for most flooding conditions.

Limitations:

- Effectiveness of chemical stabilization, particularly lime, can degrade over time due to leaching of chemical additive.
- Heavy loads on saturated, chemically stabilized soils may result in excessive deformations that fracture the surface, thereby degrading the protection.
- Heavy loads on saturated, mechanically stabilized soils may result in excessive deformation such as ruts.

Considerations



B.3.a Relocate Culvert

Relocate the culvert to a location that is less likely to be affected by damaging flows. For example, the crossing could be moved inland so that it is outside the area affected by coastal storm surge and wave action.

Design issues:

- Right-of-way must be available or obtained.
- Will require relocation of roadway.
- Culvert must be designed to accommodate drainage conditions at the new location.

Effectiveness:

- The most effective mitigation possible, as the road will no longer be subject to damaging effects of storm surge.
- May be cost-effective in areas where more frequent floods (such as the 10-year flood) overtop the road or where the flood elevation is above the roadway surface for a short distance and when right-of-way is available.
- Allows the roadway to remain in service during flood events.

Limitations:

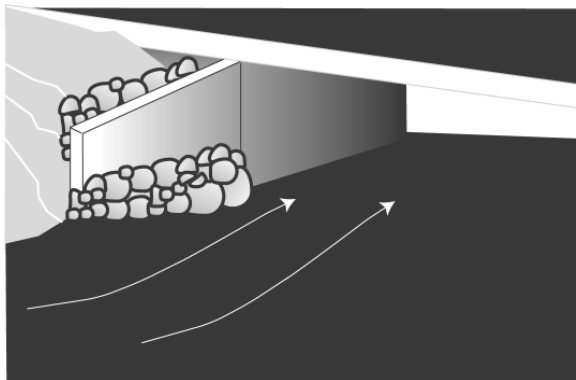
- Must be approved by the FEMA Regional Director, in accordance with 44 CFR §206.226(e).
- May not be feasible in locations where right-of-way is unavailable or expensive to acquire.

Considerations:



B.4.a Protect Approaches and Abutments Using Rip-Rap

Place **riprap** at bridge approaches and abutments. This armoring will reduce the risk of erosion during high-velocity flow.



Design issues:

- Riprap must be sized to reduce potential for displacement.

Effectiveness:

- Effective for protecting the bridge.
- Effectiveness can be increased when combined with the installation of **wingwalls** to reduce the risk of erosion.
- Considered to be generally cost-effective under Appendix A of R&R Policy 9526.1, dated August 13, 1998.

Limitations:

- Subject to displacement or undermining by high velocity flow.

Considerations:



C. Debris

Problem: Floodborne debris impact can lead to damage and failure of bridge piers and abutments.

Mitigation Objective: Reduce the risk of floodborne debris impact on piers and abutments by deflecting debris away from these elements or eliminating them to improve the response to these forces.

Mitigation measures to protect bridges from flood damage caused by floodborne debris impact include:

1. Relocate bridge..... See p. 5
2. Install debris deflectors on both sides of bridge piers See *FMH*, p. 65
3. Construct bridge wingwalls See *FMH*, p. 49
4. Replace multi-spans with a single span Bridge See *FMH*, p. 56

II. WIND DAMAGE: Mitigation for Category C Facilities - Roads & Bridges

Basic Causes of Damage

- Wind pressures and windborne debris impact on traffic poles and equipment.
- Wind pressures and windborne debris impact on overhead and roadside signs.

This section discusses mitigation measures for common wind damage to the following roadside facilities:

A. Light and Traffic Poles

B. Overhead and Roadside Signs

A. Light and Traffic Poles

Problem: High wind pressures and windborne debris impact forces cause damage to light and traffic signal poles as well as ground-level equipment.

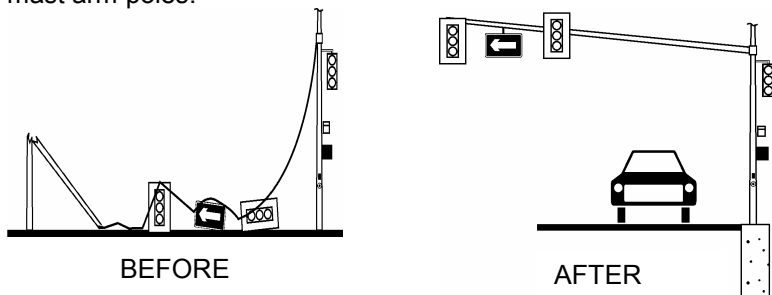
Mitigation Objective: Reduce the risk of high wind pressures and windborne debris impact forces by reinforcing or strengthening light and traffic poles and ground-level equipment to increase the resistance to these forces.

Mitigation measures to protect light and traffic signal poles and equipment from wind damage include:

1. Replace strain poles with mast arm poles..... p. 15
2. Replace strain poles with higher strength poles..... p. 16

A.1 Replace Strain Poles with Mast Arm Poles

Strain poles that support lights and overhead traffic signals on suspended cables appear particularly prone to damage in hurricane-force windstorms. In order to avoid future damage and prevent collapse, damaged strain poles can be replaced with mast arm poles.



Design issues:

- State and local standards for light/traffic signal poles apply.
- Poles must be properly supported on engineered foundations to avoid overturning or collapse, even when the ground is saturated.
- Consider vibration dampers to reduce objectionable mast arm sway.
- Traffic safety regulations may require breakaway poles for some applications
- Treat steel poles in coastal areas to resist corrosion.

Effectiveness:

- Very effective when properly designed and constructed.
- Effectiveness can be increased when combined with **reinforcing overhead signs** and adding harmonic dampeners to reduce wind amplification effects.
- Effectiveness can be increased by using impact-resistant light and traffic control fixtures.

Limitations:

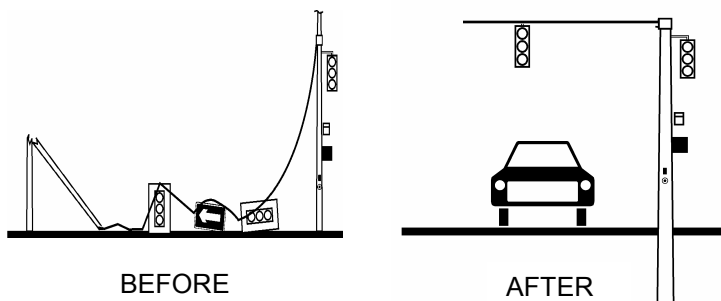
- May not prevent failure of lights and/or traffic signals.
- Poles still subject to loss of electrical power.
- May not prevent damage from wave impact forces.
- May not prevent damage from windborne debris impact.

Considerations:



A.2 Replace Strain Poles with Higher Strength Poles

Strain poles that support lights and overhead traffic signals on wires appear particularly prone to damage in hurricane-force windstorms. In order to reduce future damage and avoid collapse, replace damaged strain poles with higher strength poles. Strengthening poles may be accomplished either by replacing a damaged pole with similar material having a higher class rating, or by using poles with higher strength for the same class rating



Design issues:

- State and local standards for light/traffic signal poles apply.
- Poles must be properly supported on engineered foundations to avoid overturning or collapse, even when the ground is saturated.
- Verify current design loads carried by support cables suspended from strain poles.
- Treat steel poles in coastal areas to resist corrosion.
- Pole loads can be reduced by replacing older traffic signals with lighter, light-emitting diode (LED) signals.

Effectiveness:

- Effective when properly designed and constructed.
- Effectiveness can be increased by using impact-resistant light and traffic control fixtures.

Limitations:

- May not prevent failure of lights and/or traffic signals.
- Poles still subject to loss of electrical power.
- May not prevent damage from wave impact forces.
- May not prevent damage from windborne debris impact.

B. Overhead and Roadside Signs

Problem: High wind pressures and windborne debris impact forces cause breakage or blow-off of overhead and roadside signs and collapse of sign supports.

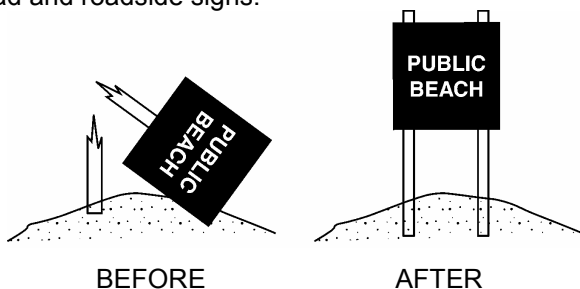
Mitigation Objective: Reduce the risk of high wind pressures and windborne debris impact forces by reinforcing or strengthening roadside signs and sign supports to increase the resistance to these forces.

Mitigation measures to protect overhead and roadside signs from wind damage include:

1. Strengthen overhead and roadside signs.....p. 18
2. Replace strain poles with mast arm poles See p. 15
3. Replace strain poles with higher strength
Poles See p. 16

B.1 Strengthen Overhead and Roadside Signs

Strengthen overhead and roadside signs using improved sign construction materials, increased size and number of connectors and fasteners, and improved pole embedment. These measures will reduce breakage and prevent blow-off or collapse of overhead and roadside signs.



Design issues:

- State and local standards for roadway signs may apply to ordinance updates.
- Sign construction materials used to strengthen overhead and roadside signs include aluminum and high-strength plastics.
- Add structural frame behind the sign to reduce sign failure.
- Overhead and roadside signs should employ redundant, strong, **corrosion-resistant connections** and fasteners to the frame or post that support them to prevent blow-off.
- Sign poles must be properly embedded or supported on engineered foundations to avoid overturning or collapse.
- Breakaway posts may be required for roadway signs located in or near the shoulder of the road.

Effectiveness:

- Effective when properly designed and constructed.
- Effectiveness can be increased when combined with strengthening sign posts.
- Effectiveness may be increased by combining signage to reduce the number of potential sign failures.

Limitations:

- Will not prevent collapse of sign supports or loss of electrical power.
- May not prevent sign damage from wave impact forces.
- May not prevent sign damage from windborne debris impact.

III. SURGE DAMAGE: Mitigation for Category D Facilities – Water Control Facilities

Basic Causes of Damage

- Storm surge inundation (i.e. coastal flooding from slow-moving and high velocity floodwaters and/or breaking wave forces) of drainage structures, pipes and pump stations
- Erosion and scour around drainage structures, irrigation facilities, and shoreline protective structures
- Floodborne debris plugging drainage structures

This section discusses mitigation measures for common surge damage to roads, roadside facilities, culverts, and bridges, which are caused by:

- A. *Inundation*
- B. *Erosion and Scour*
- C. *Debris*

A. Inundation

Problem: Inundation from storm surge or from heavy rains may exceed the capacity of drainage structures such as ditches or pipes, overflowing and damaging the surrounding area. Capacity is exceeded because the drainage structure was not designed for an event of such magnitude.

Mitigation Objectives: Prevent storm surge inundation by increasing flow capacity.

Mitigation measures to increase flow capacity include:

1. Increase ditch capacity..... See *FMH*, p. 4
2. Replace with larger pipe culvert See *FMH*, p. 21
3. Add multiple pipe culverts See *FMH*, p. 24

B. Erosion and Scour

Problem: Coastal erosion and scour associated with storm surge causes the following damages to Category D Facilities:

1. Floodwaters or wave action can scour drainage and/or irrigation ditches, which causes the ditches to be overtopped, resulting in damage to the ditches or related facilities such as culverts.
2. Overtopping by floodwaters or waves causes erosion and scour around shoreline protective structures such as groins, jetties, breakwaters, and revetments.

Mitigation Objectives: Prevent erosion and scour of Category D Facilities as follows:

1. Reduce risk of drainage or irrigation ditch erosion and overtopping by hardening erodible areas.
2. Reduce the risk of coastal erosion and scour around shoreline protective structures by protecting these elements to improve the response to these forces.

Mitigation measures to protect drainage and irrigation ditches from erosion and scour damage include:

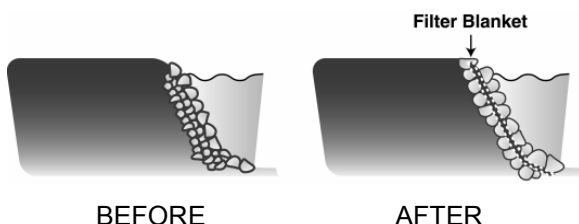
- 1.a. Install lining in the ditch..... See *FMH*, p. 5

Mitigation measures to protect shoreline protective structures from erosion and scour damage include:

- 2.a. Improve shoreline protective structures p. 22

B.2.a Improve Shoreline Protective Structures

Improve shoreline protective structures including groins, jetties, breakwaters, and revetments to reduce erosion and scour damage. Improvements include deeper foundations, toe reinforcement, improved materials, and filter blankets to reduce impacts of shore erosion and scour.



Design issues:

- Foundation or base on shoreline protection structures should extend below expected scour line.
- Improved materials can include replacement of riprap with interlocking concrete forms (i.e., dolos or core-lock units) for increased durability.
- Filter blankets/**geotextiles** prevent erosion through shoreline protective structures.
- Design shoreline protection structures to resist impact of storm surge and wave forces.

Effectiveness:

- Adequate base/bearing depth is very effective in reducing erosion and scour damage to shoreline protective structures.
- Filter blankets and geotextile effective in reducing erosion of backfill material throughout shoreline protective structures such as gabions and rip-rap protected slopes.

Limitations:

- Deepening base on existing shoreline protection structures can be costly and difficult.
- Filter blankets can clog and lose effectiveness.

Considerations:



C. Debris

Problem: Floodborne debris from storm surge or from heavy rains may plug drainage pipes with debris or sand, causing overflow and damage to the surrounding area.

Mitigation Objectives: Prevent damage around drainage pipes by reducing or eliminating the risk of plugging from floodborne debris.

Mitigation measures to protect drainage structures from damage caused by inundation include:

1. Install entrance debris barriers..... See *FMH*, p. 30
2. Install a relief culvert See *FMH*, p. 32

IV. SURGE DAMAGE: Mitigation for Category E Facilities – Buildings & Contents

Basic Causes of Damage

- Coastal storm surge inundation of buildings, outdoor utilities and equipment
- Erosion and scour around building foundations
- Corrosion from salt-spray on connections and building elements

This section discusses mitigation techniques to address common surge damage to the building and supporting facilities which are caused by:

- A. *Inundation*
- B. *Erosion and Scour*
- C. *Corrosion*

A. Inundation

Problem: Inundation causes the following damages to Category E facilities:

1. Structural elements (foundations, load-bearing walls, etc.) are damaged or destroyed by hydrostatic, hydrodynamic, and/or breaking wave forces from storm surge inundation. Also, non-structural elements (interior and exterior finishes, etc.) are damaged or destroyed by inundation of floodwaters and/or sewer system backflow.
2. Building utilities and equipment are damaged or destroyed by hydrostatic, hydrodynamic, and/or breaking wave forces related to storm surge inundation.

Mitigation Objectives: Reduce or prevent inundation damage to Category E facilities as follows:

1. Elevating, relocating, floodproofing, or improving structural and non-structural to increase the resistance and/or improve the response to these forces.
2. Elevating or floodproofing utilities and equipment to increase the resistance to these forces.

Mitigation measures to protect building structural and non-structural elements from damage caused by inundation:

- | | | |
|------|---|----------------|
| 1.a. | Elevate building on piles | p. 26 |
| 1.b. | Install breakaway walls | p. 27 |
| 1.c. | Improve pile foundations..... | p. 28 |
| 1.d. | Install openings in foundation walls & crawlspaces..... | p. 29 |
| 1.e. | Improve wall-to-foundation connections..... | p. 30 |
| 1.f. | Use flood-resistant building materials | p. 31 |
| 1.g. | Relocate building | See FMH, p. 72 |
| 1.h. | Wet floodproof building | See FMH, p. 74 |
| 1.i. | Dry floodproof building | See FMH, p. 75 |
| 1.j. | Install backflow prevention devices..... | See FMH, p. 76 |

Mitigation measures to protect building utilities and equipment from damage caused by inundation include:

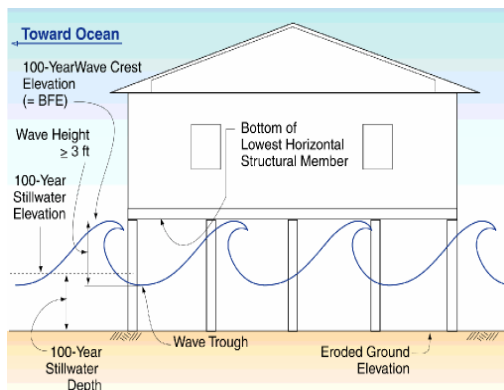
- | | | |
|------|--|---|
| 2.a. | Install Ground Fault Interrupter (GFI) circuits..... | p. 32 |
| 2.b. | Elevate HVAC equipment | p. 33 |
| 2.c. | Elevate pool filter and pump equipment..... | p. 34 |
| 2.d. | Elevate elevators or elevator control equipment | p. 35 |
| 2.e. | Construct flood-resistant equipment enclosures | p. 36 |
| 2.f. | Secure fuel and other storage tanks | p. 37 |
| 2.g. | Use flexible utility connections at building service entrance..... | See <i>Earthquake Mitigation Handbook</i> , p. 57 |

A.1.a Elevate Building on Piles

Elevate on piles so the lowest horizontal structural member is at or above the Base Flood Elevation (BFE) in accordance with “V Zone” construction requirements. This will minimize the damages from breaking wave forces due to storm surge inundation.

Design issues:

- Local floodplain ordinance may apply.
- Add freeboard of 1 foot or more above the BFE if possible.
- Establish condition of existing structure, foundations, and site soils prior to elevation.
- Lowest floor must be structural deck.
- Use area under the building for parking, access, or storage.
- Refer to the *Coastal Construction Manual* (FEMA Publication 55) and FEMA’s Coastal Construction Fact Sheet Series for a summary of V Zone requirements.



Effectiveness:

- Minimizes damages to building elements above the BFE.
- Generally cost effective for substantially damaged buildings under Appendix A of R&R Policy 9526.1, August 13, 1998.
- Effectiveness can be increased by adding freeboard, **improving pile foundations**, using **corrosion-resistant connectors and fasteners**, and **protecting the underside of elevated building floors**.

Limitations:

- Generally limited to relatively light structures.
- Building access will be impeded during flood events.
- Minimally driven piles can fail under breaking wave forces.
- May not be feasible if building is in poor condition or if flood depth is too high.
- May require additional mitigation considerations for areas of heavy floodborne debris or high winds.

Considerations:

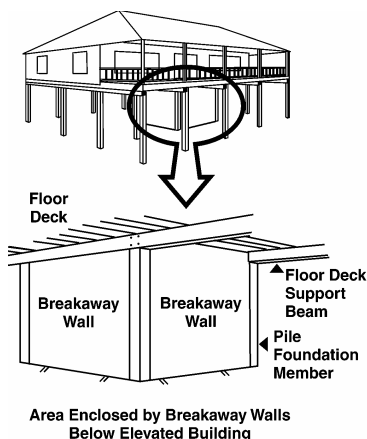


A.1.b Install Breakaway Walls

Breakaway walls may be installed to enclose the area underneath elevated coastal buildings used for parking, access, and storage. This will minimize the damaging effects of breaking wave forces, erosion, and scour on the rest of the building.

Design issues:

- Breakaway walls are typically wood frame walls or lattice work designed and constructed to fail and break apart under flood or wind loads between 10 and 20 pounds per square foot (psf).
- Breakaway walls may be designed for capacities greater than 20 psf only if they are certified by a registered professional engineer or architect to fail under the BFE without damaging the rest of the structure.
- Breakaway walls must be unobstructed by utilities, bracing, or other structures, and must not be finished on the inside.
- Openings to minimize hydrostatic pressure may be required in breakaway walls installed in A Zones.
- Refer to FEMA Technical Bulletin 9-99, *Design and Construction Guidance for Breakaway Walls Below Elevated Coastal Buildings*, and FEMA Coastal Construction Fact Sheet No. 26, *Enclosures and Breakaway Walls*, for additional technical details.



Effectiveness:

- Effective at minimizing the damaging effects of breaking wave forces due to storm surge inundation as well as erosion and scour on the elevated structure.
- Use area under the building for parking, access, or storage.

Limitations:

- Damaged contents in breakaway walls may not be covered by flood insurance under the National Flood Insurance Program (NFIP).

Considerations:

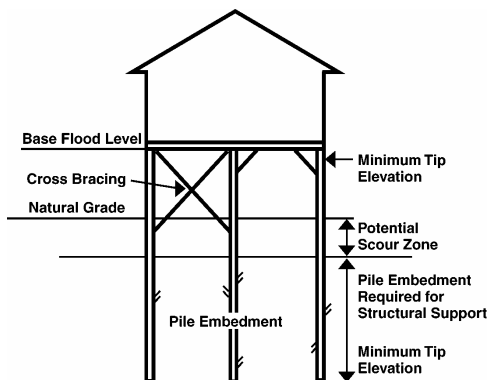


A.1.c Improve Pile Foundations

Improve pile foundations by providing improved pile-to-beam connections and adequate lateral bracing for unsupported pile lengths. This will reduce the potential for foundation damages from breaking wave forces on the building due to storm surge, as well as provide increased resistance to erosion and scour.

Design issues:

- Improve pile-driving techniques to develop full design capacities and reach specified pile embedment.
- Embed piles below the maximum anticipated erosion and scour depths to resist overturning.
- Use adequate pile cross section or lateral bracing for potential increase in unsupported pile length and prevent pile buckling.
- Provide diagonal or knee bracing between piles parallel to the direction of the current and waves to increase lateral resistance and help prevent pile buckling.
- Improve pile-to-beam connections by using **corrosion-resistant connectors and fasteners** and avoiding over-notching of piles.
- Refer to FEMA Coastal Construction Fact Sheet No. 12, *Pile Installation*, and Fact Sheet No. 13, *Wood-Pile-to-Beam Connections*, for additional technical details.



Effectiveness:

- Reduces structural damage or collapse to elevated coastal buildings during hurricanes due to inadequate pile foundations.
- Effectiveness can be increased by **protecting the underside of elevated building floors**.

Limitations:

- May require additional mitigation considerations for areas of heavy floodborne debris or high winds.
- Minimal benefit if piles insufficient depth for erosion and scour.
- May not be cost effective for undamaged pile foundations.

Considerations:

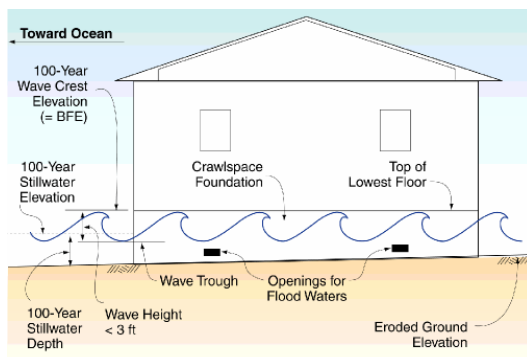


A.1.d Install Openings in Foundation Walls, Crawlspace

The crawlspace foundation walls of coastal buildings should be retrofitted with wall openings. The top of the lowest floor of the building should be located at or above the Base Flood Elevation (BFE) in accordance with “A Zone” construction requirements. These measures will minimize the damages from hydrostatic and buoyancy forces on the building due to storm surge inundation.

Design issues:

- Consult local floodplain management ordinance.
- Add freeboard of 1 foot or more above the BFE if possible.
- Anchor foundation walls of coastal buildings to the footing and reinforce with steel bars and grout.
- Install crawlspace wall openings known as “hydrostatic vents” (1 square inch/square foot of floor space) to allow floodwaters to enter and exit underneath the structure.
- Refer to the *Coastal Construction Manual* (FEMA Publication 55) and FEMA’s Coastal Construction Fact Sheet Series for a summary of A Zone requirements.



Effectiveness:

- Reduces damages to building elements above BFE.
- Add freeboard and use **corrosion-resistant connectors and fasteners** to increase effectiveness.

Limitations:

- Building access will be impeded during flood events.
- Meeting the minimum NFIP standard allows water to wet the floor system and soak everything below the lowest floor.
- Not effective in V Zones subject to breaking wave forces, erosion, scour effects, and/or heavy debris loading. Consider **relocation, elevation on piles**, or other mitigation alternatives.
- Stainless steel with wrong fasteners can cause galvanic action and increased corrosion.

Considerations:

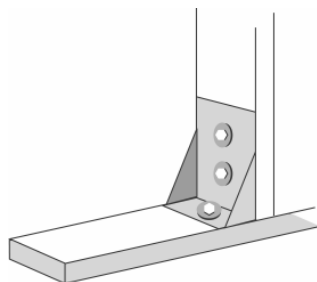


A.1.e Improve Wall-to-Foundation Connections

Install wall-to-foundation connections using brackets or straps between the wall framing and the foundation to strengthen connections and prevent wall failure from storm surge inundation or positive (blow in) and/or negative (suction) wind pressures. The bottom member of the wall frame (sill plate) should be bolted to the foundation. Use washers for all bolted and/or screw framing connections.

Design issues:

- Connection hardware must be installed according to the manufacturer's or engineer's specifications.
- The correct number of the specified fasteners (length and diameter) must be used with connection hardware.
- Avoid cross-grain tension in connections and machine nailing of fasteners.
- Drill holes in wood with sufficient cross sectional area remaining so fasteners do not pull through the holes
- Connection designs must ensure a **continuous load path** throughout the building.
- Refer to FEMA Coastal Construction Fact Sheet No. 10, *Load Paths*, and Fact Sheet No. 17, *Use of Connectors and Brackets*, for additional technical details.



Effectiveness:

- Effective protection against coastal flood damage if properly designed and constructed.
- Effective at increasing strength of connections and reducing high wind damages.
- Use **corrosion-resistant connectors and fasteners** to increase effectiveness.

Limitations:

- May not prevent damage if connections are not adequately designed or installed to resist coastal flood forces.
- Connections and fasteners may require some level of maintenance to protect them against corrosion.

Considerations:

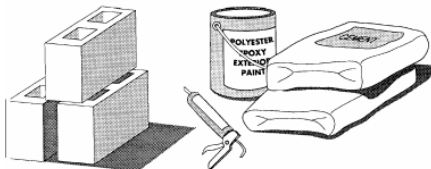


A.1.f Use Flood-Resistant Building Materials

Construct walls and floors below the BFE using **flood-resistant materials** and techniques. This **wet floodproofing** measure reduces damages and cleanup time for walls and floors subject to hurricanes and other coastal flood events.

Design issues:

- Avoid use of tile with gypsum board substrate and wood-framed walls.
- Use water-resistant and mold/mildew-resistant coatings (i.e., paint) that meet ASTM 3273 and ASTM 5590 standards on all surfaces.
- Replace carpeting and hardwood floors with terrazzo tile or other flood-resistant flooring materials.
- Refer to FEMA Technical Bulletin 2-93, *Flood-Resistant Materials Requirements*, FEMA Technical Bulletin 7-93, *Wet Flood Proofing Requirements*, and FEMA Coastal Construction Fact Sheet No. 8, *Coastal Building Materials*, for additional technical details.



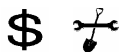
Effectiveness:

- Effective at reducing hurricane-related flood damages and cleanup time for walls and floors.
- May decrease the structure's functional downtime following a coastal flood event.
- Considered to be generally cost-effective under Appendix A of R&R Policy 9526.1, dated August 13, 1998.
- Combine with **corrosion-resistant** stainless steel **connectors and fasteners** and **improve wall-to-foundation connections** for maximum effectiveness.

Limitations:

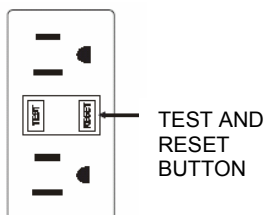
- Walls and floors still subject to coastal flood damage and cleanup.
- Not practical for long-duration flooding, wastewater flooding, high velocity floodwaters, breaking waves, or debris impact.
- Increased upkeep for some flood-resistant materials.

Considerations:



A.2.a Install Ground Fault Interrupter (GFI) Circuits

Install Ground Fault Interrupter (GFI) Circuits or automatic disconnect switches that will shut off electrical circuits in the event electrical equipment is inundated by storm surge. By shutting off electrical power to damaged equipment, further electrical damage will be avoided and potential secondary damage (such as short circuit initiated fire and stray current shock hazards to building occupants) will be reduced.



GFI CIRCUIT OUTLET DETAIL

Design issues:

- Evaluation of circuits and equipment to be isolated with GFIs or automatic disconnect switches is required.

Effectiveness:

- Effective in reducing potential injuries and property damage caused by exposed or disconnected electrical lines occurring as a result of equipment displacement or damage.

Limitations:

- May not be feasible for older buildings lacking an electrical ground system.
- Does not reduce wind and rain damage to electrical equipment.

Considerations

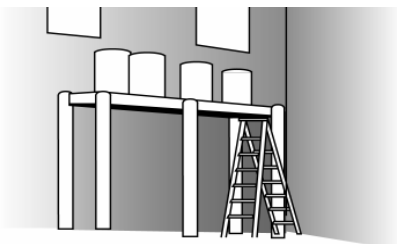


A.2.b Elevate Building Heating, Ventilating and Air Conditioning (HVAC) Equipment

Elevate HVAC equipment on platforms above the BFE. This will minimize the damaging effects of breaking wave forces, erosion, and scour on the condenser and other equipment.

Design issues:

- Mount HVAC equipment above the BFE on a properly designed platform installed specifically for the equipment or attached to the existing building.
- Locate elevated HVAC equipment platforms on the side of the building that is least exposed to flood forces.
- Secure the HVAC equipment to the platform using **corrosion-resistant connectors and fasteners** to resist movement or blow-off.
- Refer to the *Coastal Construction Manual* (FEMA Publication 55), *Protecting Building Utilities from Flood Damage* (FEMA Publication 348), and FEMA Coastal Construction Fact Sheet No. 28, *Protecting Utilities* for additional technical details.



Effectiveness:

- Prevents floodwaters from damaging the HVAC equipment.
- May reduce functional downtime due to loss of air conditioning.
- Use **corrosion resistant fasteners** and **reduce/eliminate placement of utilities below the design flood depth** to increase effectiveness.

Limitations:

- Will not prevent loss of air conditioning service due to loss of electrical power.
- May increase risk of damage from high wind pressures and windborne debris.
- May inhibit maintenance access.

Considerations:



A.2.c Elevate Pool Filter and Pump Equipment

Elevate pool filter equipment/control systems above the BFE. This measure will minimize the damaging effects of breaking wave forces, coastal erosion, and scour on the pool filter system.

Design issues:

- Local floodplain management ordinance and building code will apply.
- At-grade or elevated pool located adjacent to building in coastal area must:
 - be certified by a design professional that it will not act as obstruction that will result in damage to other buildings,
 - be structurally independent of the building and its foundation (V Zones only), and
 - have concrete decks and walkways that will break apart under flood forces.
- In V Zones, above-ground pools must be elevated above the design flood elevation and have an open (i.e., pile-supported) foundation system that can withstand coastal flood and wind forces with the bottom of the lowest horizontal structural member above the BFE.
- Pools should be oriented with their narrowest dimension perpendicular to the direction of flood flow.
- Refer to FEMA Technical Bulletin 5-93, *Free-of-Obstruction Requirements for Buildings Located in Special Flood Hazard Areas*, and FEMA Coastal Construction Fact Sheet No. 27, *Deck, Pools, and Accessory Structures*, for additional technical details.

Effectiveness:

- Prevents flood forces from damaging pool filter systems.
- **Reduce/eliminate placement of utilities below the design flood depth** to increase effectiveness.

Limitations:

- May require larger pumps and additional piping.
- May not prevent destruction of the pool itself by coastal flood forces.
- Will not prevent pool service loss from lost electrical power.
- May inhibit maintenance access.

Considerations:

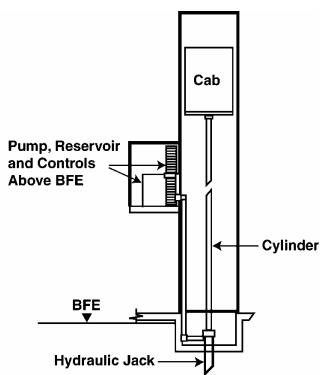


A.2.d Elevate Elevators and/or Elevator Control Equipment

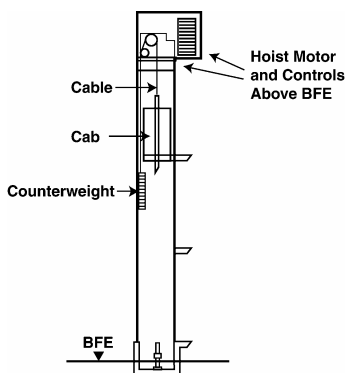
Elevate elevator electrical equipment, hydraulic pumps, motors, and control systems above the BFE. This will minimize storm surge inundation damage to hydraulic and traction elevators.

Design issues:

- Local floodplain ordinance and building code will apply.
- Because elevators beneath elevated coastal buildings are not designed to break away, systems should be designed and constructed using **flood-resistant materials**.
- Locate elevators on building side least exposed to breaking wave forces, high wind pressures, and windborne debris.
- Refer to FEMA Technical Bulletin 4-93, *Elevator Installation for Buildings Located in Special Flood Hazard Areas*, and FEMA Coastal Construction Fact Sheet No. 27, *Deck, Pools, and Accessory Structures*, for additional technical details.



HYDRAULIC ELEVATOR



TRACTION ELEVATOR

Effectiveness:

- Prevents flood forces from damaging elevator control systems.
- May reduce downtime due to loss of elevator services.
- Consider backup generators/float switch systems for medical and senior care facilities to increase effectiveness and protect building occupants.

Limitations:

- Will not prevent elevator service loss from lost electrical power.
- May inhibit maintenance access.
- May be less effective for protecting hydraulic elevator systems.

Considerations:

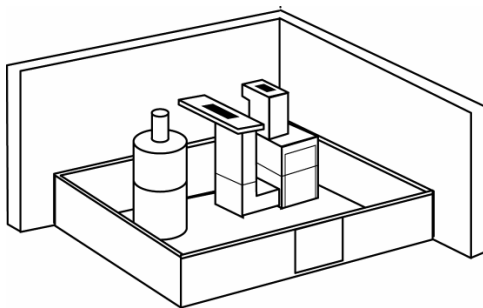


A.2.e Construct Flood-Resistant Equipment Enclosures

Construct a **flood-resistant enclosure** around building utilities and other key equipment located below the design flood elevation to minimize the damaging effects of inundation from storm surge on the enclosed utilities and equipment.

Design issues:

- Design walls and openings of flood-resistant enclosures using **flood-resistant materials** and **corrosion-resistant connectors and fasteners**.
- Flood-resistant enclosures are designed to be effective for short-duration flood events with depths less than 3 feet.
- Refer to the *Coastal Construction Manual* (FEMA Publication 55), and *Protecting Building Utilities from Flood Damage* (FEMA Publication 348) for additional technical details.



Effectiveness:

- Reduces damage to enclosed utilities and equipment from inundation in A Zones with low flood depths that rise slowly.
- May decrease the structure's functional downtime following a coastal flood event.
- Use **corrosion-resistant connectors and fasteners** and **flood-resistant materials** to increase effectiveness.

Limitations:

- May not prevent loss of utility or equipment use due to loss of utility service.
- Not practical for high flood depths, long-duration flooding, high velocity floodwaters, breaking waves, or debris impact. For these areas, **reduce/eliminate placement of utilities below the design flood depth** for maximum effectiveness.
- May inhibit maintenance access.

Considerations:

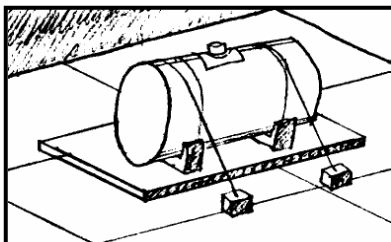


A.2.f Secure Fuel and Other Storage Tanks

Secure fuel tanks and other storage tanks below the design flood elevation to resist buoyancy. This will reduce the potential for tank flotation during coastal flood inundation events and prevent the tank's being carried away by floodwaters and impacting the structure.

Design issues:

- Use **corrosion-resistant connectors and fasteners** (e.g., galvanized steel cables or straps) to secure tanks.
- Anchor straps to the ground within a concrete slab that is heavy enough to resist the buoyant force on the tank and resistant to erosion and scour.
- Extend tank vent pipes above the design flood elevation.
- Tanks below the BFE may also be buried below the potential depth of erosion and scour and anchored to resist buoyancy.
- Do not rely on the weight of the fuel inside the tank or soils covering buried tanks to resist buoyancy.
- Refer to the *Coastal Construction Manual* (FEMA Publication 55), and *Protecting Building Utilities from Flood Damage* (FEMA Publication 348) for additional technical details.



Effectiveness:

- Reduces coastal flood damage from buoyancy.
- May reduce the possibility of the tank damaging the structure due to tank impact, fire, or explosion.
- Considered to be generally cost effective under Appendix A of R&R Policy 9526.1, dated August 13, 1998.
- Use **corrosion-resistant connectors and fasteners** and **shut-off valves** to increase effectiveness.

Limitations:

- May not prevent loss of utility due to loss of fuel line connection.
- Not practical in areas of severe erosion and scour, high velocity floodwaters, breaking waves or debris impact. For these areas, **reduce/eliminate placement of utilities below the design flood depth** for maximum effectiveness.
- May inhibit maintenance access or tank replacement.

Considerations:



B. Erosion and Scour

Problem: Coastal erosion and scour associated with storm surge can damage coastal dunes that protect buildings from flooding and undermine building foundations, resulting in partial or total building collapse.

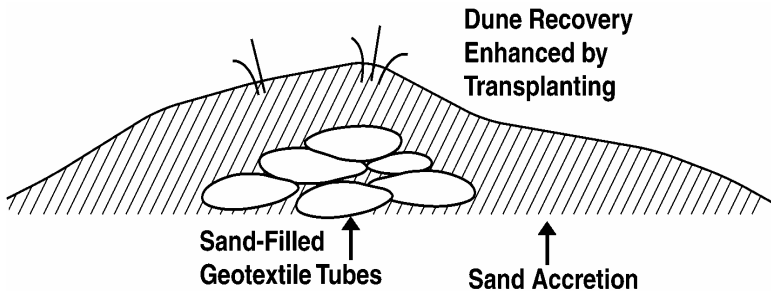
Mitigation Objective: Prevent and/or reduce damage to coastal buildings by protecting coastal dunes to reduce frequency of damaging floods from less severe storms and improve foundations.

Mitigation measures to protect buildings from erosion and scour damage include:

1. Restore and maintain coastal dunes..... p. 39
2. Elevate building on piles See p. 26
3. Install breakaway walls See p. 27
4. Improve pile foundations..... See p. 28

B.1 Restore and Maintain Coastal Dunes

Sand dunes can provide a natural defense against coastal flood forces that can damage or destroy buildings and other infrastructure. Post-storm restoration of sand dunes can be accomplished by using sand tubes, which are large tubes constructed of geotextile material that can be filled with sand and anchored along the beach to provide a foundation for restoring the original dune. Other placement techniques can also be employed to restore the original dune.



Design issues:

- Restored dunes must be of sufficient cross sectional area to resist failure during the design storm event.

Effectiveness:

- Somewhat to very effective, depending on the size of the dune and the level of flood forces impacting the dune.

Limitations:

- Dune restoration must comply with engineered design and maintenance requirements to be eligible for FEMA PA funds following a declared disaster.
- May not eliminate building damage or loss of dune in future storm events.
- Restored dune must be properly maintained in order to remain effective.
- Dune restoration may be subject to local restrictions, including environmental requirements.

Considerations:



C. Corrosion

Problem: Corrosion from salt spray and moisture can cause significant weakening of metal connectors and fasteners on coastal buildings, thereby increasing the risk of connection failures and severe building damage from flood and wind forces during hurricane events.

Mitigation Objective: Reduce the risk of corrosion on metal connectors and fasteners by using corrosion-resistant materials and techniques to reduce the risk of building damage.

Mitigation measures to protect structural building elements from flood damage caused by corrosion include:

1. Use corrosion-resistant connectors and fasteners..... p. 41
2. Increase connector size/gauge p. 42
3. Apply protective coatings p. 43
4. Use impressed current systems..... p. 44

C.1 Use Corrosion-Resistant Connectors and Fasteners

Use **corrosion-resistant connectors and fasteners** for all exterior connections and for sheathing connection on buildings in coastal areas. This measure will help maintain the strength of the building and reduce coastal flood and high wind damages in hurricane events.

Design issues:

- Corrosion-resistant connectors and fastener materials should be stainless steel if located within 3,000 feet of the ocean; beyond this distance, hot-dip galvanized connectors and fasteners may be used.
- Refer to FEMA Technical Bulletin 8-96, *Corrosion Protection for Metal Connectors in Coastal Areas*, and FEMA Coastal Construction Fact Sheet No. 8, *Coastal Building Materials*, for additional technical details.
- Use of insulating washers for connections with dissimilar materials.

Effectiveness:

- Effective at reducing corrosion damages to connections and fasteners from salt spray and moisture.
- Effective at maintaining strength of properly designed connections and reducing structural flood and wind damages to buildings.

Limitations:

- May not prevent damage if connections and sheathing are not adequately designed to resist coastal flood and wind forces.
- Most connections and fasteners will require some level of maintenance.

Considerations:



C.2 Increase Connector Size/Gauge

Use larger caliper bolts, screws, and/or nails, and thicker gauge connector plates than required to meet code or minimum design for exterior joints and connections on buildings in coastal environments. Large connectors and connection plates will help maintain the strength of the building at or above minimum design specifications in the event of corrosion.

Design issues:

- Determine minimum required caliper of bolts, screws and nails, and minimum gauge of connector plates required to support design loads and increase by a minimum of 25 percent.
- Coat exposed connections with waterproofing material after installation.

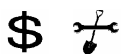
Effectiveness

- Effective at extending useful life of connections exposed to corrosive environments.

Limitations

- Requires periodic inspection and maintenance.
- May require long term replacement of some connection hardware and connector plates.

Considerations



C.3 Apply Protective Coatings

Apply ***protective coatings*** to exposed metal building elements to prevent contact with salt spray present in the coastal environment. Keeping salt spray from contact with building metal will prevent corrosion. Protective coverings include vinyl, paint, epoxy, bitumen, and others.

Design issues

- Selection of appropriate coating material, thickness, and application techniques.
- Sealing connections and joints is critical.

Effectiveness

- Properly applied coatings can be effective in preventing corrosion.

Limitations

- Protective coatings must be properly maintained.
- Sealant in joints and connections must be properly maintained.

Considerations



C.4 Use Impressed Current Systems

Use an impressed current system (galvanized cell) to protect exposed reinforcing steel in exterior reinforced concrete elements against corrosion.

Design issues

- Design of impressed current system can require many iterations and field verifications to determine final design parameters.
- Cathodic protection design must recognize dynamic environment of coastal structures.

Effectiveness

- Impressed current systems can be very effective at preventing corrosion to reinforcing steel in concrete elements exposed to coastal environments.

Limitations

- Impressed current system may require significant field testing and inspection to select required configurations.

Considerations



V. WIND DAMAGE: Mitigation for Category E Facilities – Buildings & Contents

Basic Causes of Damage

- Wind pressures on building structural elements (i.e., roof and wall framing), non-structural elements (i.e., building envelope), ancillary structures, and building utility equipment.
- Windborne debris impact on building structural elements (i.e., roof and wall framing), non-structural elements (i.e., building envelope), ancillary structures, and building utility equipment.

This section discusses the following mitigation techniques to address common wind damage to the following building elements:

- A. Structural Frame*
- B. Building Envelope*
- C. Building Utilities and Equipment*

A. Structural Frame

Problem: Buildings may be damaged or destroyed as a result of high wind pressures on building structural framing elements.

Mitigation Objective: Reduce the risk of damage to building structural framing elements by reinforcing or strengthening the structure to enhance its ability to transmit loads to the foundations.

Mitigation measures to protect building structural framing elements from wind damage include:

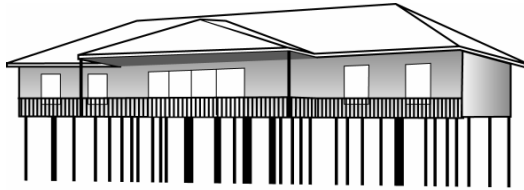
1. Use hip roofs..... p. 47
2. Improve gable end roofs p. 48
3. Install hurricane clips or straps p. 49
4. Install framing connectors p. 50
5. Eliminate ancillary structures by integrating functions into main building p. 51
6. Anchor ancillary structures..... p. 52
7. Improve wall-to-foundation connections..... See p. 30

A.1 Use Hip Roofs

Substantially damaged or destroyed gable end roofs can be mitigated by replacing them with hip roofs. This will increase the strength of the roof framing and reduce high wind damages in hurricane events.

Design issues:

- Hip roof systems provide additional lateral support by eliminating the unbraced gable ends, thereby increasing resistance to wind pressures coming from multiple directions.
- Hip roof framing is effective structurally because it laterally braces the primary roof trusses, or rafters, and supports the top of the end walls of the home against lateral wind forces. Roof slopes that minimize wind pressures are approximately 5:12.
- Hip roof systems eliminate the "hinge" formed between a gable end roof and end wall, which is the most common failure point of a gable end roof system.



Effectiveness:

- Effective at reducing damages to roof framing during high wind events.
- Install **hurricane clips** or **straps** and use **corrosion-resistant connectors and fasteners** for maximum effectiveness.

Limitations:

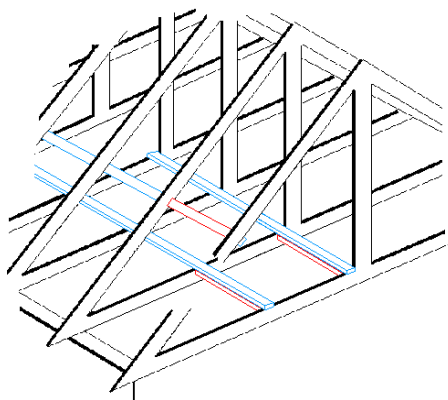
- May not be cost effective for roof systems with little or no damage. In these instances, **improve gable end roofs** or consider other mitigation alternatives.
- Will significantly impact the appearance of the building.

Considerations:



A.2 Improve Gable End Roofs

Improve gable end roofs by adding lateral bracing at end gables. This measure will increase the strength of the roof framing and reduce high wind damages in hurricanes.



Design issues

- Bracing gable ends provides lateral support and prevents failure of ends by high (positive or negative) wind pressures.
- Refer to the *Coastal Construction Manual* (FEMA Publication 55) for additional technical details.

Effectiveness:

- Somewhat effective at reducing damages to roof framing during high wind events.
- For heavily damaged or destroyed roof systems, replace gable end roofs with **hip roofs** for maximum effectiveness.

Limitations:

- Will not prevent failure of gable end roofs caused by poor attachment of roof sheathing.

Considerations:

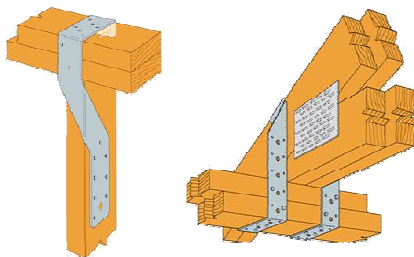


A.3 Install Hurricane Clips or Straps

Install **hurricane clips** or **straps** between the roof framing and the walls to strengthen connections and prevent roof failure due to negative wind (suction) pressures. Connections should be made between the roof and walls, between trusses, and between rafters and trusses. This will increase the strength of the building connections and reduce high wind damages in hurricane events.

Design issues:

- Connection hardware must be installed according to the manufacturer's or engineer's specifications.
- The correct number of the specified fasteners (length and diameter) must be used with connection hardware.
- Avoid cross-grain tension in connections and machine nailing of fasteners.
- Connections must be designed to ensure a **continuous load path** throughout the building.
- Refer to FEMA Coastal Construction Fact Sheet No. 10, *Load Paths*, and Fact Sheet No. 17, *Use of Connectors and Brackets*, for additional technical details.



Effectiveness:

- Effective at increasing strength of connectors and reducing high wind damages.
- Considered to be generally cost effective under Appendix A of R&R Policy 9526.1, dated August 13, 1998.
- Use **corrosion-resistant connectors and fasteners** to maximize effectiveness.

Limitations:

- May not prevent damage if connections are not designed to resist coastal flood forces as well as high wind pressures.
- Most connections and fasteners will require some level of maintenance.

Considerations:

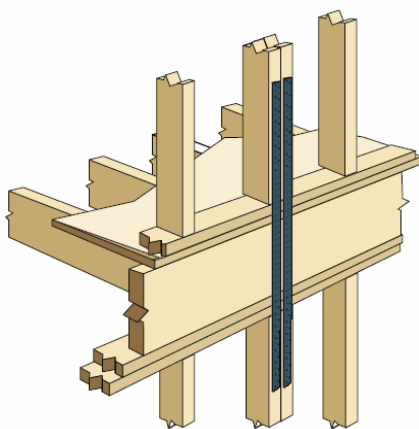


A.4 Install Framing Connectors

Install required number and size of connectors and/or fasteners, or apply construction adhesives to achieve full structural capacity of connections, thus reducing wind damage by providing continuous load path from structural elements to foundations.

Design issues

- Design connectors/fasteners/adhesives to develop the full structural capacity of the connection.
- Adequately designed connections should be capable of withstanding loads or forces equal to or greater than the members being joined (i.e., failures should occur in the members not the connection).
- Use **corrosion-resistant hardware** (bolts, screws, nails, etc.) to extend design life of connections.
- Consider lateral and uplift loads present in hurricane environment when designing connections.
- Install connectors, fasteners, and adhesives in strict accordance with manufacturer's instructions.



Proper strap connection.

Effectiveness

- Effective in increasing wind resistance in light structures.

Limitations

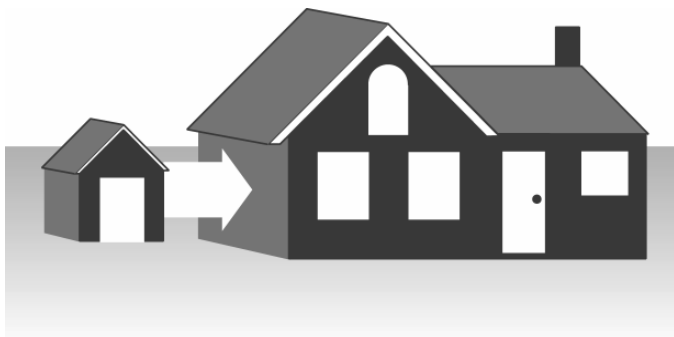
- Requires inspections to verify connections are properly constructed.
- Requires inspection and maintenance of non-corrosive resistant connection hardware.

Considerations:



A.5 Eliminate Ancillary Structures by Integrating Functions into Main Building

Eliminate light structures by integrating ancillary functions into the main building. Integrating ancillary functions into the main building will reduce damage to light structures and their contents and reduce potential windborne debris during hurricane winds.



Design issues:

- May require upgrade on main building structural elements to support new equipment loads.
- May require reconfiguration of building HVAC system to accommodate new equipment heat and/or exhaust loads.
- Verify code restrictions concerning equipment or materials prohibited from being located in main building.

Effectiveness:

- Effective in reducing damage to light structures.
- Effective in reducing the potential for windborne debris.

Limitations:

- Decrease in available building floor space.
- Code restrictions may prevent elimination of all light ancillary structures.

Considerations:

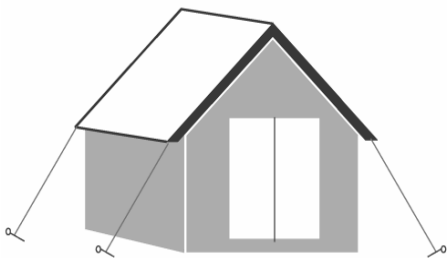


A.6 Anchor Ancillary Structures

Anchor ancillary structures such as storage sheds using additional connectors or straps. This measure will reduce the destruction of ancillary structures during a hurricane.

Design issues:

- Anchor embedment should be sufficient to resist erosion and scour and avoid pullout in saturated soils.
- Eliminate ancillary structures that cannot be anchored.
- Refer to FEMA Technical Bulletin 5-93, *Free-of-Obstruction Requirements*, and FEMA Coastal Construction Fact Sheet No. 27, *Decks, Pools and Accessory Structures*, for additional technical details.
- Local floodplain management ordinance may apply.
- Connectors or straps used to anchor ancillary structures should be strong enough to resist flotation of the structure and corrosion-resistant to prevent failure



Effectiveness:

- ***Eliminating ancillary structures*** is the most effective mitigation measure.
- Anchoring somewhat effective at reducing ancillary structure damage when properly designed and constructed, depending on the type and condition of the structure.
- Use ***corrosion-resistant stainless steel connectors and fasteners*** and construct using ***flood-resistant materials*** for maximum effectiveness.

Limitations:

- Unlikely to prevent damage from breaking wave forces or floodborne debris impact.
- May not prevent damage from high wind pressures or windborne debris impact.

Considerations:



B. Building Envelope

Problem: Buildings and their contents may be damaged or destroyed as a result of high pressures on the building envelope caused by hurricane velocity wind pressures and windborne debris impact forces.

Mitigation Objective: Reduce the risk of damage to buildings and their contents by strengthening the building envelope to increase resistance to hurricane wind pressures and windborne debris impact forces.

Mitigation measures to protect building envelope elements from wind damage include:

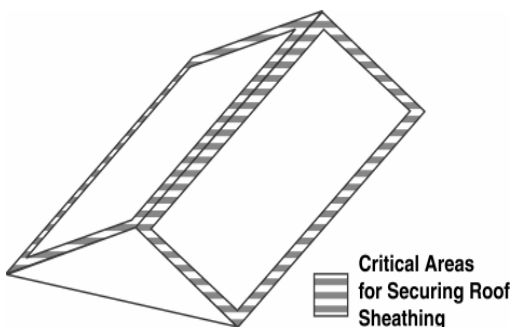
1. Secure roof sheathing..... p. 54
2. Improve shingle roofs..... p. 55
3. Improve metal roof systems..... p. 56
4. Upgrade concrete/clay tile roofs p. 57
5. Improve membrane roofs..... p. 58
6. Eliminate or improve roof ballast..... p. 59
7. Improve roof flashing, coping, and gutters p. 60
8. Anchor or reduce roof overhangs..... p. 61
9. Improve soffits p. 62
10. Strengthen siding..... p. 63
11. Improve exterior doors p. 64
12. Brace garage doors p. 65
13. Install window shutters..... p. 66
14. Strengthen window glass p. 67

B.1 Secure Roof Sheathing

When replacing failed roof sheathing, or completely replacing roof, secure roof sheathing to roof framing to prevent roof failure due to negative wind (suction) pressures: increase the number of nail fasteners, especially at the corners (where negative wind pressures are highest); use screws instead of nails to secure the roof sheathing; and combine nails or screws with an adhesive to increase the uplift strength of the roof sheathing to roof framing connection. Securing roof sheathing increases wind load capacity and reduces high wind damages in hurricanes.

Design issues:

- The roof sheathing should be at least $\frac{1}{2}$ inch thick and securely attached to the roof trusses.
- Use minimum 8d ring shank nails (2.5 inches long) with full round heads to fasten roof sheathing panels. Avoid overdriving nails.
- Ring shank or screw shank nails are required near ridges, gables, and eaves in areas with design wind speeds over 110 mph (3-second gust).
- When using screws to secure plywood sheathing, use minimum #8 stainless steel deck screws, countersunk heads, 2.5 inches.
- Fastener spacing and size requirements for coastal construction are typically different than for non-coastal areas.
- All screws or nails used to attach the roof sheathing must penetrate the underlying roof trusses a minimum of one inch for secure attachment.
- Refer to FEMA Coastal Construction Fact Sheet No. 18, *Roof Sheathing Installation*, for additional technical details.



Effectiveness:

- Increases wind load capacity at minimal cost.
- Increases life and wind load capacity of roof coverings.
- Use **corrosion-resistant fasteners** to increase effectiveness.

Limitations:

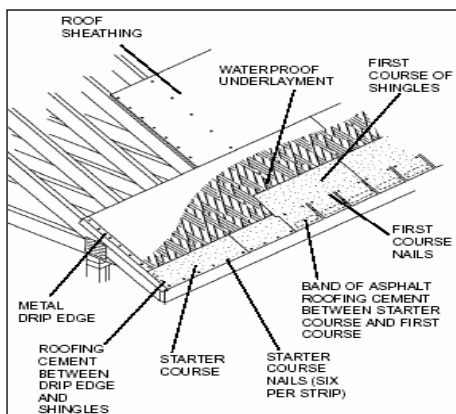
- Only a portion of roof sheathing may be exposed for re-fastening.

B.2 Improve Shingle Roofs

Improve asphalt **shingle roofs** by using proper fasteners, sheathing, venting, etc., for high wind areas. This will likely reduce the possibility of shingle blow-off and damage to the underlying roof structure during hurricane wind events.

Design issues:

- Use 6 nails per shingle and 6 nails per starter strip. Space nails evenly and penetrate at least $\frac{3}{4}$ inch into planking or through the sheathing. Ring shank or screw shank nails recommended.
- Overlap shingles and underlayment properly, and seal joints and penetrations properly.
- Use roofing cement under the edges of shingles along the eaves, fascia, and ridges to keep wind from getting underneath and initiate peeling of shingles.
- Refer to FEMA Coastal Construction Fact Sheet No. 20, *Asphalt Shingle Roofing for High-Wind Regions*, or FEMA Hurricane Charley Recovery Advisory No. 2, *Asphalt Shingle Roofing for High-Wind Regions* for additional technical details.



Effectiveness:

- Improves performance of asphalt shingle roof systems to resist blow-off during hurricane wind events when properly installed.
- For major roof repairs or replacement, **secure roof sheathing**, **enhance secondary moisture protection**, and use **corrosion-resistant fasteners** for maximum effectiveness.
- More effective with only one layer of shingles. Old roof shingles should be removed before installing new shingles in a replacement situation.

Limitations:

- Will not prevent damage from poor sheathing attachment or windborne debris.

Considerations:



B.3 Improve Metal Roof Systems

Improve metal roof systems: Increase the number of fasteners, use proper spacing of fasteners, and secure flashing at corners and along hips, valleys, and ridges. This will reduce the potential for metal roof damage or blow-off from high wind pressures.

Design issues:

- Select systems that meet or exceed ASTM E 1592 or UL-90 uplift testing requirements.
- Use properly spaced mechanical fasteners, e.g., clips, screws.
- Use double rows of fasteners along eaves, hips, and ridges, and to secure hip and ridge flashings.
- Use aluminum/zinc alloy coating on steel panels to increase corrosion-resistance.
- For structural metal roof panels with concealed clips, specify standing seams at 12 inches on center over a concrete deck.
- For a steel deck, specify a self-adhering modified bitumen membrane and 3-inch thick rigid insulation, followed by the metal panels installed on wood nailers.
- At self-adhering membrane laps, specify metal strips over deck where the laps do not occur over deck ribs, or specify a suitable cover board between deck and self-adhering membrane.
- If the metal panels are punctured during a storm, the secondary membrane should provide watertight protection unless the roof is hit with missiles of very high energy.
- Do not use architectural metal panels on schools.
- Refer to Chapter 6 of *Design Guide for Improving School Safety in Earthquakes, Floods and High Winds* (FEMA Publication 424) for additional technical details.

Effectiveness:

- Increases strength of metal roofing system and reduces damage from high wind pressures.
- Use **corrosion-resistant connectors and fasteners, reduce or eliminate roof overhangs**, and **upgrade edge flashing**.
- Use screws instead of nails for attaching clips, panels, and flashings to improve roof strength.
- Install metal roofing over a solid roof deck.

Limitations:

- May not prevent damage due to failure of roof flashing (especially at the corners) or large roof overhangs
- Will not prevent damage due to undersized roof framing, or windborne debris impact.

Considerations:

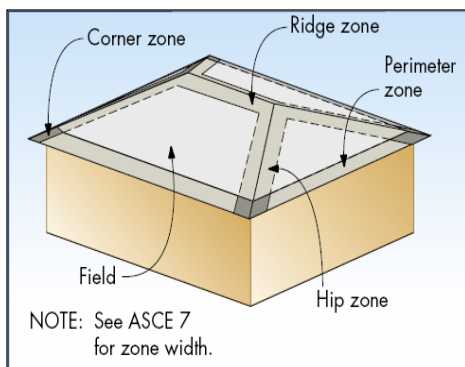


B.4 Upgrade Concrete/Clay Tile Roof Systems

Upgrade concrete/clay tile roof systems by improving connection systems and improving factor of safety for design. This will reduce the risk of tile blow-off, leaving areas of the roof exposed to the elements.

Design issues:

- Increase the design factor of safety for tile roof systems. A safety factor of 3 (instead of 2) is recommended for mechanically fastened systems, and a safety factor of 4 (instead of 2) is recommended for foam-set attachment systems.
- Install clips on tiles at corner zones, ridge zones, perimeter zones, and hip zones.
- Puncture resistance is increased if ASTM D 226 Type II (#30) felt underlayment is installed over the sheathing.
- Refer to FEMA Draft Hurricane Charley Recovery Advisory No. 3, *Tile Roofing for High-Wind Regions*, for additional technical details.



Effectiveness:

- Improves performance of roof systems to resist blow-off during hurricane wind events if properly designed & installed.
- For major roof repairs or replacement, **secure roof sheathing, enhance secondary moisture protection**, and use **corrosion-resistant fasteners** for maximum effectiveness.

Limitations:

- Concrete and clay tiles are made from brittle materials that are susceptible to damage from windborne debris.
- Will not prevent damage from poor roof sheathing attachment.

Considerations:



B.5 Improve Membrane Roofs

Improve roof membrane/insulation fastening systems using high wind design criteria. Use of these measures will likely reduce the possibility of membrane blow-off and subsequent damage to the building during hurricanes.

Design issues:

- Use properly spaced mechanical fasteners such as screws instead of welds to secure roof deck.
- Specify required pull out resistance for mechanically attached roof membrane/insulation systems
- Refer to Chapter 6 of *Design Guide for Improving School Safety in Earthquakes, Floods and High Winds* (FEMA Publication 424) for additional technical details.

Effectiveness:

- Effective at reducing membrane tearing or blow-off from high winds.
- Can help protect subsequent damage to the underlying roof structure from high wind pressures during hurricanes.
- **Upgrade edge flashing and gutters** by enhancing attachments to the building frame to increase effectiveness.

Limitations:

- May not prevent damage due to failure of roof flashing (especially at the corners) or large roof overhangs.
- Will not prevent damage due to undersized roof framing or windborne debris impact.
- Unless equipped with secondary protection (per FEMA 424), missile damage can result in significant water leakage.

B.6 Eliminate or Improve Roof Ballast

Upgrade or replace gravel ballast (aggregate surfaced) roofs to prevent potential windborne debris damage caused by aggregate being picked up by the wind during hurricanes and extreme wind events.

Design issues:

- Upgrade from lightweight ballast to larger and heavier ballast to prevent ballast from becoming windborne during a hurricane.
- If replacing ballast, either a new membrane will need to be installed or measures taken to compensate for the loss of aggregate.
- Unballasted roofs should be mechanically attached to the roof deck.
- Refer to Chapter 6 of *Design Guide for Improving School Safety in Earthquakes, Floods and High Winds* (FEMA Publication 424), for additional technical details.

Effectiveness:

- Effective in reducing windborne debris from aggregate.
- May result in reduced windborne debris damage to building from which the aggregate is removed as well as surrounding buildings.
- Considered to be generally cost-effective under Appendix A of R&R Policy 9526.1, dated August 13, 1998.

Limitations:

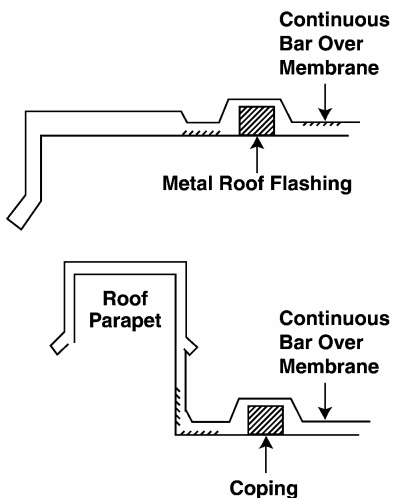
- Roof should be inspected by roof manufacturer to ensure roof remains under warranty.
- Heavier ballast may reduce the live load capacity of the roof.
- Removal of ballast may increase damage to roof surface from sun exposure.

B.7 Improve Roof Flashing, Coping, and Gutters

Improve roof flashing, coping, and gutters by using the correct fasteners and sealants, increasing lap lengths, and using proper spacing between fasteners. This will reduce the likelihood of edge flashing and coping bending or blow-off and subsequent damage to the underlying roof structure from high wind pressures during hurricanes.

Design issues:

- Design gutters for uplift. Since uplift guidance is currently not available, use professional judgment.
- Refer to Chapter 6 of *Design Guide for Improving School Safety in Earthquakes, Floods and High Winds* (FEMA Publication 424) and FEMA Coastal Construction Fact Sheet No. 23, *Roof-to-Wall and Deck-to-Wall Flashing* for additional technical details.



Effectiveness:

- Effective at reducing possible edge flashing and coping bending or blow-off and subsequent damage to the underlying roof from hurricane-force wind pressures.
- Reducing the potential gaps between edge flashing/coping and roofing materials at corners also reduces the potential for failure by wind and water penetration.
- Considered to be generally cost-effective under Appendix A of R&R Policy 9526.1, dated August 13, 1998.
- Use **corrosion-resistant connectors and fasteners** and **improve membrane roofs** to increase effectiveness.

Limitations:

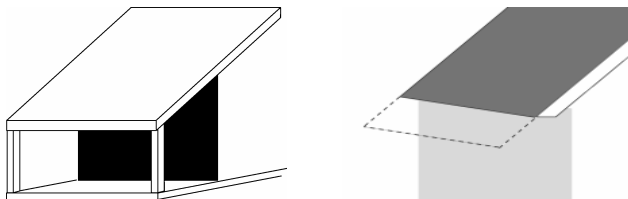
- May not prevent damage due to failure of roof membrane, roof decking or large roof overhangs.
- Will not prevent damage due to undersized roof framing or windborne debris impact.

Considerations:



B.8 Anchor or Reduce Roof Overhangs

Damaged roof overhangs can be mitigated by anchoring overhanging and porch roofs to the structure using mechanical fasteners to connect the roof truss to the columns and the columns to the floor deck or foundation. Another option is to reduce or eliminate roof overhangs wherever possible to reduce the uplift forces on the roof system. These measures will decrease the potential for wind uplift failure of roof overhangs.



Design issues:

- Avoid unsupported roof overhangs greater than 2-feet wide. Such overhangs are subject to high wind pressures and are often a starting point for total roof failure.
- Wherever possible, use posts and columns to minimize the unsupported length (span) of the overhang or porch roof. Use mechanical fasteners to connect the roof members to the columns/posts and the columns/posts to foundation elements.
- The designer should not design roof overhangs to break away at weak connections as a method to reduce damage to the structure itself because this will increase potential windborne debris and may damage the building envelope.

Effectiveness:

- Reduces damages to structures with large roof overhangs.
- May reduce wind-blown water infiltration through **soffits**.
- **Corrosion-resistant fasteners** increase effectiveness.

Limitations:

- Will not prevent failure of roof overhangs from poor attachment of roof sheathing.
- May require modification of roof drainage systems and may reduce energy efficiency.

Considerations:



B.9 Improve Soffits

Improve **soffit** design by installing metal or wood framing behind the soffit and enhanced fastening of soffit panels and vents. This will reduce the loss of soffits from hurricane wind pressures and decrease non-structural building damage from wind-driven rain if the soffits are pushed in or blown off.

Design issues:

- Wood soffit framing should be standard 2" x 4" minimum dimensional lumber, properly fastened, using hurricane type straps and tees properly nailed.
- Soffit panels should be nailed with rim shank nails with full heads, or screwed with full-headed stainless deck screws (#8) with sufficient penetration of frame, at least one inch or more.
- Heavy CDX plywood could be used for soffit panels instead of aluminum or vinyl, with traditional opening for soffit vents.
- Soffit vents should be nailed or screwed same as the soffit.
- Building codes do not address the issue of wind-resistant soffits.
- Design for positive and negative wind pressures.

Effectiveness:

- Reduces wind-driven rain from entering the interior of the building if no other damage to building exterior.
- Greatly reduces percentage of opening to the wind, which may lead to failure of roofing or entire building envelope.
- Use **corrosion-resistant fasteners** and **reduce roof overhangs** to increase effectiveness.
- Consider use of filter media or baffles for secondary protection.

Limitations:

- Structurally stronger when built into new construction.
- Will not prevent damage from poor attachment of roof sheathing or roof overhang failure.
- Will not prevent damage from windborne debris impact.

Considerations:

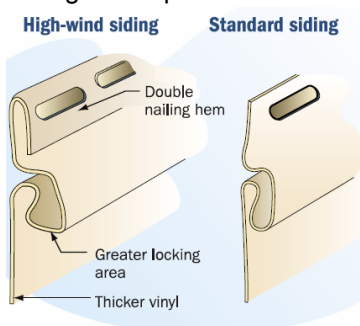


B.10 Strengthen Siding

Strengthen vinyl and metal siding by using additional fasteners and proper spacing between system components. This will reduce likelihood of siding pull-out or blow-off and subsequent damage to the underlying roof from high wind pressures.

Design issues:

- Use vinyl siding manufactured for high wind areas (i.e., double thickness at nailing edge).
- Use sufficient properly spaced and located fasteners to improve wind resistance of siding.
- Fasteners should be compatible with the siding material and properly spaced (sufficiently close together). For vinyl siding, use fasteners with a minimum head diameter of 5/16-inch and minimum shank diameter of 1/8-inch.
- A small clearance (1/32-inch to 1/16-inch) between the nail head and the siding is recommended to allow for thermal expansion and contraction of siding materials.
- For metal siding, use unsealed end laps of at least 3 inches. Siding panels should overlap the foundation slab by 3 to 4 inches, or install 3 to 4 inches of flashing at the wallbase.
- Refer to FEMA Coastal Construction Fact Sheet No. 24, *Siding Installation and Connectors*, for additional details.



Effectiveness:

- Using sufficient siding fasteners can improve wind resistance.
- **Corrosion-resistant connectors and fasteners** compatible with the siding materials will increase effectiveness.
- Use “housewrap” or an air-barrier film underneath siding to provide additional protection against wind-induced water infiltration. Refer to FEMA Coastal Construction Fact Sheet No. 22, *Housewrap*, for additional technical details.

Limitations:

- Siding panel thickness should be sufficient to resist pullout.
- May not prevent damage due to failure of wall sheathing.
- Will not prevent damage due to windborne debris impact.

Considerations:



B.11 Improve Exterior Doors

Improve exterior doors by using proper fasteners and stronger materials for door construction. This will reduce damage or failure of entry doors from hurricane-force wind pressures, thus reducing interior damage to buildings and contents.

Design issues:

- Use enough proper size and type of fasteners appropriately spaced to secure door frames to the wall system.
- Doors should be attached using three hinges that are screwed into the framing members as well as the door frame. A minimum 1-inch deadbolt throw is also recommended.
- Increase door strength and impact resistance by using solid wood or metal doors and adding top and bottom throw bolts.
- Add an impact-resistant glazing to existing glass doors or protect glass doors with securable **shutters**.
- Consider out-swinging doors to reduce degradation of weatherstripping.
- Refer to FEMA Coastal Construction Fact Sheet No. 21, *Door and Window Installation*, for additional technical details.

Effectiveness:

- Reduces damage or failure of entry doors from high wind pressures, thereby reducing interior damage to buildings and contents.
- Solid wood or metal doors may also be effective at reducing damage from windborne debris.
- Effectiveness can be increased by using proper **weatherstripping** around doors to minimize water intrusion from wind-driven rain.
- Effectiveness of metal doors can be increased by using corrosion-resistant coating on doors and **corrosion-resistant connectors, fasteners**, and hardware.

Limitations:

- Improperly attached door frames may fail under high wind loads.
- Hollow-core wood doors or unprotected glass doors are vulnerable to damage from windborne debris impact.
- Will not prevent damage from coastal flood forces.
- Metal doors in coastal environments are subject to corrosion.

Considerations:



B.12 Brace Garage Doors

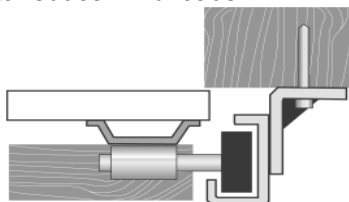
Brace sectional garage door panels horizontally or vertically, and retrofit garage door hardware. These measures will reduce damage or failure of large doors from high wind pressures during hurricanes, and may reduce the more serious building damage.

Design issues:

- Sectional door panels may be horizontally braced with 2" x 4" wood girts or steel rails, garage door hardware may be retrofitted to withstand high wind pressures.
- Check adequacy of nailers used to secure garage door tracks and rollers.
- Strengthen tracks and rollers.
- Use single vs. double-wide doors to reduce wind loads.

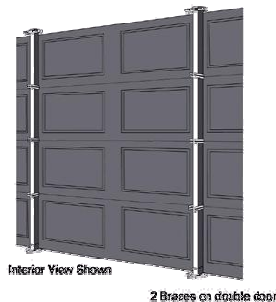


HORIZONTAL DOOR BRACING



DOOR BRACING/RAIL DETAIL

- As an alternative, vertical bracing may be used to retrofit older doors.
- Vertical door braces are made of high-quality aluminum, with telescoping sections, and braces that attach to hinges that prevent doors from being blown in or sucked out.
- Another option for older doors is to replace the entire door and frame with a stronger assembly.



VERTICAL DOOR BRACING

Effectiveness:

- Effective at reducing damage or failure of garage bay doors from high wind pressures, and may reduce the potential for more serious building damage or even collapse.

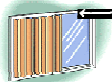

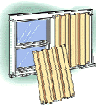
Limitations:

- Will not prevent damage/failure from windborne debris.
- At present, vertical door braces are limited to sectional doors up to 10 feet high.
- Building personnel need to be present to install vertical garage door braces.

B.13 Install Window Shutters

Install accordion, roll-down, or Miami-Dade **shutters** to protect windows/other openings from glass breakage from windborne debris impact forces and interior damage to buildings.

Design issues:

- **Accordion shutters** have a unique, interlocking folding blade system, designed to cover large spans and fold away for an unobstructed view. Accordion shutter systems provide high wind protection, and may include a key-lock feature for security. 
- **Motorized shutters** can address the needs of storm protection and security. Motorized shutters are made of impact-resistant PVC or aluminum and offer a dependable, effective defense against flying debris during storms as well as intruders. Motorized shutters are especially useful for multi-story buildings or facilities with little or no manpower to install shutters. 
- **Metal panel (Miami-Dade style) shutters** provide a rigid deterrent to windborne debris. Metal panel shutters are made from durable aluminum or steel sheets; their unique design requires minimal storage space. 
- All shutter systems must be properly anchored to the structural framing. Shutters should not be attached to the window frame or brick veneer face.

Effectiveness:

- Effective in preventing penetration of building envelope and the resulting damages to interior when properly installed and tested per ASTM E 1886 and E 1996.
- Use **corrosion-resistant connectors and fasteners** to increase effectiveness.
- **Strengthen window glass** to maximize effectiveness.
- Considered to be generally cost effective for critical facilities and vulnerable public buildings under Appendix A of R&R Policy 9526.1, dated August 13, 1998.

Limitations:

- Shutters will not prevent damage from building roof or structural failure.
- Shutters may need to be installed & taken down every time they are needed or may be difficult to install on upper levels.
- Motorized shutters without manual over-ride may mean the building cannot be ventilated to prevent mold accumulation.

Considerations:

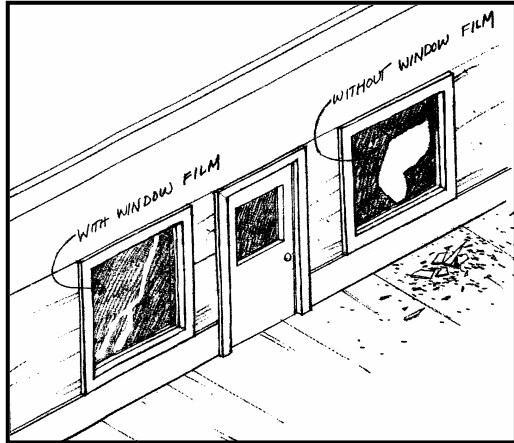


B.14 Strengthen Window Glass

Strengthen window glass using window film or laminated glass. This can reduce window glass breakage or breaching of openings from windborne debris impact forces during hurricanes, thereby reducing interior damage to buildings and contents.

Design issues:

- If impacted by debris, window film or laminated glass panes may break or need replacing. Additionally, they should be designed to stay in frames and protect against water infiltration.
- For window film, the fastening system that locks the film in place should be specified and conform to its standard testing specifications or protocols.
- Laminated glass should be tested to meet or exceed the requirements of ASTM E 1886 and E 1996.



Effectiveness:

- Effective when properly installed and tested per ASTM E 1886 and E 1996.
- Some window films also provide blast protection.
- ***Install shutters to protect windows*** to maximize effectiveness.

Limitations:

- Some window films can be scratched and can yellow from sun exposure.

Considerations:



C. Building Utility Equipment

Problem: Building equipment and utilities may be damaged or destroyed as a result of being displaced by high pressures caused by hurricane velocity wind.

Mitigation Objective: Reduce the risk of damage to building equipment and utilities due to being displaced by hurricane force winds.

Mitigation measures to protect building equipment and utilities from wind damage include:

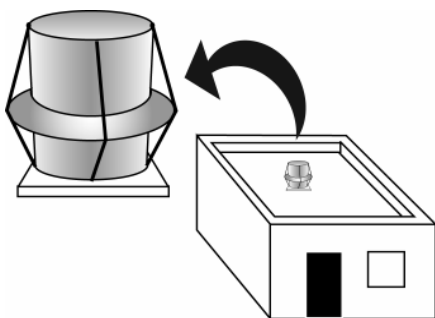
1. Anchor rooftop equipment..... p. 69
2. Reposition rooftop equipment..... p. 70
3. Eliminate ancillary structures by integrating functions into main building..... See p. 51

C.1 Anchor Rooftop Equipment

Anchor rooftop equipment (such as HVAC units, exhaust fans and cowlings, satellite dishes, solar collectors, and lightning protection systems) using properly sized and spaced fasteners. These measures will reduce blow-off of rooftop equipment from high wind pressures and limit the potential for windborne debris.

Design issues:

- For fan cowlings and vent hoods, use of 1/8-inch diameter stainless steel cables is recommended to anchor the equipment. Use two to four cables, depending on the wind design loads. Alternatively, heavy straps can be used.
- Refer to Chapter 6 of *Design Guide for Improving School Safety in Earthquakes, Floods and High Winds* (FEMA Publication 424), and FEMA Coastal Construction Fact Sheet No. 28, *Protecting Utilities*, for additional details.
- Design criteria should include ASCE 7-02 *Minimum Design Loads for Buildings and Other Structures*.



Effectiveness:

- Effective for reducing blow-off of rooftop utility equipment from high wind pressures and limiting the potential for windborne debris that can damage the structure.
- Considered to be generally cost effective under Appendix A of R&R Policy 9526.1, dated August 13, 1998.
- Use **corrosion-resistant connectors and fasteners** to increase effectiveness.
- Relocate equipment inside the building to maximize effectiveness.

Limitations:

- May not prevent equipment damage from windborne debris.
- May not prevent loss of utility due to loss of electrical power.

Considerations:



C.2 Reposition Rooftop Equipment

Reposition rooftop equipment to locations of reduced exposure to hurricane winds. Positioning rooftop equipment in locations of reduced wind exposure will lessen potential damage to equipment and potential damage to other building elements caused by loose, windborne equipment.

Design issues:

- Consider wind flow at parapet walls and other protective elements in determining location of rooftop equipment.
- Consider impacts on realigned supply and return lines to relocated equipment.

Effectiveness:

- Effective in reducing wind damage to rooftop equipment.
- Can be effective in reducing secondary damage caused by loose, windborne equipment.

Limitations:

- May require larger capacity to compensate for longer distance to service locations.
- May require structural review of load capacity of potential new equipment locations.
- Limited number of protected areas may be available.
- Relocation of some equipment may cause increased wind exposure to remaining equipment.

Considerations



VI. WIND-DRIVEN RAIN DAMAGE: Mitigation for Category E Facilities – Buildings & Contents

Basic Causes of Damage

- Wind-driven rain penetrating through building openings.
- Wind-driven rain damaging building utility equipment.
- Corrosion from salt spray on connections and non-structural elements.

This section discusses the following mitigation techniques to address common wind-driven rain damage to buildings and contents:

- A. Building Upgrades*
- B. Building Utility Equipment*

A. Building Upgrades

Problem: Heavy, wind-driven rain during hurricanes can penetrate through roof and wall sheathing after the roof and wall coverings are damaged or lost and cause extensive water damage to building elements and contents.

Mitigation Objective: Reduce the risk of wind-driven rain damage to building elements and contents by upgrading and providing additional moisture protection to increase the resistance to these forces.

Mitigation measures/upgrades to protect building elements from wind-driven rain damage include:

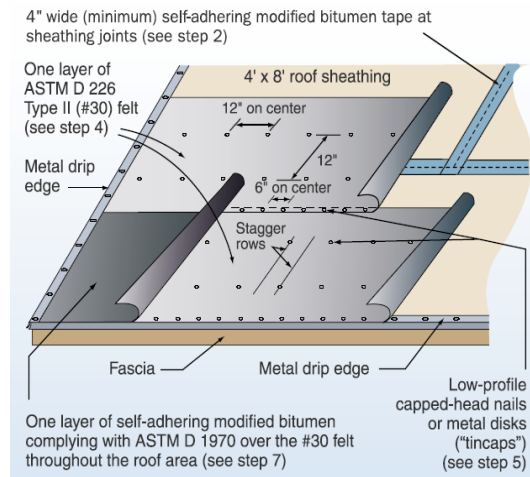
1. Enhance secondary moisture protection..... p. 73
2. Increase weatherstripping around windows and entry doors..... p. 74
3. Use flood-resistant building materials See p. 31
4. Improve soffits See p. 62
5. Install window shutters..... See p. 66

A.1 Enhance Secondary Moisture Protection

Enhance secondary moisture protection for roof and exterior wall sheathing using felt and other materials secured to the sheathing beneath the roof and exterior wall coverings. This measure can reduce non-structural building damage from wind-driven rain in the event the wall or roof coverings are damaged or blown off.

Design issues:

- There are various materials and installation options available to enhance secondary moisture protection for roof and wall sheathing.
- Verify roof and wall sheathing are adequately secured to the sheathing prior to adding enhanced moisture protection.
- Refer to FEMA Coastal Construction Fact Sheet No. 9, *Moisture Barrier Systems*, and FEMA Hurricane Charley Recovery Advisory No. 1, *Roof Underlayment for Asphalt Shingle Roofs* for additional technical details.



Effectiveness:

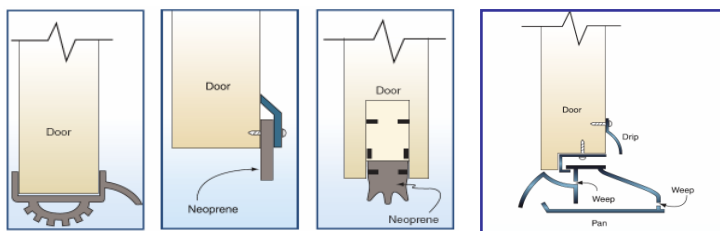
- Effective in stopping wind-driven rain from damaging exterior and interior non-structural elements when the exterior roof or wall coverings are breached.
- Consider use of **corrosion-resistant** drip edge and **fasteners** to maximize effectiveness.

Limitations:

- May not be cost effective for roof systems with little or no damage.
- Will not prevent failure of roof systems from poor attachment of roof sheathing.
- Some options not practical for long-term moisture protection without repair of roof or wall coverings.

A.2 Increase Weatherstripping Around Windows and Entry Doors

Increase **weatherstripping** around windows, entry doors. For high wind areas, consider designing a vestibule as well. These measures can reduce damage to interior elements from hurricane wind-driven rain and moisture penetration that can enter the structure at the edges of entry doors and windows.



Design issues:

- Specify wind-driven rain resistant weatherstripping at exterior doors and windows.
- For high wind areas (basic wind speed > 120 mph), anticipate some leakage from high design wind pressures & numerous opportunities for leakage path development. Use a vestibule in addition to robust weatherstripping.
- Vestibules should be designed so that both the inner and outer doors are equipped with weatherstripping, and the vestibule itself is constructed using **flood-resistant materials** (e.g., concrete or tile) and a floor drain.
- Refer to Chapter 6 of the *School Safety Design Guide* (FEMA Publication 424), and FEMA Coastal Construction Fact Sheet No. 21, *Door and Window Installation*.

Effectiveness:

- Effective in minimizing wind-driven rain entry around doors and windows and damaging the interior of building.
- Use **corrosion-resistant connectors and fasteners** to increase effectiveness.
- For high wind areas, consider a vestibule design, **improve entry doors**, **strengthen window glass** and/or **install shutters** to maximize effectiveness.

Limitations:

- Not practical for protecting doors and windows from inundation by coastal flood forces from storm surge.
- Will not prevent breakage of doors and windows due to high wind pressures or windborne debris impact forces.

B. Building Utility Equipment

Problem: Heavy, wind-driven rain during hurricanes can penetrate and cause extensive water damage to building utility equipment.

Mitigation Objective: Reduce the risk of wind-driven rain damage to building utility equipment by relocating or providing additional moisture protection to increase the resistance to these forces.

Mitigation measures to protect building utility equipment from wind-driven rain damage include:

1. Install rain-resistant venting.....p. 76
2. Install Ground Fault Interrupter (GFI) circuits See p. 32
3. Eliminate ancillary structures by integrating functions into main building See p. 51

B.1 Install Rain-Resistant Venting

Install rain-resistant roof vents to reduce potential damage from rain water infiltration into buildings. Rain-resistance can be increased by use of goose-neck vent pipes, fixed vent caps, detached rain hoods, flaps for side discharge vents (J vents), and adequate sealant at vent-roof membrane joint.

Design issues:

- Maintain adequate airflow after adding rain-resistance protection.
- Add flap on large vents to prevent infiltration by horizontal wind-driven rain.

Effectiveness:

- Effective in reducing building damage caused by water infiltration through vent pipes.

Limitations:

- Sealant at pipe-roof membrane joint requires regular inspection and maintenance.

Considerations



VII. SURGE DAMAGE: Mitigation for Category F Facilities - Utilities

Basic Causes of Damage

- Coastal storm surge inundation of ground-level utility equipment.
- Surge-induced coastal erosion and scour of ground-level and buried utility transmission and distribution lines.

This section discusses mitigation measures for common surge damage to utility equipment, transmission and distribution lines, which are caused by:

D. Inundation

E. Erosion and Scour

A. Inundation

Problem: Inundation causes the following damages to Category F facilities:

1. Coastal storm surge causes inundation damage and/or failure of ground-level utility equipment below the design flood elevation.
2. Coastal storm surge causes inundation damage and/or failure of ground-level utility transmission and distribution lines below the design flood elevation.

Mitigation Objectives: Prevent or reduce inundation on Category F facilities as follows:

1. Reduce the risk of storm surge inundation damage to utility equipment and lines by elevating, relocating, and anchoring equipment below the design flood elevation to increase the resistance and/or improve the response to these forces.
2. Reduce the risk of storm surge inundation damage to utility transmission and distribution lines by protecting lines below the design flood elevation to increase the resistance and/or improve the response to these forces.

Mitigation measures to protect utility equipment from inundation damage include:

- | | | |
|------|--|------------------------|
| 1.a. | Relocate utility | See <i>FMH</i> , p. 82 |
| 1.b. | Elevate utility..... | See <i>FMH</i> , p. 83 |
| 1.c. | Anchor & tie-down buoyant facilities | See <i>FMH</i> , p. 95 |

Mitigation measures to protect utility transmission and distribution lines from inundation damage include:

- | | | |
|------|----------------------------|------------------------|
| 2.a. | Encase utility lines | See <i>FMH</i> , p. 84 |
| 2.b. | Line damaged pipes..... | See <i>FMH</i> , p. 86 |
| 2.c. | Bury utility lines | See <i>FMH</i> , p. 87 |

B. Erosion and Scour

Problem: Coastal storm surge causes erosion and scour that can undermine support of ground-level and buried utility equipment and transmission and distribution lines located below the design flood elevation.

Mitigation Objective: Reduce the risk of storm surge damage to utility equipment and transmission and distribution lines caused by erosion and scour by increasing the resistance and/or improving the response to these forces.

Mitigation measures to protect utility equipment and transmission and distribution lines from erosion and scour damage include:

1. Relocate utility equipment..... See *FMH*, p. 82
2. Encase utility lines See *FMH*, p. 84
3. Line damaged pipes..... See *FMH*, p. 86
4. Bury utility lines See *FMH*, p. 87

VIII. WIND DAMAGE: Mitigation for Category F Facilities - Utilities

Basic Causes of Damage

- Wind pressures and windborne debris impact on overhead utility equipment.
- Wind pressures and windborne debris impact on utility transmission and distribution lines.

This section discusses the following mitigation techniques to address common wind damage to utilities including

A. Utility Equipment

B. Transmission and Distribution Lines.

A. Utility Equipment

Problem: High wind pressures and windborne debris impact forces cause failure or blow-off of overhead utility equipment and failure or collapse of tank structures.

Mitigation Objective: Reduce the risk of damage from high wind pressures by anchoring overhead equipment and tank structures to increase the resistance to these forces. Reduce the risk of windborne debris impact forces by protecting utility equipment to reduce exposure to these forces.

Mitigation measures to protect utility equipment from wind damage include:

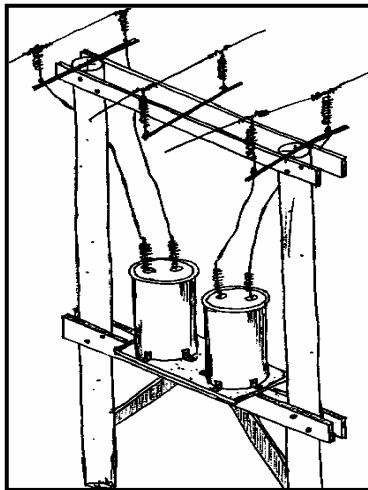
- 1. Anchor electrical equipment.....p. 82
- 2. Improve anchorage of tank structures.....p. 83
- 3. Eliminate ancillary structures by integrating functions into main building See p. 51

A.1 Anchor Electrical Equipment

Anchor pole-mounted transformers, electrical and instrumentation cabinets and motor control centers to withstand hurricane wind-induced wind loads without excessive movement. This measure will keep electrical equipment from sliding, toppling or falling due to inadequate anchorage.

Design issues:

- Pole-mounted electrical equipment may be mounted and anchored on wood platforms attached to one or more pole(s).
- Connections to the transformers should be flexible enough to help isolate the stresses from other sources.
- Design electrical equipment anchorages to resist corrosion.
- Access to electrical equipment must be maintained after mitigation.
- State and local standards for electrical equipment may apply.



Effectiveness:

- Effective when properly designed and installed.
- Anchoring of pole-mounted electrical equipment may also reduce coastal flood damages from hurricane events.
- Effectiveness can be increased when combined with ***replacing wood utility poles with stronger materials or installing additional pole supports.***

Limitations:

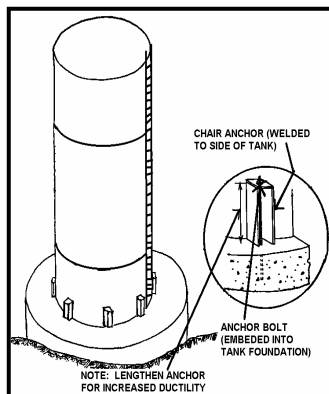
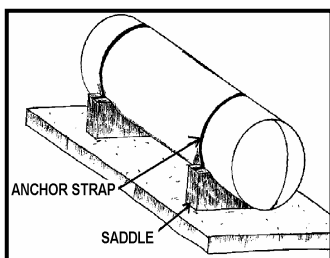
- Will not prevent collapse of utility poles or loss of electrical power.
- May not prevent damage to grade-level electrical equipment from coastal flooding.
- May not prevent damage to electrical equipment from windborne debris impact.
- May not prevent loss of electrical power to the equipment.
- May increase maintenance costs due to decreased access.

A.2 Improve Anchorage of Tank Structures

Improve foundation anchors for vertical & horizontal tank structures to resist high wind. This will keep tank structures from sliding, toppling, or falling from inadequate anchorage.

Design issues:

- For vertical tanks, anchor systems can consist of: metal straps welded to tank and embedded in a concrete footing and/or vertical anchor bolts connected with chair anchors into the foundation.



- Horizontal tanks, above & below ground, should be securely supported and anchored with saddles or other supports.
- Design mitigated tank structure anchors to resist corrosion.
- State and local standards for tank structures, such as AWWA D100-96, may apply.

Effectiveness:

- Effective in reducing tank damage from hurricane wind pressures.
- Effective at reducing damage in earthquake events.
- Considered to be generally cost-effective for fuel tanks under Appendix A of R&R Policy 9526.1, dated April 29, 1998.
- Install **flexible connections** at tank inlets/outlets to reduce pipe-related damage.

Limitations:

- Foundations need to be sufficient to support anchoring.
- May not prevent tank damage/collapse from coastal flood forces.
- May not prevent tank rupture from windborne debris impact.

Considerations:



B. Transmission and Distribution Lines

Problem: High wind pressures and windborne debris impact forces cause failure, severing or collapse of utility poles and utility transmission and distribution lines.

Mitigation Objective: Reduce the risk of high wind pressures and windborne debris impact forces by reinforcing or strengthening utility poles, and relocating or burying overhead utility lines to increase the resistance and reduce exposure to these forces.

Mitigation measures to protect utility transmission and distribution lines from wind damage include:

1. Install additional pole supports p. 85
2. Replace strain poles with mast arm poles See p. 15
3. Replace strain poles with higher strength poles..... See p. 16
4. Bury the utility..... See *FMH*, p. 87

B.1 Install Additional Pole Supports

Install additional supports to existing vertical utility poles. This measure can reduce the risk of utility pole failure by cracking, splitting, or overturning in future hurricanes and other high wind events.

Design issues:

- Additional supports include batter poles and guy wires attached at or near the top of the existing vertical pole or the use of multiple poles to support transformers and other utility equipment.
- Increased right-of-way required for batter poles.
- Design guy wires to resist corrosion.
- State and local standards for utility poles may apply.

Effectiveness:

- Effective at reducing pole damage.
- May reduce downtime from loss of overhead utilities.
- Considered to be generally cost-effective under Appendix A of R&R Policy 9526.1, dated April 29, 1998.
- Effectiveness can be increased when combined with ***anchoring*** pole-mounted ***electrical equipment***.

Limitations:

- May not eliminate loss of utility services from downed overhead lines or pole-mounted equipment.
- May not eliminate pole damage or collapse from saturated foundation soils, coastal flooding or debris impact forces.
- May not be cost effective for undamaged poles.

Considerations:



IX. SURGE DAMAGE: Mitigation for Category G Facilities – Parks, Recreational and Other

Basic Causes of Damage

- Coastal storm surge inundation of docks and piers.
- Surge-induced coastal erosion and scour of public beaches and dunes.

This section discusses mitigation measures for common surge damages including:

- A. Inundation*
- B. Scour and Erosion*

A. Inundation

Problem: Coastal storm surge causes inundation and wave damage to docks and piers.

Mitigation Objective: Reduce the risk of storm surge damage to docks and piers by restoring, maintaining, nourishing beaches, and protecting public beaches and dunes to increase the resistance to these forces.

Mitigation measures to protect docks and piers from surge damage caused by inundation include:

1. Strengthen deck systemsp. 88
2. Construct coastal defensesp. 89

A.1 Strengthen Deck Systems

Wooden docks and piers often experience significant damage or collapse of their deck systems due to storm surge inundation, breaking waves, and debris impact forces during hurricanes. Strengthening deck systems can help reduce the risk of deck damage or collapse during hurricanes.

Design issues:

- The following steps can be taken to strengthen deck systems: elevate deck above the anticipated level of coastal storm surge and wave setup, improve connections between the deck framing and the piles that support them, and improve connections between the individual deck boards and the deck framing.
- Maintenance must be performed to insure docks and piers have not deteriorated.

Effectiveness:

- Somewhat to very effective, depending on the extent of mitigation and the level of flood forces impacting the deck.
- Use **corrosion-resistant** stainless steel **connectors and fasteners** for maximum effectiveness.

Limitations:

- May not be cost effective for undamaged deck systems.
- Deteriorated docks and piers are likely to fail under storm surge and breaking wave conditions.

Considerations:

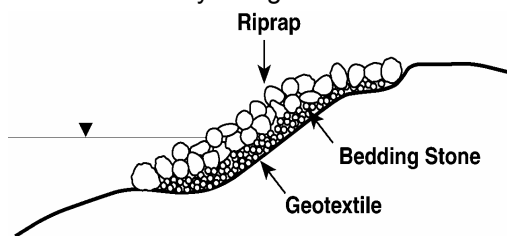
\$

A.2 Construct Coastal Defenses

Construction of coastal defenses such as groins, jetties, breakwaters and/or revetments can help protect public beaches and other facilities against inundation and coastal erosion. Coastal defenses can be constructed of riprap, large boulders, or interlocking concrete blocks (e.g., dolos or core-loc units), depending on the magnitude of the coastal flood forces.

Design issues:

- Groins or jetties are offshore structures placed perpendicular to the shoreline that help maintain beaches by trapping eroded beach sand that moves laterally along the shoreline.
- Revetments are offshore structures placed perpendicular to the shoreline that help mitigate hurricane damages by reducing wave impacts and coastal erosion.
- Submerged breakwaters are structures placed offshore and perpendicular to the shoreline and mitigate against storm surge inundation by dissipating wave setup effects before they reach the coastline.



REVETMENT (CROSS SECTION)

Effectiveness:

- Somewhat to very effective when properly designed, depending on the type of coastal defenses and the level of flood forces impacting the defenses.

Limitations:

- Coastal defenses must be properly maintained in order to remain effective.
- Jetties and breakwaters can increase shoreline loss at some locations.
- Coastal defenses may be subject to local restrictions, including environmental requirements.

Considerations:



B. Erosion and Scour

Problem: Coastal storm surge causes erosion and scour of public beaches and sand dunes that may protect coastal buildings and facilities.

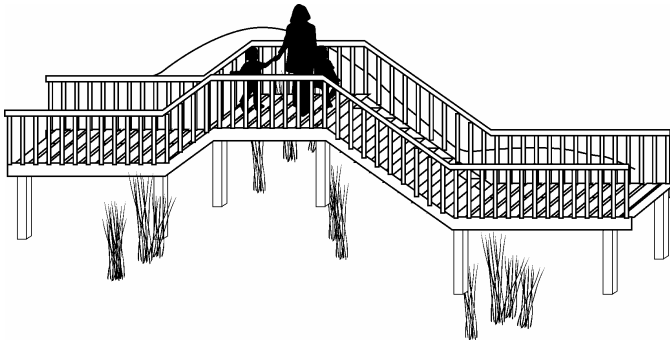
Mitigation Objective: Reduce the risk of storm surge damage to public beaches and dunes by restoring, maintaining, nourishing beaches, and protecting public beaches and dunes to increase the resistance to these forces.

Mitigation measures to protect public beaches and dunes from surge damage caused by erosion and scour include:

1. Dune maintenance p. 91
2. Beach nourishment p. 92
3. Restore and maintain coastal dunes See p. 39
4. Construct coastal defenses See p. 89

B.1 Dune Maintenance

Proper maintenance of sand dunes can provide a natural defense against coastal flood forces to buildings and other infrastructure.



DUNE WALKOVER WITH BEACH GRASS

Design issues:

- Dune maintenance techniques include planting of beach grass and other vegetation to reduce erosion and scour of the dune, and construction of dune walkovers to protect the dune from pedestrian traffic.
- Dune maintenance must comply with engineered design and maintenance requirements to be eligible for FEMA PA funds following a declared disaster.

Effectiveness:

- Somewhat to very effective, depending on the size of the dune and the level of flood forces impacting the dune.

Limitations:

- May not eliminate damage or loss of dune in future storm events.
- Maintenance is essential to remain effective.
- Dune maintenance may be subject to local restrictions, including environmental requirements.

Considerations:



B.2 Beach Nourishment

A regular program of beach nourishment along public beaches can reduce storm damage to beaches and enhance a natural defense against coastal flood forces that can damage or destroy public beaches, buildings, and other infrastructure.

Design issues:

- Beach nourishment must comply with engineered design and maintenance requirements to be eligible for FEMA PA funds following a declared disaster.
- Avoid the use of offshore sand for nourishment if the dredging or pumping results in a steeper bottom slope, as this can increase wave setup, erosion, and scour.

Effectiveness:

- Somewhat to very effective, depending on the size and frequency of the nourishment(s) and the level of flood forces impacting the beach.
- Effectiveness may be increased when combined with **construction of coastal defenses** and **dune restoration**.

Limitations:

- May not eliminate damage or loss of beach in future storm events.
- Beach nourishment must be properly maintained in order to remain effective.
- Beach nourishment may be subject to local restrictions, including environmental requirements.

Considerations:



X. WIND DAMAGE: Mitigation for Category G Facilities – Parks, Recreational and Other

Basic Causes of Damage

- Wind pressures on public beaches and dunes.
- Wind pressures and windborne debris impact forces on docks and piers.

This section discusses the following mitigation techniques to address common wind damage to the following elements:

- A. Public Beaches and Dunes*
- B. Docks and Piers*

A. Public Beaches and Dunes

Problem: High wind pressures contribute to erosion of public beaches and sand dunes that may protect coastal buildings and facilities.

Mitigation Objective: Reduce the risk of high wind pressures by maintaining sand dunes to increase the resistance to these forces.

Mitigation measures to protect public beaches and dunes from wind damage include:

1. Dune maintenance..... See p. 91

B. Docks and Piers

Problem: High wind pressures cause breakage or blow off of dock and pier structures, signs, and deck boards. More extreme wind events may create windborne debris from pieces of dock and pier structures, signs, and deck boards.

Mitigation Objective: Reduce the risk of high wind pressures and windborne debris impact forces by anchoring or eliminating dock and pier structures and signs and strengthening deck boards to increase the resistance to these forces.

Mitigation measures to protect docks and piers from wind damage include:

1. Anchor or eliminate dock/pier structures and Signs..... p. 96
2. Strengthen deck systems..... See p. 88

B.1 Anchor or Eliminate Dock/Pier Structures and Signs

Anchor dock/pier structures and signs using additional connectors or straps, and construct dock structures and signs using stronger materials and improved connections. Also, eliminate dock structures and signs whenever possible. These measures will avoid breakage and prevent blow-off or collapse of dock/pier structures and signs and reduce the potential for windborne debris.

Design issues:

- Connectors or straps used to anchor dock/pier structures and signs to supports should be strong and corrosion-resistant to prevent blow-off.
- Materials used to strengthen dock/pier structures and signs include plywood and aluminum.
- Add wood or metal framing behind signs to reduce sign failure.
- Structures and signs that cannot be anchored or strengthened should be eliminated.
- State and local standards for dock/pier structures and signs may apply.

Effectiveness:

- Effective at reducing dock/pier structure and sign damage when properly designed and constructed.
- Effectiveness can be increased when combined with ***strengthening sign poles***.
- Use ***corrosion-resistant stainless steel connectors and fasteners*** for maximum effectiveness.

Limitations:

- Will not prevent collapse of sign supports or loss of dock/pier.
- May not prevent damage from breaking wave or floodborne debris impact forces.
- May not prevent sign damage from windborne debris impact.
- May not be feasible unless the supporting deck system is properly designed and constructed.

BEST PRACTICES - INTRODUCTION

Over the years, there have been many methodologies and techniques for design and construction that have been proven to be effective at reducing hurricane damage to public facilities. However, for the purposes of this Handbook, many of these “best practices” for reducing damage are not considered to be hazard mitigation measures because they do not meet one or more of the following eligibility requirements for Public Assistance (PA) mitigation funding:

1. Measures must be cost-effective.
2. Measures must apply to permanent work. (Examples of such non-permanent work practices include emergency protective measures and/or debris removal.)
3. Measures cannot apply to alternate or improved projects if a new or replacement facility is involved.
4. Measures cannot be upgrades required to meet current codes and standards. (These costs may be covered, but are not considered mitigation.)

This section identifies best practices for the following public facilities:

- *Category C Facilities – Roads & Bridges*
- *Category D Facilities – Water Control Facilities*
- *Category E Facilities – Buildings & Contents*
- *Category F Facilities – Utilities*
- *Category G Facilities – Other Facilities*

NOTE: Best practices are not considered eligible for FEMA PA Mitigation funding.

BEST PRACTICES FOR CATEGORY C FACILITIES – ~~R~~ADS & BRIDGES

Storm Surge Design - Best Practices

- **Maintain roadside drainage** – Routine maintenance of roadside drainage systems is essential to ensure these systems perform properly during hurricanes and other coastal flood events. Remove debris from roadside drainage ditches & clean out culverts to maintain design capacity.
- **Maintain bridge decks and foundations** – When conducting routine bridge inspections/maintenance, remove debris from bridge decks to maintain drainage, and replace **riprap** & other erosion protection around bridge abutments and piers. Such practices will reduce potential surge damage during hurricanes and limit deterioration of these elements (i.e., rotting of timber decks and beams, corrosion of metal fasteners & elements, and erosion of abutments & piers.)

Wind Design - Best Practices

- **Trim and remove trees** – Trees & tree limbs downed by hurricane-force winds can damage traffic signs & signals, block roads for hours or days, & hamper disaster response/recovery operations. Trimming overhanging trees & removing dead limbs along roadside can greatly reduce wind damage to roadside equipment & limit road closures as well as reduce the potential for windborne debris.
- **Clear and eliminate roadside debris** – Immediately following a hurricane, debris such as tree limbs and garbage should be cleared to the side of the road as soon as possible to restore the flow of traffic for emergency vehicles. Once emergency response operations are complete, such roadside debris should be hauled away to reduce the potential for windborne debris and eliminate any potential safety hazards to pedestrians.

BEST PRACTICES FOR CATEGORY D FACILITIES – WATER CONTROL FACILITIES

Storm Surge Design - Best Practices

- **Perform routine maintenance** – As with roadside drainage systems, routine maintenance of water control facilities is essential to ensure proper performance during hurricanes & other coastal flood events. Remove debris from drainage and irrigation ditches, clean out culverts, and replace lost or damaged *riprap* from shoreline protective structures.
- **Consider aquatic vegetation control** – Non-native and invasive plant species can decrease the capacity canals and other water control facilities. Aquatic vegetation control programs, such as the introduction of species of fish that eliminate non-native and invasive aquatic plant species, can help control nuisance aquatic plant species. Such programs have been used successfully by Miami-Dade and Broward Counties in Florida. Note that such programs are subject to NEPA review, and should include signs posting that fishing in the canals is prohibited, to ensure the survivability of the fish.

BEST PRACTICES FOR CATEGORY E FACILITIES – BUILDINGS & CONTENTS

Storm Surge Design - Best Practices

- **Protect high-value uses** – High-value uses and critical functions located on the lowest floors of public buildings, such as records storage departments and emergency communications, should be permanently elevated above the design flood elevation or placed on upper floors to protect them from coastal storm surge inundation. For single-story buildings located below the design flood elevation, high-value uses and critical functions should be relocated outside the coastal floodplain. If elevation or relocation is not possible, provisions should be made for back-up facilities outside the coastal floodplain.

- **Reduce or eliminate placement of utilities below the design flood depth** - Reduce the placement of building utility equipment and lines below the design flood depth. Another option is to eliminate building utility equipment and lines below the design flood elevation whenever possible. These measures will decrease the potential for damages to utility systems from storm surge and limit potential secondary damages and injuries from electrical shocks, gas explosions, and sewage leaks.
- **Consider enhanced floodplain management regulations**
 - Coastal communities participating in the National Flood Insurance Program (NFIP) should consider one or more the following enhancements to their local floodplain management ordinance.
 1. Add or increase existing freeboard requirements to increase the design flood elevation by 1 foot or more above the Base Flood Elevation (BFE).
 2. Limit major repairs, renovations, improvements and/or additions and major repairs to pre-FIRM coastal buildings by establishing a cumulative substantial damage/substantial improvement clause.
 3. Require that new and substantially damaged/substantially improved buildings constructed in a coastal A Zone meet V Zone requirements (such as elevation on piles) to reduce storm surge damage.
 4. Recommend the use of epoxy-based adhesives and limit use of latex-based adhesives below the design flood elevation.
 5. Restrict use of gas-fired appliances and storage of hazardous materials in areas subject to coastal flooding.

These and other enhancements can reduce community-wide damages to storm surge. In addition, NFIP communities participating in the Community Rating System (CRS) that implement and enforce such enhancements to their local floodplain management ordinance may qualify for credits that can reduce flood insurance premiums throughout the community.

Wind Design – Best Practices

- **Design for a continuous load path** - In order to mitigate wind damage from uplift, shear and overturning forces, use proven and reliable methods for providing a **continuous load path** from the roof ridge to the soils supporting the foundation. FEMA, in a partnership with the Illinois Emergency Management Agency (IEMA), published two manuals on windstorm mitigation for light and heavy frame construction. The first manual, *Wind Storm Mitigation for Light Frame Construction Manual*, is aimed at building owners or contractors and discusses many options in constructing a building by using common connections in wood frame buildings, such as anchors, clips, and straps to provide a continuous load path for all loads-not just gravity loads. The second manual is a companion manual to the first and provides more details. The *Wind Storm Mitigation for Light Frame Construction Manual* can be downloaded at <http://www.state.il.us/iema/Prep/windmitman.htm>. The companion can be downloaded at <http://www.state.il.us/iema/Prep/comp.htm>.
- **Create roof and wall diaphragms** – Building roof and wall diaphragms can be effectively strengthened using non-corrosive tension rods or straps to provide increased rigidity and reduce structural framing damage from high wind events. However, access for installation in existing walls and roofs may be difficult, and the project will not reduce the risk of wind damage to non-structural elements.
- **Construct a shelter** - Shelters are the best means of providing near absolute protection for individuals who are attempting to take refuge during a tornado or extreme wind events where structures are unlikely to escape destruction. Group or community shelters should be designed and constructed in strict accordance with FEMA Publication 361: *Design and Construction Guidance for Community Shelters* or *The National Performance Criteria for Tornado Shelters*. (Shelters for individual homeowners all shelters should be designed and constructed in accordance with FEMA Publication 320: *Taking Shelter from the Storm*.) For all shelters, it is essential to ensure the shelter is constructed above the anticipated coastal flood level.

- **Remove trees and potential windborne missiles** – Hurricane-force winds can topple trees and create windborne missiles that can damage buildings and lead to a loss of building function. Removing trees and eliminating potential windborne missiles can reduce the risk of building damage. Trees and vegetation that are close enough to buildings to cause damage if they fall should be removed whenever possible. **Anchor or remove ancillary structures** such as storage sheds or outbuildings. Smaller objects such as trash cans and outdoor furniture should be anchored or moved indoors. For additional details, refer to the FEMA How-To Series, *Protecting Your Property from Wind* (<http://www.fema.gov/fima/how2.shtm#wind>).
- **Consider a high-performance modular unit** – Modular units and manufactured units that are assembled in a factory, constructed like conventional on-site (i.e., “stick built”) buildings, and are regulated by the same local building code as conventional on-site buildings. These units typically include hazard-resistant features such as larger studs and joists, heavier doors and door hardware, impact-resistant windows, **continuous load path** from roof to foundation attachment, stronger sheathing, and improved foundation anchorages. In recent years, modular units have been observed to suffer less damage from hurricanes than traditional manufactured units.
- **Consider concrete panel construction** – Concrete panel structures are buildings constructed of concrete board that is laminated to polystyrene foam and attached to precision-engineered pre-fabricated rigid steel wind framework connected to an engineered concrete slab. Panels are attached with heavy-galvanized sheet metal spline and stainless steel screws. When properly engineered and constructed, concrete panel buildings offer a high level of wind design in hurricane-prone areas. In addition, concrete panel construction allows smaller, simple structures to be built quickly. However, larger and more complex designs for concrete panel buildings are not yet available.
- **Consider high-performance structural steel roofing** – High-performance structural steel roofing may be used to upgrade existing damaged metal or asphalt shingle roofing. High-performance structural metal roofing uses a 2.5-inch

standing seam; which is larger than the 1 inch standing seam used for normal roofing. High-performance structural steel roofing panels are rolled and closed over the anchor clips to prevent seam failure under very high wind loads. The concealed anchor clips can be mounted on any surface including existing built-up roofing, and allow for thermal movement and the use of longer panel lengths. High-performance structural steel roofing panels are made of 24, 22, 20, or 18 gage carbon steel; however, 3004 aluminum alloy is recommended in coastal areas to reduce the risk of corrosion. High-performance structural steel roof systems very effective at reducing roof damage in high wind areas, but are more expensive than asphalt shingle or normal metal roof systems.

Wind-Driven Rain Design – Best Practices

- **Reduce or eliminate roof openings** – Roof openings for skylights and other features can disrupt the continuity of roof decks and increase the potential for entry of wind-driven rain and other roof damage. Reducing or eliminating roof openings can help strengthen roof deck systems and reduce the potential for wind-driven rain damage during hurricanes.
- **Protect underside of elevated building floors** – Protect the underside of elevated floor decks in coastal areas using additional plywood panel sheathing secured with **corrosion-resistant connectors and fasteners**. This measure will help prevent damage to floor decks from wind-driven rain during hurricanes as well as corrosion damage from salt spray. Refer to the *Coastal Construction Manual* (FEMA Publication 55) for additional details.

BEST PRACTICES FOR CATEGORY F FACILITIES – UTILITIES

Storm Surge Design - Best Practices

- **Protect water and sewage treatment plants** - Protect water and sewage treatment plants in coastal floodplains from hurricane damage and loss of service by relocation or elevation. If relocation or elevation is not possible, mitigate water and sewage treatment plants in coastal floodplains using various floodproofing techniques, including:
 1. Wet floodproofing of openings below the design flood elevation.
 2. Construction of accessory structures with flood-resistant surfaces and non-corrosive materials, connectors and fasteners.
 3. Requiring emergency plant shut-offs to protect against widespread damage or wastewater contamination.
- **Consider enhanced local regulations** – Coastal communities participating in the National Flood Insurance Program (NFIP) should consider one or more the following enhancements to reduce utility damages from storm surge:
 1. Restrict or prohibit use of underground storage tanks in hazard areas subject to storm-induced erosion and scour.
 2. Restrict placement of gas-fired equipment and storage of hazardous materials in areas subject to coastal flooding.

Wind Design - Best Practices

- **Trim and remove trees** – Trees and tree limbs downed by hurricane-force winds often damage utility poles and overhead utility lines that can lead to widespread power outages and loss of telephone service for days or weeks. Trimming overhanging trees and removing dead limbs near utility poles and overhead utility lines can greatly reduce wind damage to utility transmission and distribution networks and limit disruptions from loss of electricity or telephone service as well as reduce the potential for windborne debris.

- **Install additional poles or pole supports** – Install additional utility poles or install additional supports such as guy wires or angled (batter) piles attached to existing utility poles. These practices can limit losses to electric and telephone services by adding redundancy and reducing the risk of utility pole failures from hurricanes and other high wind events.

BEST PRACTICES FOR CATEGORY G FACILITIES – OTHER FACILITIES

- **Perform routine maintenance** – As with water control facilities and roadside drainage systems, routine maintenance of public beaches water control facilities is essential to ensure these facilities perform properly during hurricanes and other coastal flood events. Communities with public beaches should adhere to a program of routine maintenance that includes an established source of funding, cross sectional surveys and nourishment of beaches at least once every five years. Docks, piers and shoreline protective structures should be inspected regularly, and lost or damaged deck boards, pilings or *riprap* should be repaired or replaced to maintain their design capacity.

APPENDIX A

REGULATIONS AND CONSIDERATIONS

This Appendix summarizes significant regulations and issues that should be considered when developing one of the projects identified in this Handbook. These cautions are represented by symbols, the most applicable of which accompany each mitigation measure in the Handbook. The project proponent is solely responsible to ensure that all applicable codes/ standards are met, regardless if they are identified in this Handbook.



National Environmental Policy Act (NEPA)

All federal agencies must consider the effects of federally-funded projects upon the environment as required by NEPA. Actions identified by this symbol may have an impact on the environment and may require further investigation to determine the extent of any impacts.



Endangered Species Act (ESA)

The ESA protects animals and plants that are federally listed as threatened or endangered (as well as their habitat). Actions identified by this symbol may have an affect on endangered species or their habitat.

Consultation and approval by the National Marine Fisheries Service and/or the U.S. Fish and Wildlife Service may be necessary when either agency has jurisdiction.



National Historic Preservation Act (NHPA)

NHPA strives to protect our nation's heritage, and requires the review of any project that affects a structure 50 years or older that may be on (or eligible for) the Federal Register of Historic Places, or that affects a site which may contain artifacts of archaeological or cultural significance. For any action identified by this symbol, FEMA may need to consult with the State or Tribal Historic Preservation Office to determine whether any additional action or mitigation is necessary.



Clean Water Act (CWA)

The U.S. Army Corps of Engineers (Corps) is responsible for ensuring that projects in “the waters of the United States” do not adversely affect such waters. Actions identified by this symbol may require a permit by the Corps.



Coastal Barrier Resource Act (CBRA)

The CBRA seeks to minimize damage to fish, wildlife and other natural resources associated with coastal barriers by restricting Federal spending and financial assistance that encourage development of coastal barriers. Coastal barriers are located along the Atlantic and Gulf coasts and are identified on FIRMs as Coastal Barrier Resources System (CBRS) units. Actions identified by this symbol may not be eligible for funding if they are located in a CBRS unit.



Floodplain / Wetlands

Actions identified by this symbol are subject to Executive Order 11988 on Floodplain Management and/or Executive Order 11990 on Wetlands. The Executive Orders on Floodplains and Wetlands are intended to ensure that federally-funded projects avoid long and short term impacts associated with the modification of floodplains or wetlands.



Right of Way Constraints

Mitigation measures identified by this symbol may be limited by required right of way widths, clear zone constraints, and/or geometry of embankment constraints.



Floodplain Effects

Actions identified by this symbol indicate that the action may impact landward flow or may create backwater effects seaward of the measure.



Cost

The cost of actions identified by this symbol may be prohibitively expensive.



Maintenance

Actions identified by this symbol may require significant and/or continuous maintenance.



Engineer

Actions identified by this symbol require that an engineer or other design professional be consulted or hired to develop and/or approve the mitigation.



Structure's Aesthetics Could be Impacted

Actions identified by this symbol may affect the structure's appearance and/or aesthetic value.

APPENDIXB

GLOSSARY OF TERMS AND MITIGATION KEYWORD INDEX

[Keywords are underlined]

A Zone. Under the National Flood Insurance Program, an area subject to inundation by the 100-year flood where wave action does not occur or where waves are less than 3 feet high; designated as Zone A, AE, A1-A30, A0, AH, or AR on a Flood Insurance Rate Map (FIRM). pp. 27, 29, 36, and 100.

Anchor. To secure a structure to its foundation in such a way that a continuous load path is created and so that it will not be displaced by storm surge, wind, or other forces. pp. 3, 29, 37, 39, 52, 78, 81, 82, 83, 96, and 102.

Ancillary structures. Under the National Flood Insurance Program, structures such as garages, utility sheds and other outbuildings which are on the same parcel of property as the main building and the use of which is incidental to the use of the main building.

Ancillary structures, Anchor. pp. 46 and 52.

Ancillary structures, Eliminate. pp. 46, 51, 52, 68, 75, and 81.

Automatic disconnect switches. See **Ground-Fault Interruptor (GFI) Circuits.**

Base Flood Elevation (BFE). The elevation of the base or 100-year flood, which is the flood that has a 1 percent chance of occurrence in any given year, in relation to a specified datum, such as the National Geodetic Vertical Datum or the North American Vertical Datum. The Base Flood Elevation is the basis of the insurance and floodplain management requirements of the National Flood Insurance Program. pp. 26, 29, 34, 35 and 100.

Breakaway walls. Under the National Flood Insurance Program, walls that are not part of the structural support of the building and are designed and constructed to collapse under

specific lateral loading forces, without causing damage to the elevated portion of the building or supporting foundation system. Breakaway walls are required by the National Flood Insurance Program regulations for any enclosures constructed below the Base Flood Elevation beneath elevated buildings in Coastal High Hazard Areas (V Zones). In addition, breakaway walls are recommended in areas where flood waters could reach significant velocities (usually greater than four feet per second) or include breaking waves or floodborne debris. pp. 25, 27, and 38.

Breakwaters. Shoreline protective structures, typically constructed offshore and aligned parallel to the shoreline, that provide protection from waves. pp. 21, 22,

Cathodic protection. A form of corrosion protection applied to steel elements such as buried pilings and submerged structures that involves making the surface to be protected the cathode of the system while using another metal to act as the anode. Cathodic protection may be applied by the use of an impressed current system or by a sacrificial anode system. p. 44.

Clay/concrete tile roofs, Upgrade. pp 53 and 57.

Coastal High Hazard Area. See **V Zone**.

Continuous load path. A structural design principle whereby all forces on a building must follow a continuous path starting at the roof ridge and ending at the soils supporting the foundation. All elements and connections along this load path must be properly designed and constructed to resist wind and flood damage from uplift, shear and overturning forces. pp. 30, 49, 50, 101 and 102.

Coping. The top layer or course of a masonry wall, often having an inclined upper surface to shed water. pp. 53 and 60.

Corrosion. The deterioration of metal by chemical or electrochemical reaction resulting from exposure to weathering, moisture, salt spray, or other chemicals. pp. 3, 15, 16, 24, 29, 30, 40, 41, 42, 43, 44, 52, 56, 64, 71, 82, 83, 85, 96, 98, and 103.

Corrosion-resistant connections. pp. 18, 26, 28, 29, 30, 31, 33, 36, 37, 40, 47, 49, 50, 52, 54, 55, 56, 57, 60, 61, 62, 63, 64, 66, 69, 73, 74, 88, 96, and 103.

Design flood elevation. Elevation of the design flood, usually the Base Flood Elevation plus freeboard, used as the basis for designing flood hazard mitigation measures. The design flood elevation may also be referred to as the DFE or the flood protection elevation. pp. 2, 3, 26, 29, 31, 33, 34, 36, 37, 78, 79, 99, 100, 101, and 104.

Dry floodproofing. Mitigation protective measures added to or incorporated in a structure that is not elevated above the Base Flood Elevation that are designed to keep water from entering a facility to prevent storm surge inundation damage. p. 25.

Elevate. To raise a building or other facility so that it is above the height of a given flood. pp. 2, 3, 4, 25, 26, 33, 34, 35, 38, 88, 99, and 100.

Embankment slope protection. pp. 4 and 7.

Entry doors. pp. 64, 72, and 74.

Erosion. Under the National Flood Insurance Program, the process of the gradual wearing away of land masses. In general, coastal erosion involves the detachment and movement of soil and rock fragments, during a flood or storm or over a period of years, through the action of water, wind, or other geologic processes.

Flood Insurance Rate Map (FIRM). An official map of a community, on which the Federal Insurance Administration has delineated both the Special Flood Hazard Areas and the risk premium zones applicable to the community.

Floodplain. Any land area susceptible to being inundated by flood waters. See **Regulatory floodplain.**

Flood-resistant enclosure. See **Dry floodproofing.**

Flood-resistant materials. pp. 3, 31, 35, 36, 52, 72, and 74.

Freeboard. A margin of safety added to the Base Flood Elevation used to account for uncertainties in the determination of flood elevations, such as wave heights or future floodplain development. Communities can adopt freeboard requirements (typically 1 foot or greater) as part of their local floodplain management ordinance.

Gable end roof. A double-sloping roof with a ridge and vertical triangular walls (i.e., gable end walls) at each end. pp. 46, 47, and 48.

Geotextile. A sheet or blanket made of synthetic fibers manufactured in a woven or loose nonwoven manner that is used for soil stabilization, filtering and erosion control. pp. 6, 9, 22, and 39.

Ground-Fault Interruptor (GFI) Circuits. Circuits that can compare the current flowing to and flowing from the appliance, and automatically shut off the current whenever a change in the current (equivalent to about 5 milliamperes) is detected. GFI circuits are installed in damp areas where known electrical shock hazards exist, such as kitchens, basements, restrooms, garages and outdoor outlets. pp. 25, 32, and 75.

Gravel ballast. See **Roof ballast.**

Groins. Thin, shoreline protective structures built perpendicular to the shoreline to trap drifting sand and reduce coastal erosion. pp. 56, 60

Gutters. pp. 53, 58, and 60.

Hip roof. A roof which rises by inclining planes from all four sides of a building. The self-bracing design of hip roofs typically provides better wind resistance than a gable end roof. pp. 46, 47, and 48.

Hurricane clips/straps. Structural connectors, usually metal, used to tie roof, wall, floor, and foundation members together so that they can resist high wind pressures. pp. 46, 47, and 49.

Hydrodynamic forces. Forces imposed on an object, such as a building, by water flowing against and around it. Among these forces are positive frontal pressure against the structure, drag effect along the sides, and negative pressure on the downstream side. pp. 9 and 25.

Hydrostatic forces. Force exerted by water at rest, including lateral pressure on walls and uplift (buoyancy) on floor slabs and storage tanks. The water pressure increases with the square of the water depth. pp. 25, 27, and 29.

Impressed current system. A form of cathodic protection where the metal to be protected acts as the cathode. The cathode is connected by an insulated wire to another metal that acts as the anode, and an electrical current is applied from the anode to the cathode. pp. 40 and 44.

Jetties. Shoreline protective structures, extending out from the coastline to direct and confine tidal flow to a channel or prevent erosion. pp. 21, 22, and 89.

Mast arm poles. pp. 14, 15, 17 and 84.

Membrane roofs, Improve. pp. 53, 58, and 60.

Metal roof systems, Improve. pp. 53 and 56.

National Flood Insurance Program (NFIP). Federal program created by Congress in 1968 that makes flood insurance available in communities that enact and enforce satisfactory floodplain management regulations. pp. 27, 99, 100, and 104.

Post-FIRM building. For insurance rating purposes, a post-FIRM building was constructed or substantially improved after December 31, 1974, or after the effective date of the initial Flood Insurance Rate Map of a community, whichever is later. A post-FIRM building is required to meet the National Flood Insurance Program's minimum Regular Program flood protection standards.

Pre-FIRM building. For insurance rating purposes, a pre-FIRM building was constructed or substantially improved on or before December 31, 1974, or before the effective date of the initial

Flood Insurance Rate Map of the community, whichever is later. Most pre-FIRM buildings were constructed without taking the flood hazard into account.

Protective coatings. Protective coverings such as vinyl, paint, epoxy, bitumen that are applied to exposed metal building elements to prevent corrosion. pp. 40 and 43.

Regulatory floodplain. Flood hazard area within which a community regulates development, including new construction, the repair of substantially damaged buildings, and substantial improvements to existing buildings. In communities participating in the National Flood Insurance Program, the regulatory floodplain must include at least the area inundated by the base flood, also referred to as the Special Flood Hazard Area (SFHA).

Roof flashing. Pieces of metal roofing used to prevent seepage of water into a building around any edge, intersection or projection in a roof such as vent pipes, adjoining walls, and valleys. pp. 53, 56, 58, and 60.

Revetments. Shoreline protective structures built by facing an embankment with rip-rap, large boulders, or interlocking concrete blocks to protect the embankment from erosion or scour caused by flood waters or wave action. pp. 21, 22, and 89.

Relocate. To move a building or other facility to a new location outside the flood hazard area. pp. 2, 5, 6, 7, 8, 10, 25, 78, 79, and 99.

Riprap. Broken stone, cut stone blocks, or rubble that is placed on slopes or around coastal facilities to protect them from erosion or scour caused by flood waters or wave action. pp. 7, 11, 22, 98, and 105.

Roof ballast. pp 53 and 59.

Sacrificial anode system. A form of cathodic protection where the metal to be protected acts as the cathode. The cathode is connected by an insulated wire to another metal that acts as the anode, and the anode corrodes to protect the cathode.

Sand dunes. Under the National Flood Insurance Program, natural or artificial ridges or mounds of sand landward of the beach. pp. 39, 90, 91, 94.

Scour. Removal of soil or fill material by the flow of flood waters. The term is frequently used to describe storm-induced, localized conical erosion around pilings and other foundation supports where the obstruction of flow increases turbulence. See **Erosion**.

Secondary moisture protection, Enhance. pp. 55, 57, 72, and 73.

Sheathing. pp. 53, 54, 55, and 57.

Shingle roofs, Improve. pp. 53 and 55.

Shoreline protective structures. See **Breakwaters, Groins, Jetties, and Revetments.** pp. 21, 22, 89.

Shutters. Wood or metal coverings designed to limit damage to windows and other openings from by high winds and windborne debris impacts. pp. 53, 64, 66, 67, 72, 74.

Siding. Vinyl and aluminum panels used to cover and protect exterior building walls. pp. 53 and 63.

Soffit. The underside of a roof overhang. Vinyl or aluminum soffit panels are used to cover and ventilate roof overhangs. pp. 61, 62, 72.

Soil stabilization. See **Geotextile**.

Special Flood Hazard Area (SFHA). Under the National Flood Insurance Program, an area having special flood, mudslide (i.e., mudflow) and/or flood-related erosion hazards, and shown on a Flood Hazard Boundary Map or Flood Insurance Rate Map as Zone A, AO, A1-A30, AE, A99, AH, V, V1-V30, VE, M or E. See **A Zone** and **V Zone**.

Substantial damage. Damage of any origin sustained by a structure whereby the cost of restoring the structure to its undamaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred.

Substantial improvement. Any reconstruction, rehabilitation, addition or other improvement to a structure, the total cost of which equals or exceeds 50 percent of the market value of the structure before the start of construction of the improvement. The definition of “substantial improvement” includes buildings that have been repaired after suffering substantial damage.

V Zone. Under the National Flood Insurance Program, an area of special flood hazard extending from offshore to the inland limit of a primary frontal dune along an open coast and any other area subject to high-velocity wave action from storms or seismic sources. On a Flood Insurance Rate Map, the Coastal High Hazard Area is designated Zone V, VE, or V1-V30. These zones designate areas subject to inundation by the 100-year flood where wave heights or wave run-up depths are greater than or equal to 3.0 feet. pp. 26, 29, 34, and 100.

Wall-to-foundation connections, Improve. pp. 25, 30, 31, and 46.

Weatherstripping. Plastic, rubber or metal strips used around door and window openings to prevent wind-driven rain and air from entering a building. pp. 64, 72, and 74.

Wet floodproofing. Mitigation protective measures added to or incorporated in a structure that is not elevated above the Base Flood Elevation that minimize damage to a facility and its contents from water that is allowed into a building. pp. 25 and 31.

Wingwalls. Walls placed at the ends of culverts or bridge abutments to direct water flow and control erosion. pp. 2, 7, 11, and 12.

APPENDIXC

ACRONYMS

BFE	Base Flood Elevation
CBRA	Coastal Barrier Resources Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
EO	Executive Orders
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
<i>FMH</i>	<i>Flood Mitigation Handbook</i>
HAZMIT	Hazard Mitigation
HMGP	Hazard Mitigation Grant Program
HVAC	Heating, Ventilation and Cooling
MIT	Mitigation
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NHPA	National Historic Preservation Act
PA	Public Assistance
PL	Public Law
PL 93-288	Robert T. Stafford Disaster Relief and Emergency Assistance Act
USACE	U.S. Army Corps of Engineers

APPENDIXD

REFERENCES

Coastal Construction Fact Sheet Series. FEMA Homebuilder's Guide to Coastal Buildings. Published by FEMA, Washington, DC (TBD).

Coastal Construction Manual. FEMA Publication No. 55, 3rd Edition, June 2000. Published by FEMA, Jessup, MD (2000).

Design and Construction Guidance for Community Shelters. FEMA Publication 361, July 2000. Published by FEMA, Jessup, MD (2000).

Design Guide for Improving School Safety in Earthquakes, Floods and High Winds. FEMA Risk Management Series Publication 424, January 2004.

(<http://www.fema.gov/fima/rmsp424.shtm>)

Design Guidelines for Flood Damage Reduction. Prepared by AIA Research Corp., Washington, D.C., for the Federal Emergency Management Agency. FEMA Publication No. 15, December 1981.

Engineering Principles and Practices of Retrofitting Flood-Prone Residential Structures. FEMA Publication 259, 2nd Edition, June 2001. Published by FEMA, Jessup, MD (2001).

Floodproofing Non-Residential Structures. Prepared by Booker Associates for the Federal Emergency Management Agency. FEMA Publication No. 102, May 1986.

Handbook of Steel Drainage and Highway Construction Products, Second Edition. Published by American Iron & Steel Institute, Washington, DC (1971).

Homeowner's Guide to Retrofitting: Six Ways to Protect Your House From Flooding. FEMA Publication No. 312, June 1998. Published by FEMA, Washington, DC (1998).

NFIP Technical Bulletins. FEMA.
(<http://www.fema.gov/fima/technbul.shtm>)

Protecting Building Utilities From Flood Damage: Principles & Practices for the Design & Construction of Flood Resistant Building Utility Systems. FEMA Publication No. 348, November 1999. Published by FEMA, Jessup, MD (1999).

Public Assistance Guide. FEMA Publication No. 322, October 1999. Supersedes FEMA 286, issued in September 1996. Published by Response and Recovery Directorate, FEMA, Washington, DC (1999).

“Stormwater Management Practices in Tennessee.”

Stormwater Management for Public Officials and Planners: Development of an Educational Manual and Workshop Project, Contract Agreement No. 48226. Published by the University of Tennessee Civil & Environmental Engineering Department and the Tennessee Water Resources Research Center (December 1997). (<http://www.engr.utk.edu/research/water>)

Taking Shelter from the Storm. FEMA Publication 320, 2nd Edition, August 1999. Published by FEMA, Jessup, MD (1999).

Water-Resources Engineering, by Linsley, R.K. & Franzini, J.B. Published by McGraw-Hill, New York (1964).

Wind Storm Mitigation for Light Frame Construction Manuals. Manuals by FEMA in partnership with the Illinois Emergency Management Agency (IEMA).

(<http://www.state.il.us/iema/Prep/windmitman.htm> and [/comp.htm](http://www.state.il.us/iema/Prep/windmitman.htm))

APPENDIX E

FEMA POLICY 9526.1 HAZARD MITIGATION FUNDING UNDER SECTION 406 (STAFFORD ACT)

1. **Date Signed:** August 13, 1998
2. **RR Policy Number:** 9526.1
3. **Subject:** Hazard Mitigation Funding Under Section 406 (Stafford Act)
4. **Purpose:** Provide guidance on the appropriate use of Section 406 hazard mitigation discretionary funding. This will ensure national consistency in the use of Section 406 mitigation funds; and promote measures that reduce future loss to life and property, protect the federal investment in public infrastructure, and, ultimately, help build disaster resistant communities.
5. **Scope and Audience:** This policy applies to all disasters declared after publication of this document. It is intended to guide all FEMA personnel responsible for the administration of the FEMA public assistance grant program.
6. **Background:**
 - a. The Robert T. Stafford Disaster Relief and Emergency Assistance Act, as amended, provides FEMA the authority to fund the restoration of eligible facilities which have sustained damage due to a Presidentially declared disaster. Within the enabling act, Section 406 also contains a provision for the consideration of funding additional measures, not required by applicable codes and standards (further described in 44 CFR 206.226) that will enhance a facility's ability to resist similar damage in future events.

In providing discretionary authority for the addition of hazard mitigation measures to permanent work

restoration, Congress recognized that, during the repair of damaged components of facilities, there would be a unique opportunities to prevent recurrence of similar damage from future, similar disaster events. Such measures are in addition to any measures undertaken to comply with applicable codes and standards, although such compliance, itself, could be considered a form of mitigation.

- b. Section 406 hazard mitigation funding and Section 404 hazard mitigation funding are distinct. Proposals for measures intended to benefit undamaged facilities, and measures not directly related to the damaged elements for which restoration work on a facility is performed are candidates for funding under Section 404. Section 406 funding is more appropriately viewed as stemming from, and related directly to, the repair work required as a result of the disaster. If a combination of Section 404 and Section 406 funding is intended, the Section 404 application should be submitted in a timely manner.
- c. Section 406 hazard mitigation funding under the Stafford Act is a discretionary spending program. While the law provides that the President may authorize funds for eligible projects, it does not require funding. FEMA, Grantee and Subgrantee interests in disaster resistance must be balanced with the supplemental nature of disaster assistance and FEMA's obligation for the prudent stewardship of Federal disaster funds.
- d. Only FEMA is authorized to interpret and implement the Stafford Act and regulations issued pursuant to the Stafford Act. Accordingly, only FEMA has the authority to determine which repairs (code/standard-mandated or otherwise) it will fund pursuant to the Stafford Act. The Stafford Act and applicable regulations cannot be read or interpreted as authorizing State or local building officials or agencies to determine the amount of Federal disaster assistance funds FEMA will contribute to a project.

7. Policy:

- a. Section 406 provides discretionary authority to fund mitigation measures in conjunction with the repair of damaged facilities. The mitigation measures must be related to eligible disaster-related damages and must directly reduce the potential of future, similar disaster damages to the eligible facility. These opportunities usually present themselves during the repair/replacement efforts.
- b. While all parties must remain mindful of relative costs and benefits and prudent use of Federal disaster funds, a calculation of benefits and costs, using the FEMA approved computer model, no longer is necessary for justification of Section 406 funds.
- c. Mitigation measures must be determined to be cost-effective. Any one of the following means may be used to determine cost-effectiveness:
 - 1. Measures may amount to up to 15% of the total eligible cost of the eligible repair work on a particular project.
 - 2. Certain mitigation measures (see Appendix A) will be determined to be cost-effective, as long as the mitigation measure does not exceed the eligible cost of the eligible repair work on the project.
 - 3. For measures that exceed the above costs, the Grantee or Subgrantee must demonstrate through an acceptable benefit/cost analysis that the measure is cost-effective.
- d. Proposed projects must be approved by FEMA prior to funding. They will be evaluated for cost effectiveness, technical feasibility, and compliance

with statutory, regulatory and executive order requirements. In addition, the evaluation must ensure that the mitigation measures do not negatively impact a facility's operation or risk from another hazard.

- e. Costs of meeting applicable codes/standards in accordance with 44 CFR 206.226 is distinct from mitigation funding.
- f. There may be no duplication in funding between Sections 404 and 406. Therefore, the Grantee and Subgrantee must be able to identify specific hazard mitigation work that will be accomplished with funding through Section 406. Section 404 funding may not duplicate that work, although Section 404 may be additive and accomplished on Section 406 facilities. The appropriate split on a project between funds under Sections 404 and 406 is a FEMA decision.
- g. Costs approved for project-specific mitigation measures under Section 406 of the Stafford Act may not be applied to improved projects which will involve the replacement of the disaster-damaged facility, whether on the same site or an alternate site. However, funds recommended for mitigation measures may be approved for an improved project which will include the work required to repair the disaster-damaged facility and restore its function, as well as improvements.
- h. The cost caps (15% or 100%) for Section 406 hazard mitigation measures related to windows will be based on the total cost of damage to: 1) the damaged element, and 2) the affected building contents.

8. **Supercession:**

- a. Paragraph 3.a) of October 14, 1994 Memorandum on "Benefit-cost Analysis in Support of Potential Hazard Mitigation Projects" directed to Regional

Directors and Federal Coordinating Officers from Craig Wingo (RR) and Robert Shea (HM). The memorandum was published in Chapter 4511.600 of Public Assistance Policy and Guidance Compendium.

- b. References to Section 406 funding of March 1995 Memorandum on "Benefit-cost Analyses in Support of Potential Hazard Mitigation Projects directed to Regional Directors and Federal Coordinating Officers from Craig Wingo (RR) and Robert Shea (HM). The memorandum was published in Chapter 4511.600 of Public Assistance Policy and Guidance Compendium.
- c. April 26, 1995 memorandum from Craig Wingo (RR) to William Tidball (FCO, DR-1008) on Section 406 Discretionary Hazard Mitigation Funding. Published in PA Compendium Chapter 4511.600.

9. **Authorities and References:**

- a. Section 406 (e) of the Robert T. Stafford Act, as amended: "(1) General Rule. For purposes of this section, the cost of repairing, restoring, reconstructing, or replacing a public facility or private, nonprofit facility on the basis of the design of such facility as it existed immediately prior to the major disaster and in conformity with current applicable codes, specification, and standards (including floodplain management and hazard mitigation criteria required by the President or by the Coastal Barrier Resources Act (16 U.S.C. 3501 et seq.)) shall, at a minimum be treated as the net eligible cost of such repair, restoration, reconstruction, or replacement."
- b. Reference: March 24, 1995 memorandum entitled "ENVIRONMENTAL POLICY MEMO #3 Policy for Projects Completed Without Environmental Review Required by the National Environmental Policy Act (NEPA).

10. **Originating Office:** RR-IS
11. **Review Date:** Two years after publication
12. **Signature:**

_____ *signed*
Lacy E. Suiter
Executive Associate Director
Response and Recovery Directorate
13. **Distribution:** Regional Directors, Regional and
Headquarters RR Division Directors

SEE ATTACHED APPENDIX FOR POTENTIAL MEASURES
THAT ARE PRE-DETERMINED TO BE COST EFFECTIVE

HAZARD MITIGATION FUNDING UNDER SECTION 406 (STAFFORD ACT) APPENDIX (4/29/98)

The following potential mitigation measures (reference: See Paragraph 7.c. of the policy) are determined to be cost-effective if they:

- do not exceed 100% of project cost,
- are appropriate to the disaster damage,
- will prevent future similar damage,
- are directly related to the eligible damaged elements,
- do not increase risks or cause adverse effects to the property or elsewhere,
- meet standards of good professional judgment, and
- otherwise meet requirements stipulated in the policy on Hazard Mitigation Funding Under Section 406 (Stafford Act), RR Policy Number: 9526.1

This list will continue to be evaluated and will evolve over time as new information becomes available.

1. Infrastructure Systems:

A. Drainage/crossings and bridges

1. Drainage structures - When drainage structures are destroyed, replacing the structure with multiple structures or a larger structure. However, structures need to be considered with regard to a total drainage system and should not be replaced without a watershed hydrology study.
2. Low span bridges - Demolish/replace damaged low span bridges or other crossings that act to collect debris, increase flooding, and/or can be severely damaged.

3. Low-water crossings - Where traffic counts are low, replacing bridges with carefully placed low-water crossings.
4. Debris traps - Installing traps upstream of a culvert to prevent culverts from becoming clogged by vegetation.
5. Gabion baskets, riprap, sheetpiling, and geotextile fabric installation - Installation to control erosion.
6. Headwalls and wing walls - Installation to control erosion.
7. Restraining cables on bridges - Installation of cables to restrain a bridge from being washed off piers or abutments.

B. Sanitary and storm sewer systems

1. Access covers - When feasible, access covers can be elevated to the hydraulic grade line. There are a number of devices that prevent infiltration into access holes.
2. Sewer lines -
 - a. Repair, lining or encasement of damaged sections to prevent infiltration or structural collapse.
 - b. Relocating sections of damaged sewer lines to avoid damage from slip-out on roads or to avoid damage to lines crossing a stream or drainage area.
3. Pump stations -
 - a. Equipment or controls in a pump station that are subject to damage

from the 100-year flood can be elevated. Pump station buildings can be dry floodproofed.

- b. Installation of camlocks, transfer switches, and electrical panels to ease the hook-up of portable emergency generators.

C. Wastewater treatment plants

- 1. Elevation of equipment and controls that can be elevated easily.
- 2. Dry or wet floodproofing of buildings.

D. Potable water

- 1. Well systems -
 - a. Reduction of infiltration and subsequent contamination of the aquifer. Methods include casing the well or raising the elevation of the well head.
 - b. Elevation of controls, mechanical equipment, or electrical service associated with use of the well to protect them from flood damage.
- 2. Raw water intakes - Strengthening to prevent damage from erosion, scour and flood debris.
- 3. Water treatment plants -
 - a. Elevation of equipment and controls that can be elevated easily.
 - b. Dry floodproofing.

E. Electric power distribution

1. Pad-mounted transformers - elevating above the base flood elevation, or lowering them or burying them in non-flood, high-wind areas.
2. Using multiple poles to support transformers.
3. Burying lines.
4. Anchoring or otherwise protecting fuel tanks from movement in a disaster.
5. Replacing damaged poles with higher-class pole, or with a different material pole such as replacing wood poles with spun concrete.
6. Adding guy wire or other additional support to power lines.
7. Removing large diameter communication lines from power poles.
8. Providing looped distribution service or other redundancies in the electrical service to critical facilities.

F. Above ground storage tanks - Strengthening or stiffening base connections.

G. Underground pipelines - Installation of shut-off valves (based on accepted practice) so that damaged sections of pipeline can be isolated.

2. Buildings - General

A. General effects of flood damage -

1. Buildings substantially damaged under NFIP regulations - Repair, dry floodproofing, or

elevation so they are protected to meet minimum NFIP regulations. If the building is replaced, rather than repaired, no Section 406 hazard mitigation funding is appropriate.

2. Buildings not substantially damaged under NFIP regulations - If technically feasible, dry floodproofing. Electrical panels, machinery rooms, emergency generators can be elevated above the BFE or dry floodproofed. If dry floodproofing is not feasible, these buildings should be wet floodproofed.
- B. **Roofs** - Because the failure of a roof covering can lead to extensive damage to contents and operation, damaged roofing should never be replaced with the same material unless the cause of failure has been identified and corrected.
1. Low slope roofs - Replacement of the entire roof with a roof covering with a secondary membrane and a fully adhered roof covering that is not subject to progressive failure, such as a modified bitumen. Mechanically fastened insulation or membranes are not acceptable.
 2. Curbing and flashing - Single membrane and built up roofs can be susceptible to progressive failure from flashing and curbing failure. These items should be inspected and repaired or replaced. National Roofing Contractors can provide technical advice.
 3. Ballasted roof systems - Roof systems with gravel or other small ballast should be replaced with ballast of sufficient weight that it does not become airborne causing increased damages.
 4. Roof-mounted equipment should be attached to a foundation that will resist expected wind forces.

5. Hurricane clips - Hurricane clips may be recommended for use in high-wind areas.
- C. **Shutters** - In areas subject to hurricane winds, shutters are appropriate in the following areas:
1. All windows on critical facilities such as hospitals.
 2. The lower floors of buildings with windows most likely to be struck by debris.
 3. Windows of buildings with very high value contents that can be damaged by water (such as libraries and document centers).
 4. Windows of buildings subject to debris from nearby ballasted roofs, metal buildings, manufactured homes or other structures likely to fail and result in debris.
- D. **Anchoring** - Anchoring of mechanical and electrical equipment in critical facilities.
- E. **Flexible piping** - Installation of flexible piping at pipe/conduit connections to equipment to accommodate expected movement in an earthquake.
- F. **Bracing** -
1. Bracing of overhead pipes and electrical lines to meet seismic loads.
 2. Bracing interior walls and partitions that could collapse, preventing safe exit from the building.
 3. Bracing parapets, anchoring veneer or cladding, and bracing other non-structural elements that could collapse and cause

injury or block safe exit of a building during an earthquake.

- G. **Replacement of glass** - Replacement of glass (with break resistant material) in mullions to prevent breakage and fallout in the event of building movement.