Tom Smith
David Conrad
Dave Low
Mark Matulik
Wallace Wilson

HURRICANE IKE IN TEXAS & LOUISIANA

4 Performance of Critical Facilities

Critical facilities are important before, during, and after natural hazard events. They are needed to prepare for an event, house emergency workers during an event, and manage response and recovery operations after an event. Hurricane Ike had a significant impact on many of these facilities, totally destroying some of them and severely interrupting the operations of several others.

Several of the observed facilities were damaged by flooding, and many experienced wind damage, even though they were subjected to winds that were below current design wind speeds. Most critical facilities did not perform any better than commercial buildings. The poor building performance placed additional burdens on response and recovery personnel as they endeavored to provide assistance to their communities after the event.

Critical facilities are Category III and IV buildings as defined in ASCE 7-05 and the 2006 IBC (Section 1604, General Design Requirements, Table 1604.5). Category III and IV buildings include, but are not limited to, hospitals and other medical facilities, fire and police stations, primary communications facilities, EOCs, schools, shelters, and power stations and other facilities required in an emergency. In addition to the buildings listed in Categories III and IV, other buildings can play vital roles in recovery after an event, such as buildings used to provide housing for emergency workers.

Buildings that sustained damage from flooding may not have been elevated enough to reduce damage from the flood levels experienced. Most of the wind damage was to envelope systems and rooftop equipment. Except for occasional shuttering of glazed openings, most of the investigated buildings did not appear to have been designed and constructed with wind-resistant enhancements to the building envelope and rooftop equipment.

Table 4-1 lists the type and total number of critical facilities that were observed by the MAT. Sections 4.1 through 4.4 describe the performance of some of these critical facilities.

Table 4-1. Critical Facilities Observed by the MAT

Facility Type	Louisiana	Texas		Total Number of Facilities Observed by MAT
	Exposed to flood and wind*	Exposed to wind only**	Exposed to flood and wind	
Schools/shelters (Section 4.1)	2	3	4	9
Hospitals/healthcare (Section 4.2)	2	4	1	7
Police, Fire, EOC (Section 4.3)	5	7	6	18
Government Buildings (Section 4.4)	2	6	6	14

* In portions of Louisiana, critical facilities experienced relatively low wind speeds (e.g., 50 mph or less).

** Critical facilities observed in Texas experienced wind speeds of 90 mph or greater (peak gust, Exposure C, 33 feet above grade).

Special Flood-Related Provisions for Critical Facilities

The 2006 edition of the IBC requires Category III and IV buildings to be designed and constructed in accordance with ASCE 24-05, which calls for these buildings to be elevated above the NFIP minimum elevation requirement. ASCE 24-05 elevation provisions are summarized in Table 4-2 (refer also to Section 2.2).

States and communities often impose their own freeboard requirements on critical facility construction in flood hazard areas. For example, Pennsylvania requires special permits and requires at least 1.5 feet of freeboard (Commonwealth of Pennsylvania, 2001). Louisiana encourages the addition of 1 foot of freeboard for projects receiving State funds.

Under Executive Order 11988,[1] Floodplain Management, Federal agencies undertaking actions (funding, permitting, constructing, etc.) affecting critical facilities are to avoid the 0.2-percent-annual-chance (500 year) floodplain. If that is not possible, Federal agencies are to protect (elevation or floodproofing) critical facilities to the 0.2-percent-annual-chance (500-year) flood level.

Table 4-2. ASCE 24-05 Elevation Requirements for Critical Facilities

Building Component	Category III		Category IV	
	Zone A	Zone V and Coastal A Zone*	Zone A	Zone V and Coastal A Zone*
Lowest Floor Elevation**	BFE + 1 foot, or DFE, whichever is higher	BFE + 1 or 2 feet**, or DFE, whichever is higher	BFE + 2 feet, or DFE, whichever is higher	BFE + 1 or 2 feet**, or DFE, whichever is higher
Dry-Floodproofing	BFE + 1 foot, or DFE, whichever is higher	Not allowed	BFE + 2 feet, or DFE, whichever is higher	Not allowed
Flood-Damage Resistant Materials	BFE + 1 foot, or DFE, whichever is higher	BFE + 2 or 3 feet**, or DFE, whichever is higher	BFE + 2 feet, or DFE, whichever is higher	BFE + 2 or 3 feet**, or DFE, whichever is higher
Utilities and Equipment Elevation	BFE + 1 foot, or DFE, whichever is higher	BFE + 2 or 3 feet**, or DFE, whichever is higher	BFE + 2 feet, or DFE, whichever is higher	BFE + 2 or 3 feet**, or DFE, whichever is higher

BFE = base flood elevations; DFE = design flood elevation

* Coastal A Zone is the area subject to wave heights of 1.5 to 2.9 feet during the base flood; on newer FIRMs it will be the area between the LiMWA (limit of moderate wave action) and Zone V.

** Lowest floor elevation = top of lowest floor (walking surface) in Zone A, and bottom of lowest horizontal structural member supporting the lowest floor in Zone V and Coastal A Zone.

Special Wind-Related Provisions for Critical Facilities

The 2006 edition of the IBC has only two special wind-related provisions pertaining to Category III and IV buildings:

- **Importance factor:** The importance factor for these buildings is 1.15, rather than the 1.0 factor that is used for most other types of buildings. Using the 1.15 importance factor effectively increases the design loads for the MWFRS and C&C by 15 percent.
- **Windborne debris loads:** For buildings located within windborne debris regions (as defined in ASCE 7-05) of hurricane-prone regions, exterior glazing is required to be impact-resistant. For Category III and IV buildings located where the basic wind speed is 130 mph or greater, the glazing is required to resist a larger momentum missile load than the glazing on other types of buildings.

1 http://www.fema.gov/plan/ehp/ehplaws/eo11988.shtm

4.1 Schools/Shelters

In addition to their traditional role as educational facilities, schools often play an important role in providing space for sheltering, emergency response, and recovery after a hurricane. Thus, their loss of use can greatly affect a community's ability to rapidly respond to the needs of disaster victims.

4.1.1 Crenshaw Elementary and Middle School (Port Bolivar, TX)

The Crenshaw Elementary and Middle School in Port Bolivar, TX, opened in 2005 (Figures 4-1 and 4-2). The school is located approximately 2,400 feet inland of the Gulf shoreline. It is elevated on concrete columns, with the bottom of the first floor beams approximately 10 feet above grade.

The facility did not suffer flood damage because of its elevated construction, but considerable floodborne debris washed underneath the school (Figure 4-3). A debris line on a fence under the school indicated the flood depth was approximately 5.5 feet above grade; a debris line on a fence adjacent to the school was surveyed and found to be at elevation 14.8 feet NAVD (URS, 2008).

The school received some wind damage to its roof and rooftop equipment. The gym roof deck is cementitious woodfiber. Other roof deck areas are steel. According to ASCE 7-05, the basic (design) wind speed for this location is approximately 130 mph. The estimated maximum wind speed during Hurricane Ike was approximately 110 mph.[2]

General Wind Damage. The building suffered some wind damage to its roof, as a result of the gutter blowing off the roof and damage to rooftop equipment, described below.

Figure 4-1. September 19, 2008, aerial view of Crenshaw Elementary and Middle School

2 All estimated speeds in this Chapter are peak gust, Exposure C, at 33 feet taken from *Estimates of Maximum Wind Speed Produced by Hurricane Ike in Texas and Louisiana* (ARA, 2008).

Figure 4-2.
General view of Crenshaw Elementary and Middle School

Figure 4-3.
Wall of house washed underneath Crenshaw School during Ike (note shutters still attached to wall)

The gutter and most of its brackets blew off the gym roof (Figure 4-4), but the roof membrane did not progressively peel as is typically the case when a gutter is blown away. The brackets were attached with two ring-shank nails, both of which were located near the top of the bracket, as shown in the inset in Figure 4-4. Since both fasteners were near the top of the bracket, they provided little resistance to outward rotation (moment) as the wind pulled and lifted the gutter away from the building. Significant permanent outward deformation was observed at gutters at other roof areas of the building (similar to the condition shown by the inset at Figure 4-41). To resist the moment force, a screw should have been placed near the lower edge of the bracket, as shown by the red line in the inset at Figure 4-4. Screws should be used to attach brackets because they are more resistant than nails to dynamically induced pull-out forces. The gutter brackets were not attached to the gutter (see discussion in Section 4.3.2).

The MAT observed the rooftop equipment on the facility. The rooftop exhaust fans had too few fasteners, although none of the fans blew away during this storm. The exhaust fans were attached with two screws per side; for this location, FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings* (2007), recommends six screws per side. The hood blew off two units, which allowed rain to enter the building (Figure 4-5).

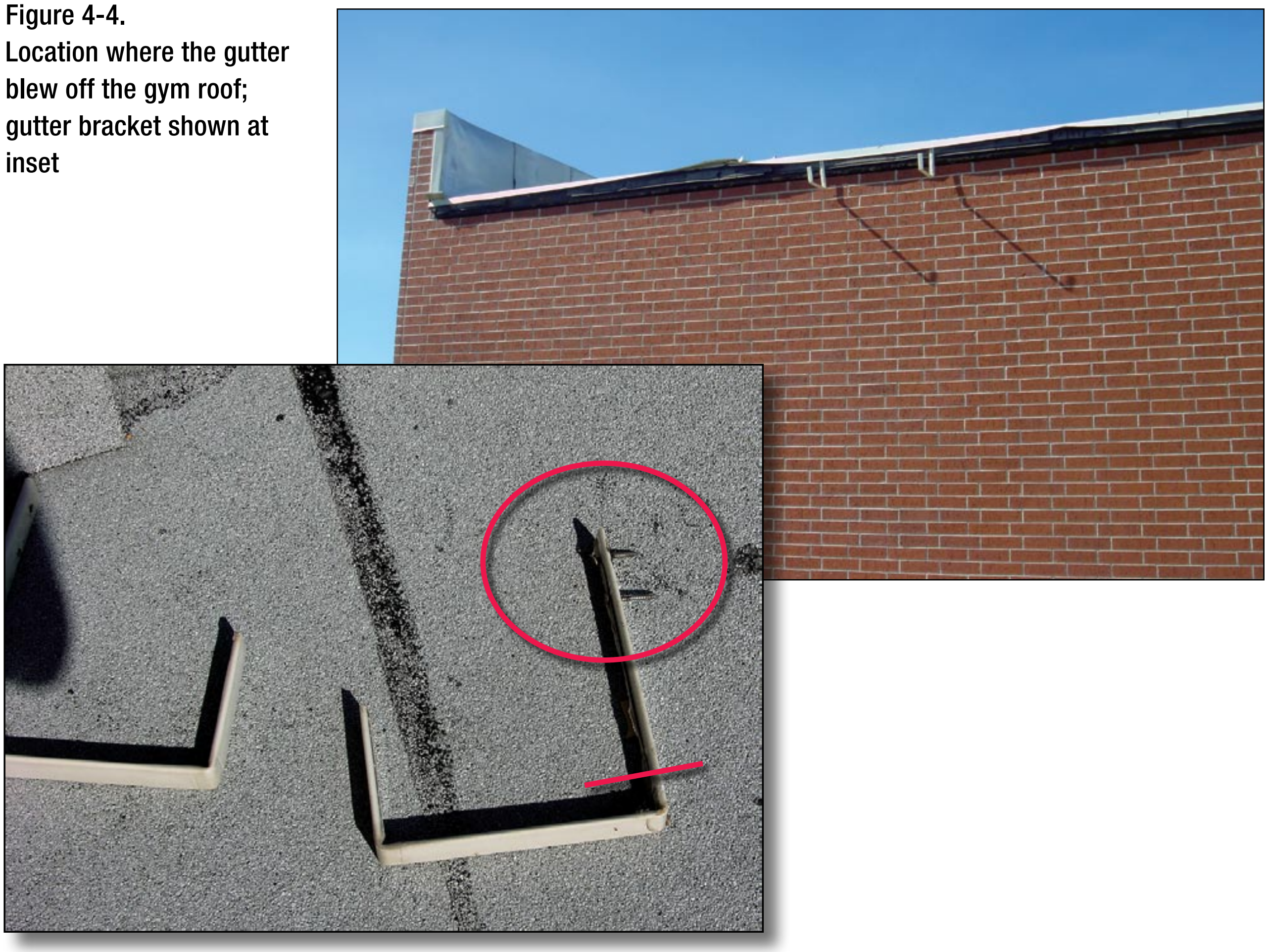


Figure 4-4.
Location where the gutter blew off the gym roof; gutter bracket shown at inset

Access panels blew off a few pieces of rooftop equipment. As shown in Figure 4-6, rain was able to directly enter the building during the storm and was still able to at the time of the MAT visit. The ductwork shown in Figure 4-6 was easy to shake back and forth by hand (illustrated by the double-headed red arrow). Had the winds been near design conditions, the ductwork may have blown away.

Functional Loss. The school was closed after Ike but served as a location for emergency operations and many community meetings during the post-Ike response and recovery period. At the time of the MAT investigation, the building was being used to house fire department personnel from other areas in Texas. These personnel provided emergency services for those involved in recovery efforts.

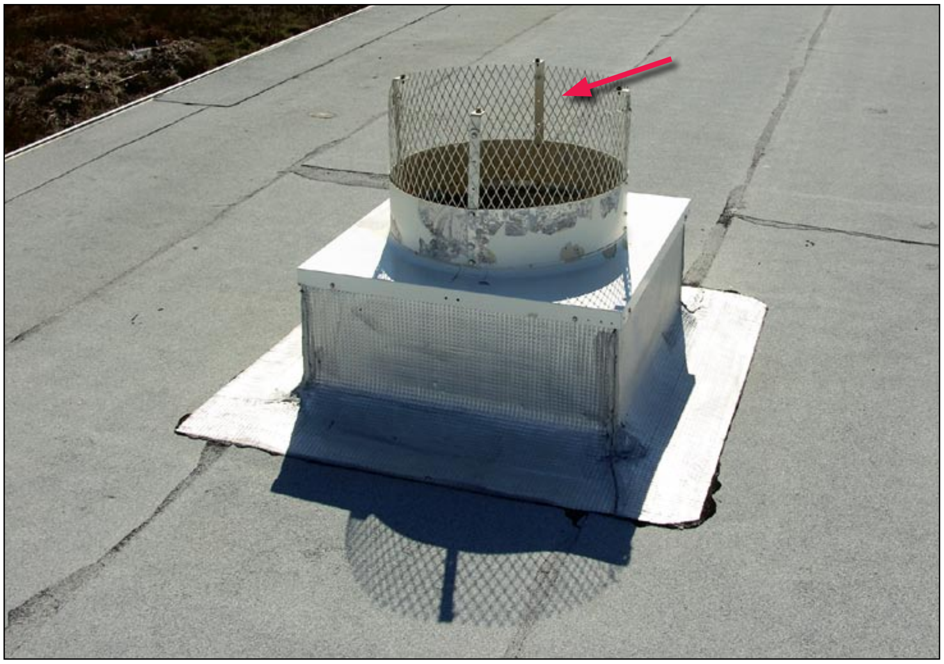


Figure 4-5.
Wind blew off the hood, allowing rain to directly enter the building

Figure 4-6.
Missing access panel allowed rain intrusion; ductwork could be easily flexed

Although some water infiltrated damaged rooftop equipment, the storm's impact on this facility's functioning as a critical facility was minimal. The school reopened in February 2009 when some students were able to return to the school.

Vulnerabilities and Other Observations. Had the winds been stronger, significant water infiltration would have been likely due to roof membrane blow-off associated with gutter failure.

4.1.2 South Cameron Parish High School (Grand Chenier, LA)

The South Cameron Parish High School located in Grand Chenier, LA, received significant damage from flooding during Hurricane Ike. The school is located on Grand Chenier Highway and is approximately 2.1 miles from the Gulf of Mexico shoreline. The facility had been previously damaged by flooding during Hurricane Rita, including extensive damage to the school and gymnasium. Although repairs and reconstruction were still in progress when Ike hit, facility personnel stated that the damages observed by the MAT were caused by Ike. However, no mitigation for flooding had been performed and the facility was not elevated.

The school complex is comprised of two flood zones. The southern portion is located in flood hazard Zone AE (BFE = 12 feet NGVD); the northern portion is located in Zone VE (BFE = 12 feet NVGD). In March 2006, FEMA published ABFE Maps showing the southern portion as Zone AE (ABFE = 13 feet NGVD) and the northern portion as Zone VE (ABFE = 13 feet NGVD). The March 2008 Preliminary DFIRM, released by FEMA after completion of the post-Katrina and Rita flood hazard studies, shows the entire site will be remapped as Zone VE (Coastal High Hazard Areas) with a BFE of 15 feet. The gymnasium and track and the modular units are all in the northern portion.

General Flood Damage. The interiors of all the buildings were flooded. A debris line on the fence at the front of the school indicated flood depths reached approximately 5 feet above grade. The wooden gymnasium floor was damaged, and metal walls seaward of the gymnasium were breached by flooding. Approximately 15 modular classrooms were inundated by storm surge floodwaters (Figures 4-7 and 4-8). At the time the MAT inspected the school, students had been relocated to other schools in the Parish.

General Wind Damage. The MAT did not access the roof at this facility, so a determination of wind damage could not be made.

Figure 4-7.
Damage to South Cameron Parish School modular units

Figure 4-8.
High school gymnasium at South Cameron Parish School

Functional Loss. The South Cameron Parish School suffered a complete loss of function. The school experienced storm surge inundation. The school was not operational at the time of the MAT's visit.

4.1.3 Johnson's Bayou School (Cameron, LA)

The Johnson's Bayou School, grades K–12, suffered significant flood damage during Hurricane Ike. Like South Cameron High School, this critical facility is located on Gulf Beach Highway and is approximately 1.3 miles from the Gulf of Mexico shoreline.

General Flood Damage. The facility was flooded by storm surge with depths reaching 5 to 6 feet. Some masonry walls were flood damaged, as were interior walls, furnishings, and electrical systems (Figures 4-9 through 4-12).

Figure 4-9.
Johnson's Bayou School interior building damage

Figure 4-10.
Johnson's Bayou School – damage to wall on front side of facility (soffit of driveway canopy was also damaged)

Figure 4-11.
Johnson's Bayou School gymnasium interior damage

Figure 4-12.
Johnson's Bayou School CMU wall collapse. (Note: HVAC units that had previously been damaged were relocated to an elevated platform under the FEMA Public Assistance Program.)

General Wind Damage. Significant wind damage occurred to the roof system for the school gymnasium (Figure 4-13). Figure 4-13 also shows the significant damage to the walkway canopy. The Johnson's Bayou School experienced damage to roof coverings and rooftop equipment. The breached building envelopes allowed widespread rainwater damage and storm surge floodwater intrusion to the interior.

Functional Loss. The combination of storm surge flooding to depths reaching 5 to 6 feet with widespread rainwater damage from the breached building envelope resulted in the loss of school operations. At the time of the MAT inspection, the school was not operational.

Figure 4-13.
Johnson's Bayou School gymnasium. The red ovals indicate damage to canopy and roof.

4.2 Hospitals/Health Centers

When a hurricane strikes, hospitals and health centers, EOCs, and shelters are the most important buildings in a community. In addition to providing continuity of care for patients in hospitals before a storm, hospitals also receive large numbers of people seeking medical treatment after strong hurricanes. Blunt-force trauma injuries caused by windborne debris, falling trees, collapsed ceilings, partial building collapse, and flood-related injuries occur during hurricanes; however, most hurricane-related injuries typically occur in the days afterward. These injuries are typically due to chainsaw accidents, stepping on nails, lacerations incurred while removing debris, vehicle accidents at intersections that no longer have functional traffic lights, people falling off roofs as they attempt to make emergency repairs, and carbon monoxide poisoning or electrical shock from improper use of emergency generators. Therefore, at a time when many hospitals in an area may be functionally impaired or no longer capable of providing service due to building damage, hospital staffs are faced with a higher than normal number of people seeking treatment. Before arrival of a hurricane, hospitals also often admit an influx of women in their third trimester of pregnancy who wish to be at the hospital in case they go into labor during the storm or shortly thereafter, when getting to the hospital could be hazardous or impossible.

4.2.1 San Jacinto Methodist Hospital (Baytown, TX)

The San Jacinto Methodist Hospital in Baytown, TX, was constructed around 1974, and a medical office building was added in 1995. The hospital sustained some wind and water leakage damage during Hurricane Ike. According to ASCE 7-05, the basic wind speed for this location is approximately 113 mph. The estimated maximum wind speed during Hurricane Ike was approximately 105 mph. Figure 4-14 is a general view of the building. The facility was evacuated on September 11, 2008, because of a mandatory evacuation order. The facility was reoccupied on September 18, 2008.

In the aftermath of Tropical Storm Allison (2001), mitigation work was performed on the facility in 2003–2004 using HMGP grant funds. The work included reroofing the medical office building and a portion of the hospital. The roof that was replaced at the office building was a modified bitumen membrane. The roof that was replaced at the hospital was an aggregate-ballasted, single-ply membrane. Mineral surface modified bitumen membranes over rigid insulation were used for the mitigation work. Both of these roof areas have steel roof decks. According to project records, the new roofs had a Factory Mutual Global 1-90 rating (i.e., the roof system was sufficient for field of roof design pressures up to 45 psf). (Note: The field design uplift load is approximately 30 psf, hence the specified system had sufficient uplift resistance to meet the ASCE 7-02 load.)

General Wind Damage. The facility experienced some water leakage at the three-story wing shown in Figure 4-14. Some of this leakage was likely due to damaged rooftop equipment. The MAT observation of the roof on this portion of the facility indicated that at least one fan cowling was blown away. No special attachment was provided for the fan cowlings (such as that shown in FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings* [2007]). However, special attachment was provided for the condenser shown in Figure 4-15. Strapping condensers is a practice that is recommended in FEMA 543 and 577. Unless strapped, condensers frequently topple over.

Figure 4-14. General view of San Jacinto Methodist Hospital

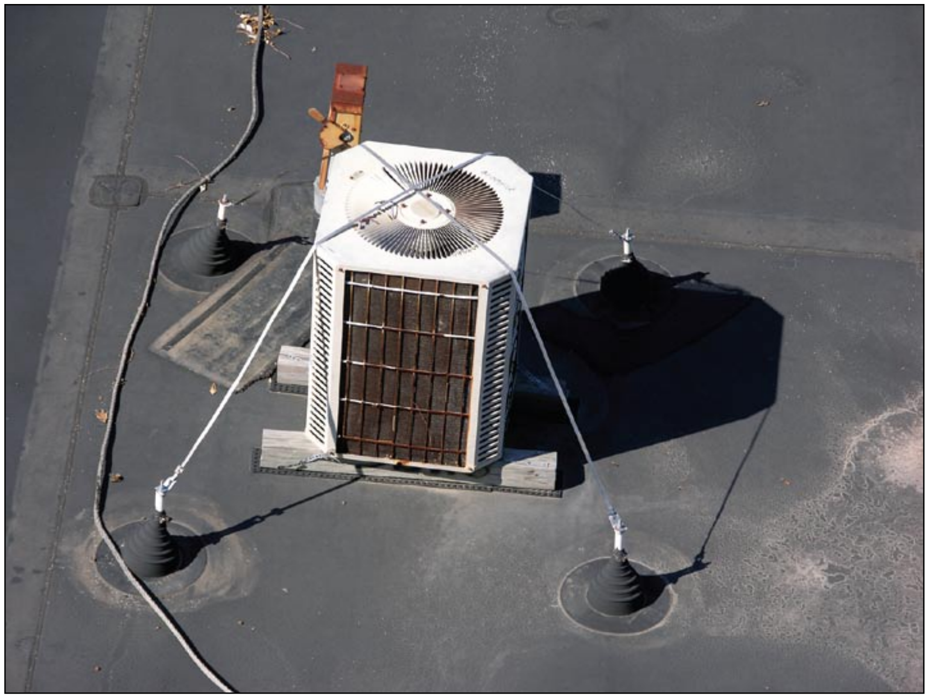


Figure 4-15. Condenser with tie-down cables

In a few areas, the lightning protection system (LPS) conductors became detached from the roof membrane (Figure 4-16). Loose conductors can puncture and tear roof membranes, and they no longer provide the intended protection. FEMA 543 and 577 provide guidance for attachment of LPSs to resist wind.

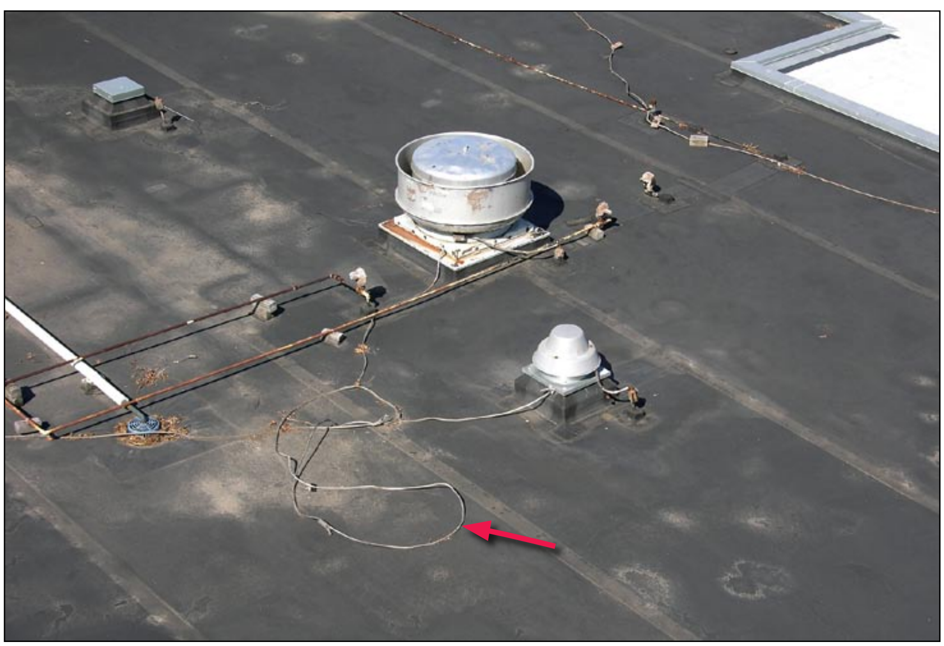


Figure 4-16. Detached LPS conductor

The satellite dish shown in Figure 4-17 was held down only with CMU. This attachment technique was adequate for the winds experienced at this site, but dishes attached by this method have failed in other hurricanes, as shown in the inset at Figure 4-17. The dish shown in the inset was blown completely off the roof; only the CMU remained (FEMA 488).

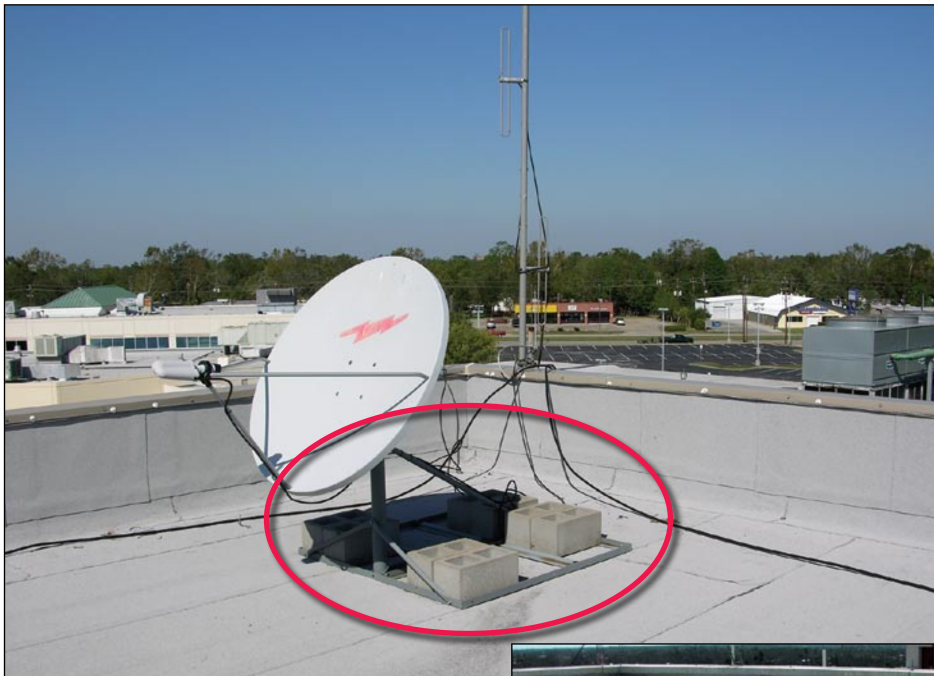


Figure 4-17.
This satellite dish was held down with CMU only; inset shows all that remains from a similarly mounted dish after a strong hurricane

Functional Loss. Water infiltration resulted in some damage to interior finishes, and the leakage disrupted use of some rooms. However, the disruption did not adversely affect delivery of services. It cost approximately $60,000 to repair the damages. For approximately 3 weeks after the facility was reoccupied, the facility's emergency generator provided power during intermittent municipal power outages. There was no interruption of water or sewer service.

Vulnerabilities and Other Observations. At the two mitigated roofs and the other non-mitigated roofs, had the winds been stronger, extensive damage to rooftop equipment and significant water infiltration would have been likely due to equipment blow-off and roof membrane punctures associated with rooftop equipment failures and detached lightning protection equipment. Also, had the winds been stronger, depending upon wind direction, glazing damage would have been likely from windborne debris comprised of tree branches near the facility and/or aggregate from a built-up roof (BUR) on a building near the hospital campus.

> **Glazing protection:** Since this building is not in a windborne debris region, glazing protection is not required. However, debris-induced glazing damage has been documented to have occurred during wind speeds slightly in excess of 100 mph (peak gust at 33 feet, Exposure C). Accordingly, in hurricane-prone regions, FEMA 543 and 577 recommend glazing protection when the basic wind speed is 100 mph or greater. Providing glazing protection at this facility as part of the mitigation work would have been prudent.

Additionally, had the winds been stronger, portions of the exterior insulation finish system (EIFS) wall covering may have blown away or been penetrated by windborne debris. EIFS wall covering failures are commonplace during hurricanes. This wall covering system can offer good high-wind performance, but great attention to design and application is needed to do so. FEMA 577 does not recommend this type of wall covering on hospitals in hurricane-prone regions.

The MAT also observed a lack of adequate pre-storm preparations. As part of the pre-storm preparations, hospital roof areas should be checked. As part of this check, roof drains, scuppers, and gutters should be cleaned of debris so that they are capable of draining the roof during the hurricane (some of which produce a tremendous quantity of rain). Figure 4-18 is a view of one of the mitigated roofs. Clearly this roof drain area had not been cleared of debris for quite some time.

Performance of HMGP Mitigation Work. When the facility undertook mitigation work, conducting a comprehensive vulnerability assessment and then mitigating the significant vulnerabilities, or alternatively, recognizing the residual risk that remains, would have been prudent (see FEMA 577).

Replacing the aggregate-surfaced roof was appropriate, because aggregate can be blown off and damage glazing or injure people that come to the hospital during a hurricane. However, the mitigation work was not as robust as it should have been. Although the roof membrane choice was appropriate (and one that is recommended in FEMA 577) and had adequate uplift resistance, the new roofs did not incorporate secondary membranes to avoid water leakage in the event the membranes were punctured by windborne debris. In addition, as previously described, much of the rooftop equipment was not adequately anchored, including fan cowlings, fans, some heating, ventillation, and air-conditioning (HVAC) units, condensate drain lines, and the LPS.

> **Inadequate fan anchorage:** One of the 2-foot by 2-foot exhaust fans was attached with two screws per side, but for this location, FEMA 577 recommends four screws per side. One of the 3-foot by 3-foot fans had three screws per side, but for this size of fan, FEMA 577 recommends five screws per side.

In addition to the inadequacies of the mitigation work that was performed, the mitigation work only addressed a portion of the hospital. Other roofs and rooftop equipment had (and still have) significant wind vulnerabilities. Before implementing a mitigation project, a comprehensive vulnerability assessment should be conducted to identify significant vulnerabilities. If funds are not available to correct all identified deficiencies, the work should be systematically prioritized so that the items of greatest need are corrected first. Following this process also allows the building owner to be aware of residual risks that remain when mitigation projects don't address all significant vulnerabilities at a facility. For further information about mitigating existing facilities, see FEMA 577, Section 4.4.

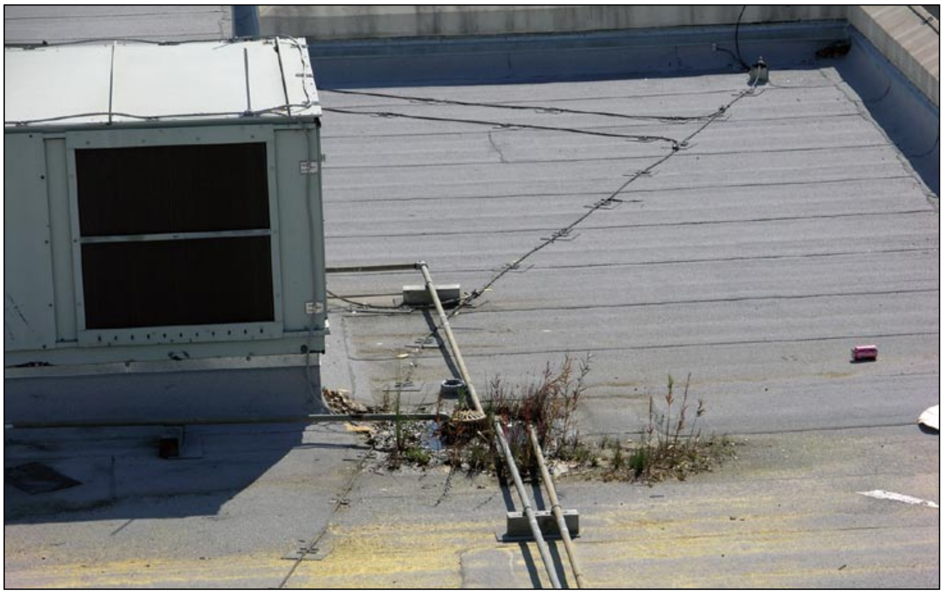


Figure 4-18.
View of one of the mitigated roofs. Note the vegetation growth in the vicinity of the roof drain, indicating a lack of maintenance.

4.2.2 Winnie Community Hospital (Winnie, TX)

The Winnie Community Hospital, constructed in the late 1960s, received wind damage during Hurricane Ike. According to ASCE 7-05, the basic wind speed for this location is approximately 119 mph. The estimated maximum wind speed during Hurricane Ike was approximately 108 mph. Figure 4-19 shows a general view of the building. Because of flooding concerns, Chambers County issued a mandatory evacuation order for this hospital and other healthcare facilities around noon on September 11 (approximately 1 ½ days before Hurricane Ike made landfall). The evacuation was accomplished within 2 hours, but was hampered by a lack of ambulances, which were also needed to evacuate hospitals in Beaumont and Galveston. The hospital reopened to offer limited urgent care 3 days after Ike's landfall.

General Wind Damage. An entry canopy blew away (Figure 4-19). A few windows were broken (likely by windborne debris) and wind-driven water entered at several of the windows. At one area, a portion of the edge flashing deformed outward and the nailer lifted, which caused a few of the bricks at the top course to fall. Had the winds been somewhat stronger, the edge flashing would likely have lifted and caused a portion of the roof membrane to blow away.

Figure 4-19.
A Winnie Community Hospital entry canopy (red oval) blew away

Numerous pieces of HVAC equipment were on the roof. Many condensers toppled, but apparently none punctured the single-ply roof membrane. However, water entered the building where some rooftop ductwork blew away (Figure 4-20). Access panels were blown away at a piece of equipment and the communications tower collapsed (both shown in Figure 4-21).

Figure 4-20.
Water entered the building where ductwork blew away

Figure 4-21.
Collapsed communications tower and blown-away access panels (red circle)

Functional Loss. At the time the hospital was reoccupied, municipal power was out, so power was provided by the hospital's emergency generator. After 2 days, the generator's governor failed, leaving the hospital without power and unable to provide urgent care services. The generator failure caused a power surge, which damaged several pieces of hospital equipment (including refrigerators). This, in turn, resulted in the loss of vaccines, medications, lab reagents, and food. Equipment had to be retested to ensure that it was safe for use.

The facility had to be vacated for 4 days until a backup generator was delivered and connected. FEMA supplied the portable generator (inset at Figure 4-22) and the facility was able to reopen. Altogether, the facility ran on emergency power for about 2 weeks. During that time, the facility was periodically refueled. There was no interruption of water or sewer service.

Vulnerabilities and Other Observations. Had the winds been stronger, extensive damage to rooftop equipment and significant water infiltration would have been likely due to roof membrane blow-off and punctures associated with edge flashing and rooftop equipment failures.

The generator was outdoors, with a roof and walls that were open at the top and bottom for air circulation (Figure 4-22). Although the generator was not damaged by wind or windborne debris in this event, the enclosure does not provide sufficient protection for the generator.

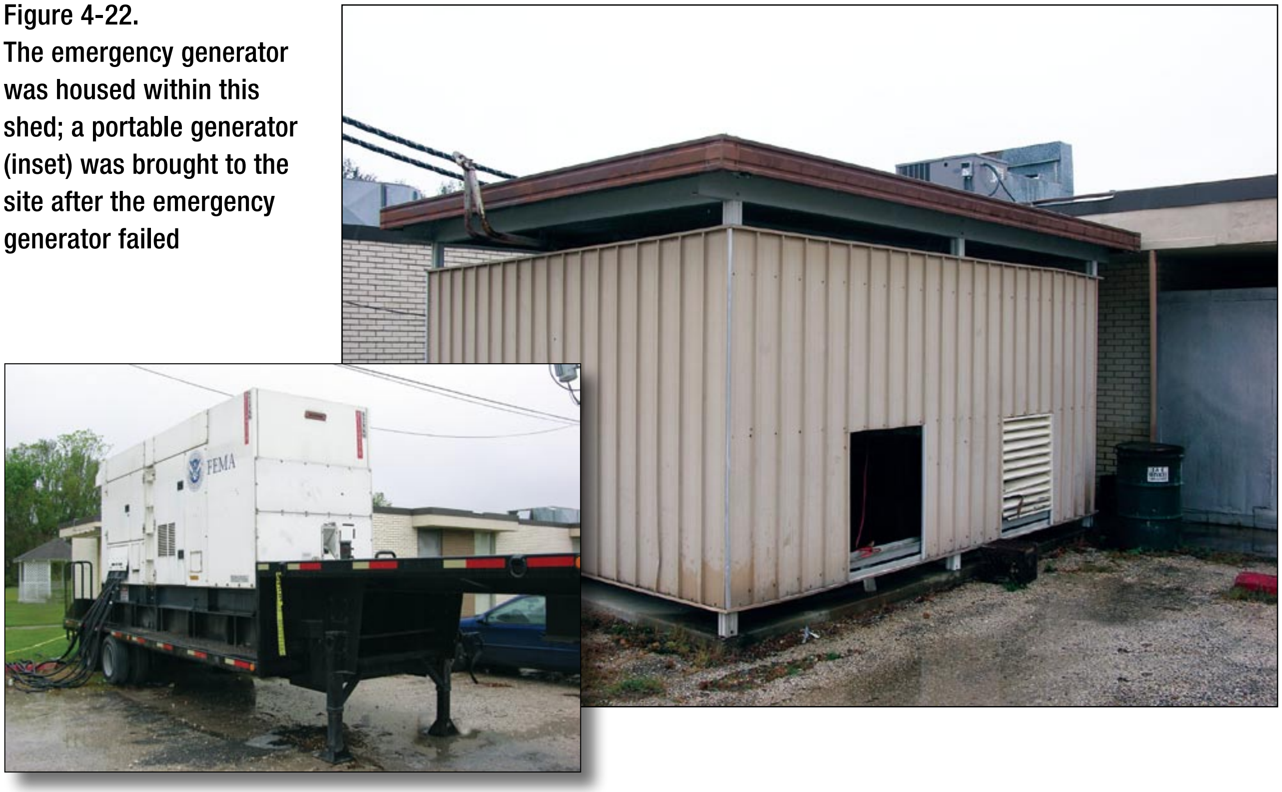


Figure 4-22.
The emergency generator was housed within this shed; a portable generator (inset) was brought to the site after the emergency generator failed

4.2.3 University of Texas Medical Branch (Galveston, TX)

The University of Texas Medical Branch (UTMB) in Galveston, TX, received significant flood damage and some wind damage. This teaching and research hospital complex has about 90 buildings on the main campus (a few of which are a few blocks from the fringes of the main campus). UTMB inhabitants were evacuated prior to the storm, including 260 patients, students, and staff.

> As of January 2009, FEMA had obligated $73 million to repair the damaged facilities, replace equipment, and recover documents (www.fema.gov:80/news/newsrelease.fema?id=47217).
>
> In addition to the devastation at UTMB and disruption of services, the temporary loss of jobs at the UTMB campus had a significant economic impact on the Galveston area.

Approximately two-thirds of the facility is located in flood hazard Zone A (BFE = 11 feet NGVD), with the remaining buildings located in shaded Zone X (area between the 1-percent-annual-chance flood and the 0.2-percent-annual-chance flood) and Zone X (outside the 0.2-percent-annual-chance flood area). A review of the UTMB Emergency Operations Plan map[3] shows that first floor elevations of campus buildings vary from approximately 7 to 16 feet NGVD.

According to ASCE 7-05, the basic wind speed for this location is approximately 132 mph. The estimated maximum wind speed during Hurricane Ike was approximately 108 mph.

3 http://www.utmb.edu/emergency%5Fplan/pdfs/Emergency%20Plan%20-%20rev%2013.pdf

General Flood Damage. The Ike flood elevation in the vicinity of UTMB fluctuated above and below approximately 12.5 feet NGVD. A review of the Emergency Plan Map showed that approximately one-third of the campus buildings have first floor elevations greater than 12.5 feet NGVD, and virtually all buildings have subgrade areas for utilities and equipment. UTMB staff reported to the MAT that approximately 90 percent of the buildings were flooded during Hurricane Ike, and approximately 90 percent of the building damage was due to flooding.

Figures 4-23 through 4-26 show some of the water marks remaining and flood clean-up underway during the MAT visit on October 20, 2008. Flooding damaged utility lines and equipment, generators, HVAC equipment, pumps and controls, gas piping for hospital and operating rooms, the morgue, offices, laboratories, and classrooms.

Figure 4-23.
High water mark (dashed blue line) shown from the outside of UTMB Building 1. The mark was measured by the MAT and found to be approximately 69 inches above the floor of the basement area inside the building.

Figure 4-24.
Clean-up underway inside the basement of UTMB Building 1. All the laboratory equipment, office and classroom contents, and interior finishes had to be decontaminated and removed for disposal.

Figure 4-25.
The Ike flood level in UTMB Building 56 pump room was approximately 30 inches above the floor, and controls and equipment were damaged

Figure 4-26. Replaced lower interior wall sections leading to UTMB Building 90

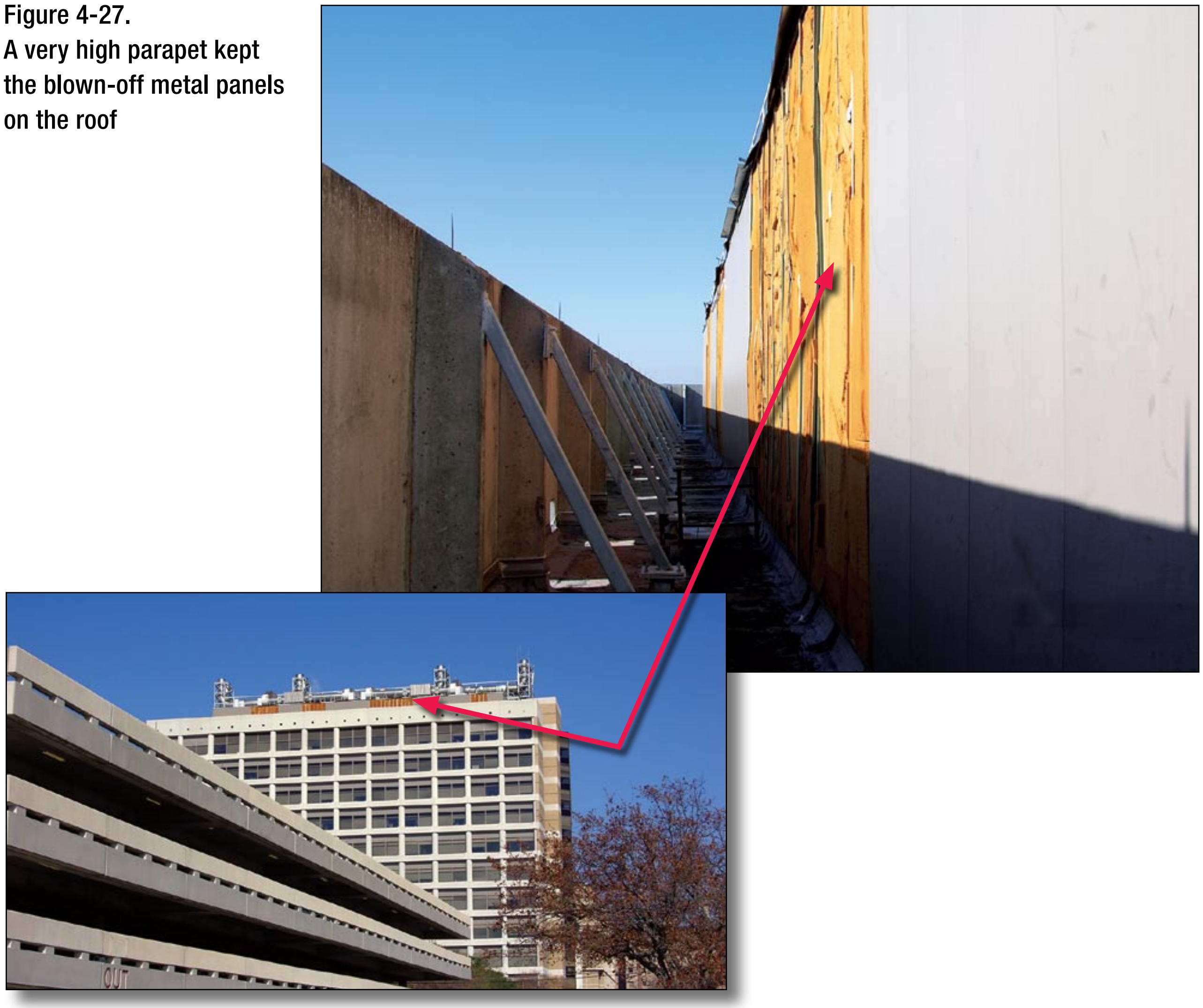
General Wind Damage. A preliminary condition assessment was conducted of the campus by a consultant (AESTIMO, INC., Facilities Engineering Consultants, Houston, TX) on September 22 and 23, 2008, to assess damage to roofs, rooftop equipment, windows, and exterior walls. To expedite the assessment process, roofs on several buildings were observed from higher rooftops. Hence, some roof membrane punctures or other types of damage may not have been identified. The report, titled *Preliminary Building Envelope Condition Assessment Report,* dated September 25, 2008, provided a list of priority buildings with 75 high priority repair items, summarized below:

- 16 buildings with broken windows (including skylights)
- 12 buildings with punctured roof membranes
- 2 buildings with roof membranes that blew off
- 5 buildings with roof system adhesion problems (i.e., the membrane did not blow off, but the insulation debonded from the deck or the membrane debonded from the insulation)
- 16 buildings with fan cowlings that blew off
- 29 buildings with fans or other rooftop equipment damage that resulted in water infiltration
- 15 buildings with flashing problems, including flashings at rooftop equipment (leakage occurred at a few flexible connectors between ducts and fans)
- 7 buildings with LPSs that detached from the roof

During their visit to UTMB in Galveston, the MAT observed the wind-induced damage described on the following page.

At the building shown in the inset of Figure 4-27, several penthouse wall panels were damaged. The panels consisted of inner and outer metal skins, with a foam insulation core. As shown in Figure 4-27, several of the outer skins blew away. The panels appeared to have been job-site fabricated, rather than having been produced as composite panels in a factory. The presence of the very high parapet prevented the metal skins from being blown from the roof and potentially damaging other parts of the facility as windborne debris. At another building, blown off EIFS was observed at a wall and at the soffits of an enclosed elevated walkway between two buildings.

Figure 4-27.
A very high parapet kept the blown-off metal panels on the roof



At the time Hurricane Alicia struck this campus in 1983, many of the buildings had aggregate-surfaced BURs and several windows on the campus were broken by wind-blown aggregate. Since Alicia, when buildings have been reroofed, they were not replaced with aggregate surfacing. However, at the time of Hurricane Ike, some aggregate-surfaced BURs still existed, such as that shown in Figure 4-28. One of the penthouse roofs was blown off during the storm. At the time of the MAT observation, that roof had been replaced by the white membrane shown by the red arrow.

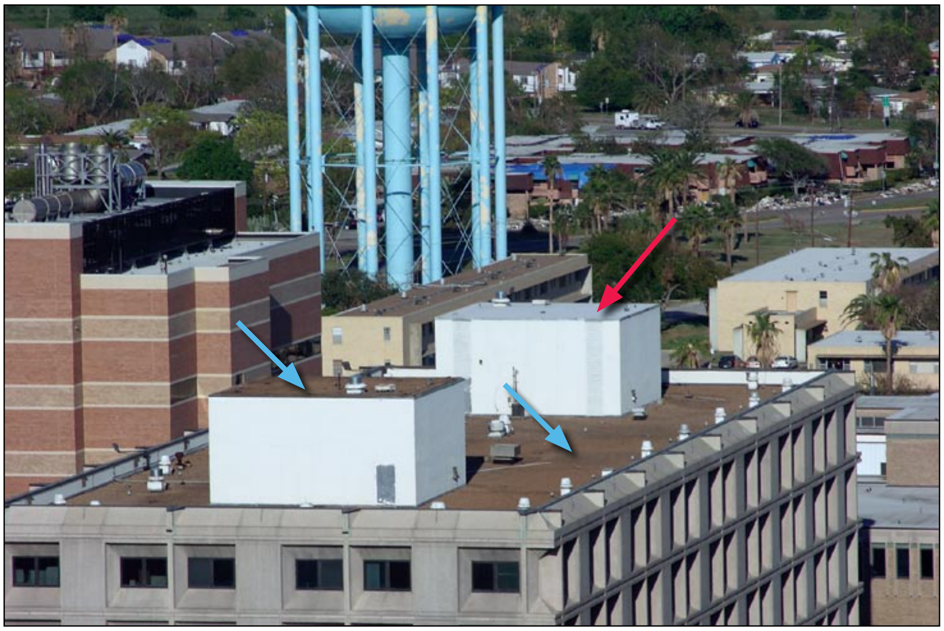


Figure 4-28.
The roofs shown by the blue arrows were aggregate-surfaced BURs at the time Ike struck; the roof shown by the red arrow is a new roof replacing one that blew off

One of the reroofing designs used by the hospital consists of a modified bitumen membrane over gypsum roof board, over rigid insulation, over a modified bitumen sheet, over a concrete deck. This is one of the roof assembly types recommended in FEMA 577. In FEMA 577, the purpose of the secondary membrane (i.e., the one over the deck) is to prevent water from leaking into the building in the event a roof membrane is punctured or blown off. However, the roof designers for the UTMB reroofing work specified the secondary membrane to avoid leakage during the tear-off and replacement of the old roof and thus, the secondary membrane fulfilled two roles.

Other rooftop equipment damage included a large stack that was blown over, even though it was guyed (Figure 4-29), and damage to two relief air hoods (Figure 4-30). One of these hoods blew off the curb.

Nine of the 32 windows in the building shown in Figure 4-31 were broken. They were likely damaged by windborne debris.

Functional Loss. The entire UTMB facility was closed following Ike. To provide emergency medical services, three portable operating rooms and a portable pharmacy were set up on the campus. Floors above the first floors of some buildings were re-opened starting in October 2008 for limited office, classroom, and laboratory use. Lower floors remain closed until clean-up and repairs are completed—some lower floors will not be reoccupied until fall 2009.

Had there been no flood damage, the wind-related damage would still have had some impact on facility functions. At one building, an emergency generator was damaged by water leakage when the roof membrane blew off.

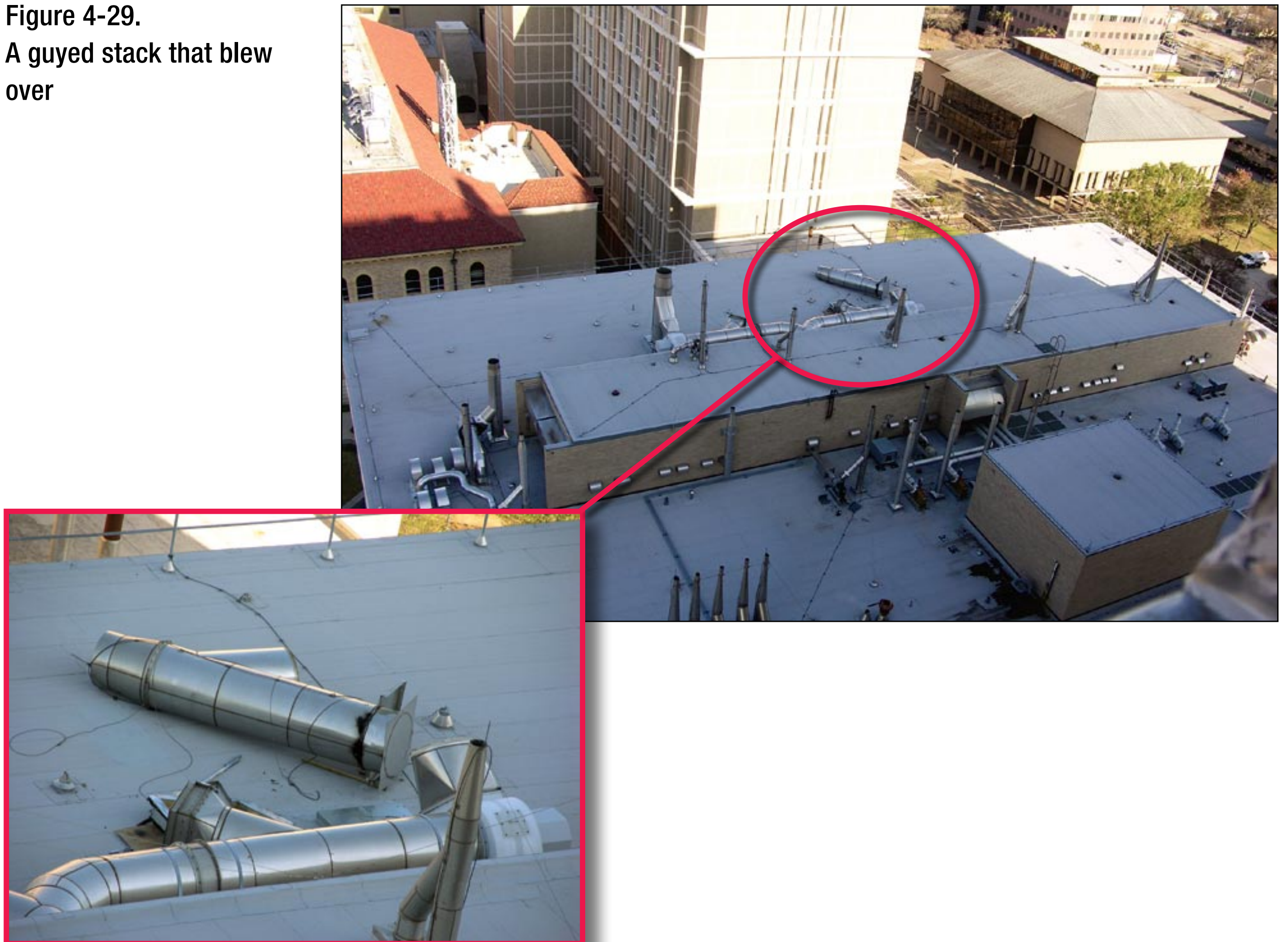


Figure 4-29.
A guyed stack that blew over

Figure 4-30.
A relief air hood blew off the curb allowing rainwater to enter the building

Figure 4-31.
Nine broken windows are shown in the red oval; the brown openings above the oval are louvers

Vulnerabilities and Other Observations. With the majority of UTMB buildings vulnerable to flooding at levels below the base flood, consideration should be given to moving critical functions and equipment to the second floor or above, or floodproofing those spaces where functions and equipment cannot be elevated. Use of flood-damage-resistant materials for repairs below the second floors of buildings would reduce future flood damages.

Hurricane Ike's maximum wind speed of 108 mph at this site was well below the current design wind speed of 132 mph. Had Ike's winds been in the vicinity of current design conditions, the wind-induced damages at this facility would likely have been significantly greater.

Considering the age of the facility and the damage experienced during Hurricane Ike and previous hurricanes, a comprehensive flood and wind vulnerability assessment should be conducted by a qualified team of professionals. Upon completion of the assessment, the vulnerabilities should be prioritized and a plan developed and implemented to mitigate the vulnerabilities in order to minimize future disruptions of healthcare delivery and expenditures for repairs.

4.2.4 South Cameron Parish Hospital (Cameron, LA)

The South Cameron Parish Hospital is located on West Creole Highway and is approximately 2.8 miles from the Gulf of Mexico shoreline. Hurricane Rita (September 2005) destroyed the original hospital on the site, and a new hospital facility was built on the same site. The new facility opened in November 2007, 10 months before Hurricane Ike struck.

When Hurricane Rita struck, the Effective FIRM for the area (1992) showed the hospital site as located in flood Zone AE, with a BFE of 9 feet NGVD. In November 2005 FEMA issued flood recovery guidance for Cameron Parish, which recommended 1 foot of freeboard above the Effective BFE. In March 2006, FEMA published ABFE Maps showing the site as Zone AE, with an

ABFE of 10 feet NGVD. The new facility was constructed with the top of the lowest floor elevation at 10 feet NGVD (Figure 4-32). Reports indicate that Hurricane Ike storm surge was just a few inches below that elevation at the site (Figure 4-33). The March 2008 Preliminary DFIRM, released by FEMA after completion of the post-Katrina and Rita flood hazard studies, shows the site will be remapped as Zone VE (Coastal High Hazard Areas) with a BFE of 15 feet. If rebuilt using the DFIRM and in accordance with ASCE 24-05, the top of the first floor of the facility would be at or above 17 feet NGVD. It should be noted that the flood hazard zone and BFE at the site were Zone V and 13 feet NGVD between 1984 and 1991, close to the 2008 preliminary DFIRM zone and BFE.

The facility also received wind damage during Hurricane Ike. According to ASCE 7-05, the basic wind speed for this location is approximately 120 mph. The estimated maximum wind speed during Hurricane Ike was approximately 70 mph.

General Flood Damage. The hospital property was flooded during Ike—surge did not enter the building but did damage conduits and piping suspended below the floor. The hospital was not fully functional until repairs were made and additional emergency power generation capacity was obtained.

The reconstructed hospital did not comply with the ASCE 24-05 elevation requirements (see Table 4-2). While the floor height satisfied the requirements in effect at the time of construction, the utilities did not—either the utilities should have been located above the lowest floor level or the entire facility should have been elevated higher to allow the suspended pipes and conduits to meet the ASCE 24-05 utility elevation requirement. The latter approach is clearly preferable since it would raise the floor level another 3 feet and provide an added factor of safety against flooding.

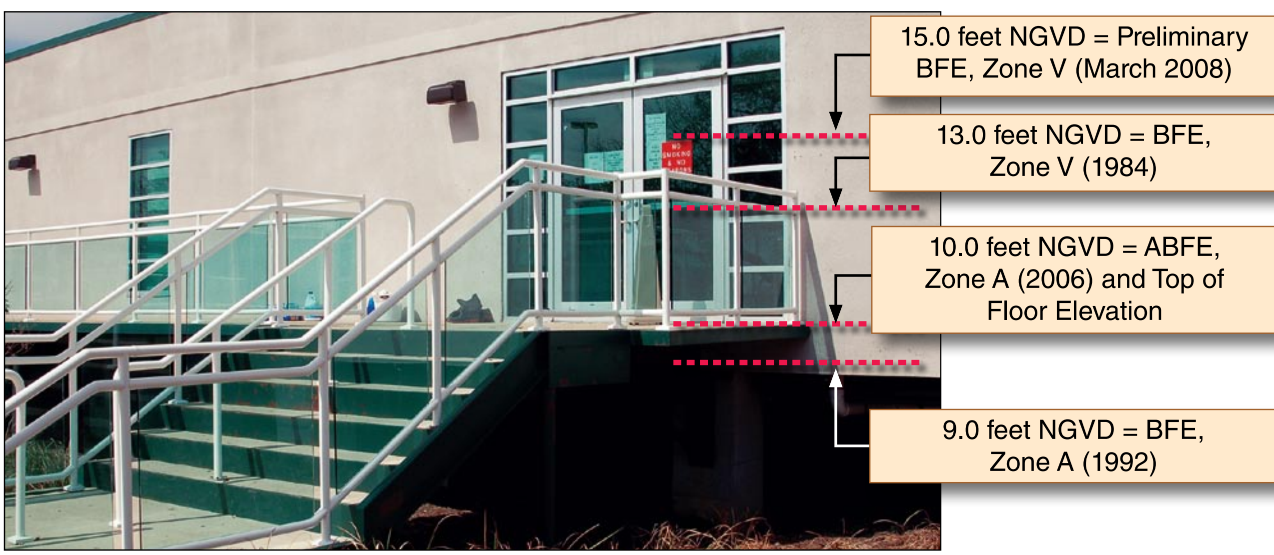


Figure 4-32.
Hurricane Ike crested approximately 6 inches below the floor of the South Cameron Parish Hospital. BFEs and flood hazard zones are shown for the site for the period 1984 to 2008 (Note: the building code may require freeboard above the BFEs shown).

Figure 4-33.
Conduits and pipes beneath South Cameron Parish Hospital. Vegetation was noted between the floor system and the steel plate of the foundation. A connection between the plate and the floor system was not visible.

General Wind Damage. The main building roof system performed well during the event. However, some damage was sustained by the canopy over the hospital's emergency room entrance driveway (Figure 4-34). The MAT also observed that some rooftop mechanical equipment was not properly fastened (Figure 4-35).

Figure 4-34.
Damage to canopy over emergency room entrance driveway

Figure 4-35.
Lack of proper fastening of rooftop equipment—a MAT member was able to easily lift this condenser unit off the curb. All equipment should be fastened to resist uplift and blow-off.

Functional Loss. The new hospital building was not flooded by Ike, and its emergency power generator was reportedly running when staff returned to the hospital several days after the storm. However, the building was not fully functional until repairs were made to conduits and piping suspended below the floor and until additional power generation capacity was brought in. The hospital's emergency generator was reported to be an in-kind replacement for the unit lost during Rita and was not sufficient to fully power the new facility. Following repairs after Ike, the Cameron Parish government temporarily relocated several of their departments into this facility.

Appropriate Mitigation in New Hospital Construction. A hospital previously located at this site was destroyed by Hurricane Rita in 2005 and replaced with the current facility. The original South Cameron Memorial Hospital was constructed using Federal funds obtained from the Hill-Burton Act, and opened in 1963, 6 years after Hurricane Audrey (1957).

The original hospital facility had a floor elevation of approximately 8 feet NGVD, and the current replacement facility has a floor elevation of 10 feet NGVD (i.e., at the ABFE established following Rita). The estimated Rita storm surge elevation at the site was 12 to 13 feet NGVD. This hospital site was also subjected to significant flooding during Hurricane Audrey (1957), whose storm surge exceeded both the original hospital floor elevation and the new hospital floor elevation.

It is not clear what, if any, influence the flood history at this site had in decisions about either choosing a site or floor elevation for the new facility. While it is true that Ike's floodwaters did not rise above the floor of the current facility, utilities below the floor were damaged by flooding and contributed to a loss of function after Ike.

The decision to rebuild a hospital at this site with the top of its floor at the ABFE of 10 feet NGVD should be re-examined. While ABFEs may represent the latest available flood level information during a reconstruction period, critical facilities should be elevated above ABFEs—especially when flood levels during a recent event have reached above the ABFE or when historical BFEs have been mapped above the ABFE, as was the case at this site.

The MAT also observed wind damage to the new facility. Specific attention to details that result in better performance in high winds should also be included in design and construction of hospitals using guidance available in FEMA 577.

Funding decisions (by communities and State, Federal, and private entities) for reconstruction of critical facilities should reward adoption of best practices by the community/owner, and discourage reconstruction to minimum wind and flood requirements.

4.2.5 Hackberry Rural Medical Clinic (Hackberry, LA)

The Hackberry Rural Medical Clinic at Hackberry, LA, is located approximately 15 miles north of the Gulf of Mexico shoreline (Figure 4-36). The medical facility received significant flooding damage from Hurricane Ike. This facility was also flooded during Hurricane Rita and the damages had been repaired.

General Flood Damage. During Hurricane Ike, the facility was inundated with 3 to 4 feet of floodwater. Interior walls were damaged, as well as contents. Water-damaged gypsum board had been removed to a height of 5 feet above the floor (Figure 4-37) and was being replaced at the time of the MAT visit.

Figure 4-36. Hackberry Rural Medical Clinic

Figure 4-37.
Hackberry Rural Medical Clinic interior repairs in progress

Functional Loss. Repairs were still underway at the Hackberry Medical Clinic and the facility remained closed at the time of the MAT visit, one month after Ike.

4.2.6 Oceanview Transitional Care Center (Texas City, TX)

The Oceanview Transitional Care Center, located in Texas City, TX, was originally built in the 1940s as a hospital. The building received wind damage during Hurricane Ike. According to ASCE 7-05, the basic wind speed for this location is approximately 125 mph. The estimated maximum wind speed during Hurricane Ike was approximately 105 mph.

Figure 4-38 is a general view of the building. The facility houses approximately 100 residents. The facility was evacuated prior to the storm because of a mandatory evacuation order for Texas City. However, the facility that they evacuated to in Houston eventually lost all power, including the emergency generator. The residents therefore returned home 3 days after the storm. The facility was powered by its emergency generator for 3 days after the residents returned until power was restored. Although the Oceanview generator did not have sufficient capacity to power the HVAC system, the residents had lights, fans, and water.

General Wind Damage. The canopy roofs and a portion of the upper roof had a low parapet. The remainder of the upper roof had metal edge flashing. The coping blew off a portion of one of the canopies and a portion of the main roof. Exposed fasteners were used to attach the inner leg of the copings. In one area, the fasteners were 3 feet 2 inches on center, which is very excessive spacing. Had the winds been stronger, roof blow-off associated with coping failure would have been likely.

Figure 4-38. General view of Oceanview Transitional Care Center

An exhaust fan on the upper roof blew off, because of an inadequate number of fasteners, and landed on a canopy roof (Figure 4-39). A temporary covering had been placed over the curb, but at the time of MAT observations, the covering was no longer in place. Two other fans also lost their cowlings, and a fan on a lower level roof blew off. There was minor water leakage to the interior of the facility (in part or solely related to this rooftop equipment damage).

The LPS became detached from several areas of the main roof. Portions of the conductors were dangling over the front and back walls (Figure 4-40). In addition to loss of lightning protection, the detached conductors had the potential to break glazing.

Functional Loss. There was no loss of function to this building as a result of Hurricane Ike.

Vulnerabilities and Other Observations. Had the winds been stronger, significant water infiltration would have been likely due to roof membrane blow-off associated with edge flashing or coping failure. Additionally, since the roofs were aggregate-surfaced BURs, aggregate blow-off would have been likely, which depending upon wind direction, may have resulted in damage to the facility's windows and/or glazing damage to automobiles or nearby buildings.

Figure 4-39.
The fan shown in the inset blew off of this curb

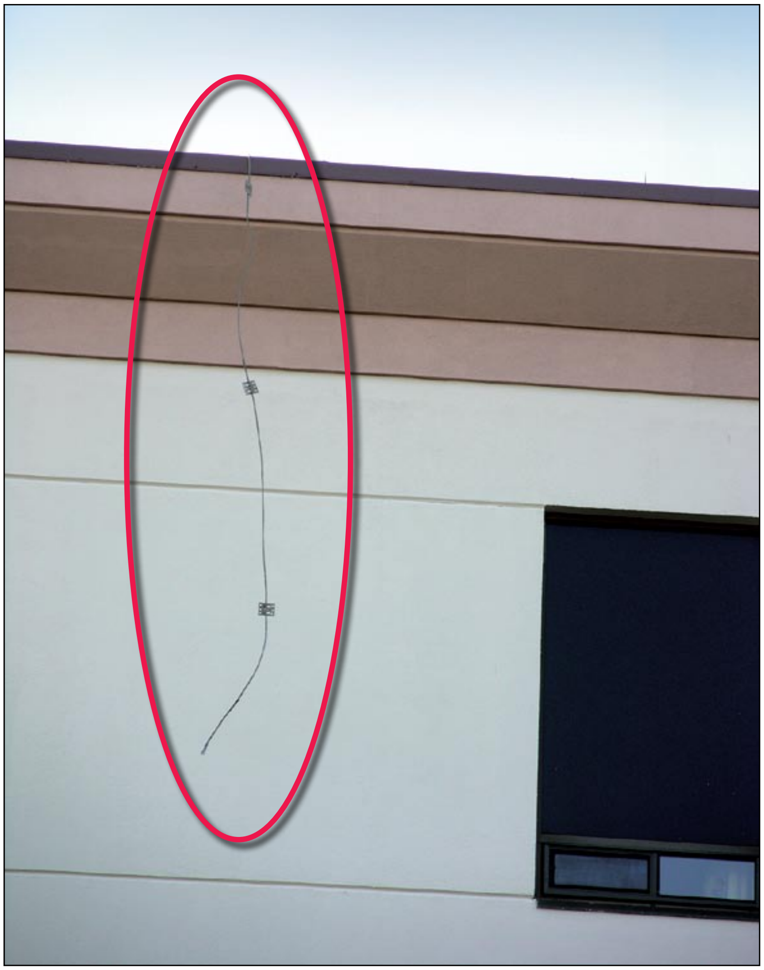


Figure 4-40.
Detached LPS conductor

4.3 First Responder Facilities (Police/Fire/EOC)

First responder facilities, including fire stations, police, and EOCs, are considered lifelines in communities. Their employees perform a community's first response function and play a critical role in ensuring the safety of all residents and protection of residences and infrastructure. For this reason, the performance of these facilities in hurricanes is of utmost importance.

4.3.1 Houston Transtar – Regional EOC (Houston, TX)

The Houston TranStar – Regional EOC is housed in a building constructed in 1996 (Figure 4-41). The Houston TranStar consortium is a partnership of four government agencies responsible for providing transportation management to the greater Houston area. In addition, it serves as a regional EOC to 14 counties. The Regional EOC building received some wind damage from Hurricane Ike. According to ASCE 7-05, the basic wind speed for this location is approximately 108 mph. The estimated maximum wind speed during Hurricane Ike was approximately 92 mph.

The roof deck for the facility is a composite concrete topping over steel decking, and the roof covering is a mineral surface modified bitumen membrane. Both the decking and the roof covering types are recommended in FEMA 543. The building originally had shutters to protect the windows. However, because of the time and expense involved with installing and removing the shutters, the windows were replaced with impact-resistant windows in 2004.

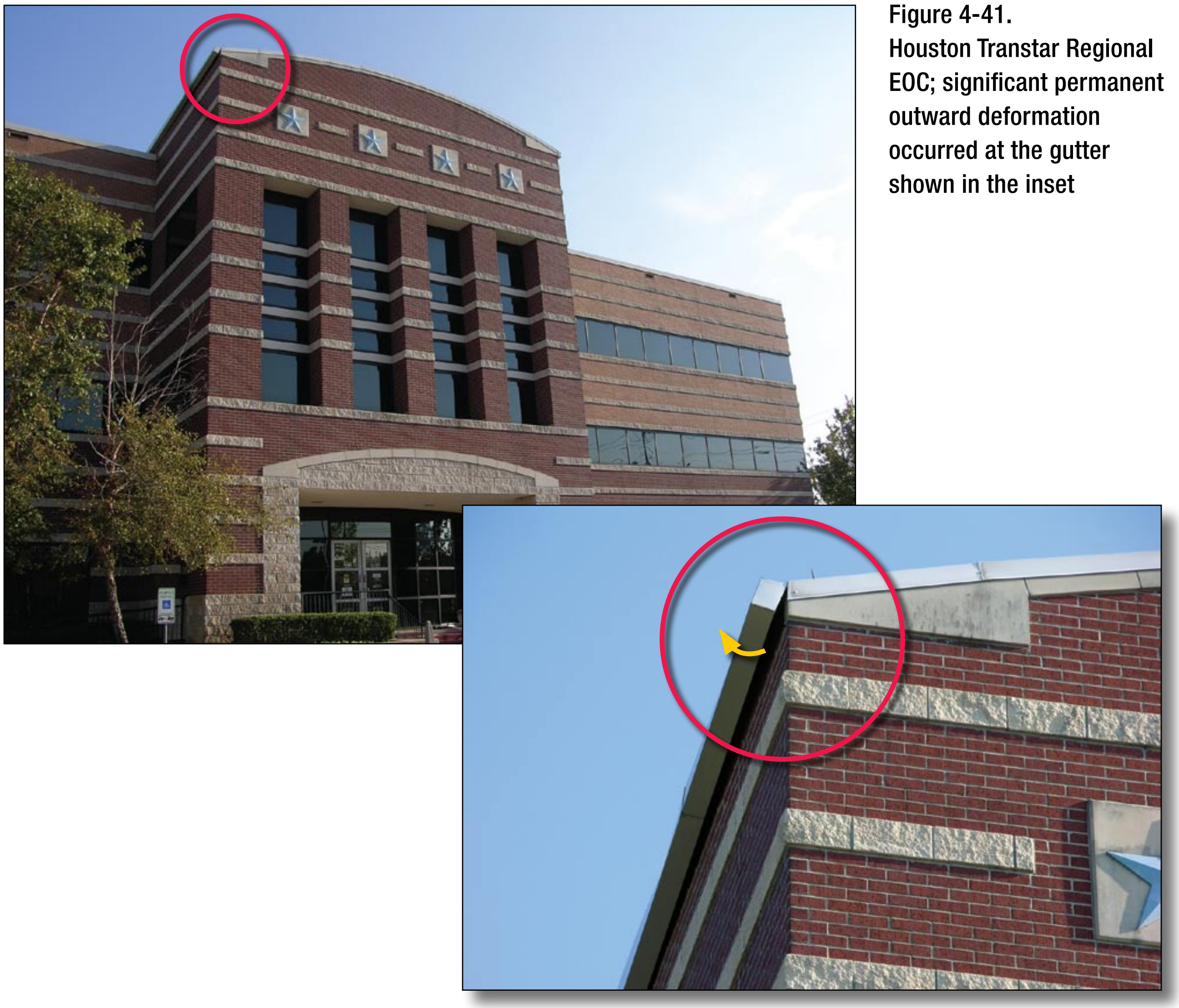


Figure 4-41. Houston Transtar Regional EOC; significant permanent outward deformation occurred at the gutter shown in the inset

General Wind Damage. Hurricane Ike caused outward deformation of the gutter shown in the Figure 4-41 inset. Had the winds been stronger, the gutter would have likely blown off. Additionally, several pieces of coping blew off the building. The outer face of the coping is 8 inches and the inner face is 4 inches (Figure 4-42). Continuous cleats are located along both sides of the parapet. The cleats were attached with roofing nails driven through the horizontal flange (blue arrow at Figure 4-42). In addition, a few widely-spaced nails were driven through the vertical flange (red arrow in Figure 4-42). The nailing provided very little resistance to outward deflection of the cleat and coping. While most of the continuous inner and outer cleats remained on the building, several sections of coping and at least one cleat blew off once the amount of deflection was sufficient for the coping to disengage from the cleat. The blown-off cleat had a face nail that was 75 inches in from the end of the cleat, hence over 6 feet of this cleat was unrestrained from outward deformation.

The wind resistance of poorly attached copings, such as the ones on this building, can be economically strengthened by face-screwing the coping as described in FEMA 543. The base flashing was stopped at the top of the parapet. It should have been run across the top of the nailer and turned down and nailed so as to provide greater watertight protection in the event of coping leakage or coping blow-off.

Figures 4-43 and 4-44 show pieces of coping that landed elsewhere on the roof. Windborne coping can easily puncture roof membranes, including tough membranes like the modified bitumen membrane on this roof (inset at Figure 4-43).

Figure 4-42.
The coping blew off because of inadequate attachment of the cleats. The blue arrow shows roofing nails driven through the horizontal flange and the red arrow shows widely spaced nails through the vertical flange.

Figure 4-43.
Coping debris (red arrow); the membrane was gouged (blue arrow) by coping debris (an ink pen shows the scale)

A substantial amount of leaf debris was observed in the vicinity of scuppers on a lower roof (Figure 4-44). During hurricanes, heavy leaf loss and accumulation on roofs has the potential to block roof drains and overflow drains and scuppers. Increasing the size of scuppers and downspouts minimizes the potential for scupper/downspout blockage.

Figure 4-44.
Coping debris (blue arrow) on a lower roof; note leaf debris near the scupper (red arrow)

Additional damage included minor leakage at a building expansion joint and toppling of a tall flue on a lower level roof, even though it was guyed (Figure 4-45). The tautness of guys should be checked annually to avoid toppling of flues.

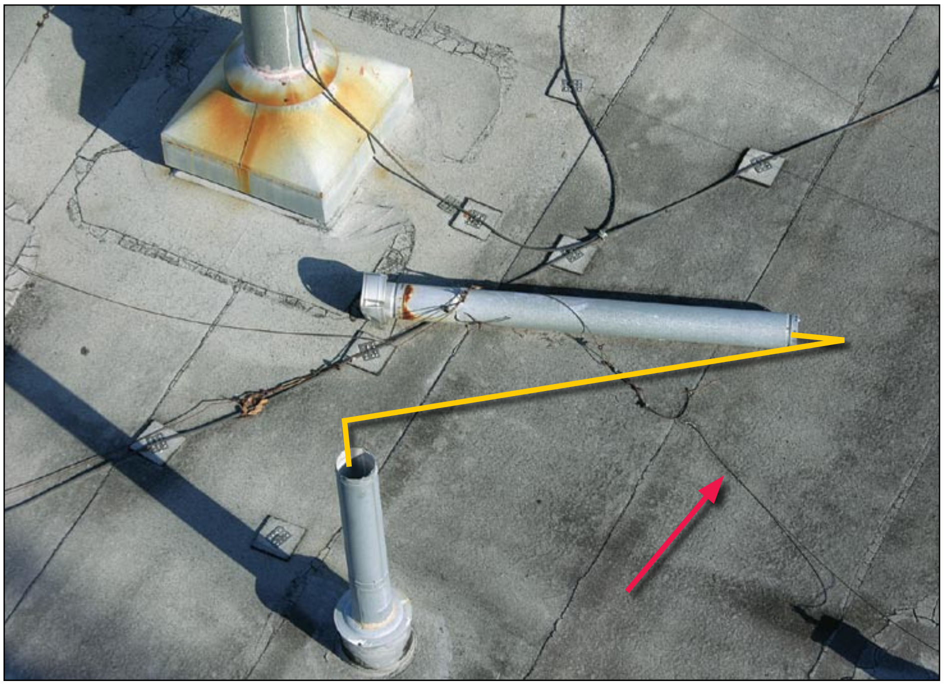


Figure 4-45.
Guyed flue blew over (red arrow indicates one of the guys)

Functional Loss. The building did not experience loss of function as a result of Hurricane Ike. However, the building experienced a power interruption when the Red Cross was allowed to connect to the building's electrical system (which at that time was being powered by the building's emergency generator). The power interruption resulted in a complete loss of electrical power to the building for approximately 15 minutes.

The building did not experience loss of water or sewer service.

Vulnerabilities and Other Observations. Had the winds been stronger, significant water infiltration would have been likely due to roof membrane blow-off associated with the coping failure. The gutters would likely have also blown off, which may have caused blow-off of the metal roof panels. Additional damage to rooftop equipment would also have occurred.

Under the right wind conditions, the emergency generator could also have been damaged because of inadequate building envelope protection. The facility's one emergency generator is housed in a separate building, shown in Figure 4-46. The coiling doors shown by the red arrow in Figure 4-46 appeared to possess little wind resistance. In addition, the louver shown by the blue arrow was not resistant to large windborne debris (which could penetrate the louver and damage the generator). Considering the importance of this facility, it would be prudent to: 1) add a back-up generator and a cam locking box (to facilitate rapid connection of a portable generator); 2) replace the coiling door with a new door rated for the design wind load and capable of resisting test missile E as specified in ASTME E 1996; and 3) replace the louver with one capable of resisting test missile E, or provide a debris-resistant shield in front of the louver. Recommendations pertaining to all three of these items are provided in FEMA 543.

Figure 4-46.
The emergency generator is housed in the circled building; the coiling door (red arrow) and the louver (blue arrow) appeared to provide inadequate protection for the generator

The facility had a very large water tank to provide potable water and water for the building's fire sprinkler system, which provides protection in the event of an interruption of municipal water.

4.3.2 Deer Park Police Station (Deer Park, TX)

The Deer Park Police Station (Figure 4-47), constructed in 2004, received wind-driven rain damage as a result of Hurricane Ike. According to ASCE 7-05, the basic wind speed for this location is approximately 112 mph. The estimated maximum wind speed during Hurricane Ike was approximately 95 mph. Shutter mitigation work was conducted after the building was constructed.

General Wind Damage. There was no apparent wind damage. However, relatively minor water leakage occurred. The building owner reported that wind-driven rain entered at the metal roof's ridge flashing.

Functional Loss. There was no loss of function at this facility from Hurricane Ike. It cost approximately $3,000 to repair the interior damage caused by the leakage.

Vulnerabilities and Other Observations. When the facility undertook shutter mitigation work, conducting a comprehensive vulnerability assessment and then mitigating the significant vulnerabilities, or alternatively, recognizing the residual risk that remains, would have been prudent (see FEMA 543). The MAT observed the following vulnerabilities.

Figure 4-47.
General view of Deer Park Police Station

The gutter brackets shown in Figure 4-48 do not provide a positive attachment between the gutter and bracket. However, the winds during Hurricane Ike were not of sufficient strength to blow off the gutters. Screwing the gutter to the brackets, as shown in the inset at Figure 4-48 (the inset photo is from an HMPG project in Port Neches), would be prudent. However, to avoid leakage at the fasteners between the bracket and gutter, the bracket should extend near or to the top of the gutter so that the fastener would be above the waterline.

Figure 4-48.
The gutters are not attached to the gutter bracket; the inset shows a bracket at another building that provides a positive connection between the bracket and gutter

The emergency generator is shown in Figure 4-49. Although the enclosure has walls around three sides, it does not provide sufficient wind and windborne debris protection. Had the generator failed to function during the storm, lack of protection would have inhibited maintenance efforts to get the generator back online. FEMA 543 recommends providing a wind- and windborne-debris-resistant enclosure all around and over the generator.

The facility's emergency generator provided power during intermittent municipal power outages. There was no interruption of water or sewer service.

Figure 4-49.
The emergency generator is inadequately protected from wind and windborne debris

4.3.3 Port Neches Fire Station (Port Neches, TX)

The Port Neches Fire Station (Figure 4-50) was constructed in 1972. In the aftermath of Hurricane Rita (2005) and at the time that Hurricane Ike struck, this building was being mitigated using HMGP funds. The mitigation work consisted of replacing all six apparatus bay sectional doors, adding window and door shutters (Figure 4-51), and installing a new modified bitumen roof system. At the time of Hurricane Ike, all the work had been completed except installation of some of the metal edge flashing. According to ASCE 7-05, the basic wind speed for this location is approximately 116 mph. The estimated maximum wind speed during Hurricane Ike was approximately 90 mph.

General Damage. This facility was not damaged during Hurricane Ike.

Functional Loss. There was no functional loss to this facility during Hurricane Ike.

Vulnerabilities and Other Observations. The MAT observed vulnerabilities that make the building susceptible to: 1) leakage due to roof membrane puncture from windborne debris, 2) fan and/or fan cowling blow-off, and 3) emergency generator damage from windborne debris.

Performance of HMGP Mitigation Work. When the facility undertook mitigation work, it would have been prudent to conduct a comprehensive vulnerability assessment and then mitigate the significant vulnerabilities, or alternatively, recognize the residual risk (see FEMA 543).

Figure 4-50.
General view of Port Neches Fire Station

Figure 4-51.
View of a new motorized shutter; the toggle in the red circle allows the shutter to be manually raised

Replacing the sectional doors, adding the shutters, and replacing the roof system were appropriate actions for the mitigation project. However, the new roof system does not provide leakage protection in the event the membrane is punctured by windborne debris. Although the roof membrane choice was appropriate (and one that is recommended in FEMA 543), the new roofs do not have secondary membranes, as recommended in FEMA 543, to avoid water leakage in the event the membranes are punctured by windborne debris.

Neither the exhaust fan cowlings nor the fans were anchored as recommended in FEMA 543. The contract documents specified two screws per side, with a maximum spacing of 16 inches on center; however, for this size fan, FEMA 543 recommends four screws per side.

The emergency generator is not located in a protected enclosure (Figure 4-52). The nearby non-reinforced masonry screen wall (red arrow) could collapse on the generator, and the generator could be damaged by windborne debris. Had the generator failed to function during the storm, lack of protection would have inhibited maintenance efforts to get the generator back online. As part of a comprehensive mitigation project, providing a wind- and windborne-debris-resistant enclosure all around and over the generator as recommended in FEMA 543 would have been prudent.

Figure 4-52.
The emergency generator is susceptible to windborne debris and damage caused by collapse of the masonry screen wall

4.3.4 High Island Fire Station (High Island, TX)

The High Island Fire Station is an older pre-engineered metal building (Figure 4-53). The facility received wind damage during Ike. According to ASCE 7-05, the basic wind speed for this location is approximately 131 mph. The estimated maximum wind speed during Hurricane Ike was approximately 110 mph.

General Wind Damage. All four apparatus bay doors blew away when the door rollers disengaged from the tracks (Figure 4-53).

At the back of the building, the bottom of the wall blew outward (Figure 4-54). The metal walls were attached to an angle that was poorly attached to the concrete slab. The angle was attached at the door jamb, but there was a 10-foot gap to the next adjacent fastener. Some wall insulation near the door was also blown away. In addition, some of the metal wall panels peeled back at a corner of the building.

Functional Loss. There was no functional loss to this facility during Hurricane Ike.

Vulnerabilities and Other Observations. The apparatus (trucks) appeared to be left in the fire station during the storm. Older buildings such as this are quite susceptible to damage (including collapse of the structural frame if winds are quite high). When apparatus are left in a station such as this, they can be damaged by building collapse.

Figure 4-53. General view of High Island Fire Station

Figure 4-54.
The metal wall at the red oval area was pushed outward because of inadequate attachment of the wall angle to the slab

4.3.5 Louisiana Fire Stations

If fire stations cannot remain operational during or after an event, the community loses a valuable and important part of its emergency response capability. The MAT visited and inspected five fire stations in Louisiana:

- Grand Caillou Volunteer Fire Station, Terrebonne Parish
- Bayou Dularge Volunteer Fire Station, Terrebonne Parish
- 7th Ward Volunteer Fire Department, Vermilion Parish
- Hackberry Volunteer Fire Station, Cameron Parish
- Grand Isle Volunteer Fire Station, Jefferson Parish

The MAT also saw, but did not inspect, flood damage to metal building systems and fire equipment at other fire stations (e.g., Muria Road Fire Station and East Creole Highway Station, Cameron Parish). A summary of the observations for each facility is included in Table 4-3.

Table 4-3. Observations of Louisiana Fire Stations

Fire Station	Parish	Ike Damage	Comments
Grand Caillou Volunteer	Terrebonne	None	Elevated above ABFE (Figure 4-55); manned during Hurricane Ike, no loss of function
Bayou Dularge Volunteer	Terrebonne	Foundation undermined	Sited along the bank of a canal, rear of building was undermined by bank erosion during Ike (Figure 4-56); erosion also occurred during Rita and had been repaired before Ike; manned during Ike, no loss of function; bank stabilization required. The Parish Council agreed to condemn the station in February 2009, and its operations will move to another station.
7th Ward Volunteer	Vermilion	Flood	Approximately 8 inches of flooding above the floor during Ike; repairs underway during MAT visit (Figures 4-57 and inset); previously flooded during Rita; station was not in use during Ike.
Hackberry Volunteer	Cameron	Flood	Flooded during Ike; previously flooded during Rita, after which the station had been cleaned but not fully repaired; station was not in use during Ike, although vehicles and equipment were damaged by flooding; replacement HVAC units from Rita were not elevated (Figure 4-58).
Grand Isle	Jefferson	Flood	Facility sustained wind and flood damage during Katrina that had not been repaired at the time of Ike (Figure 4-59); facility sustained additional flood damage during Ike, but was not in operation at the time and is now used only as a garage.
Muria Road	Cameron	Flood	Obvious flood damage to the metal building was evident during a drive-by.
East Creole Highway	Cameron	Flood	Obvious flood damage to the metal building was evident during a drive-by.

Figure 4-55.
The Bayou Grand Caillou Fire Station is elevated above the ABFE and sustained no damage

Figure 4-56.
Rear of Dularge Fire Station; note canal bank erosion sustained during Hurricane Ike

Figure 4-57.
7th Ward Fire District No.1 Fire Station; wall repairs were in progress during MAT inspection

Figure 4-58.
Condenser units were installed at Hackberry Fire Station after Ike and are vulnerable to future flooding

Figure 4-59.
Wind damage (red arrows) to Grand Isle Fire Station remaining from Hurricane Katrina

4.4 Other Government Buildings

Although few government buildings are categorized as critical facilities in ASCE 7-05 (i.e., Category III or IV buildings), many government buildings play a vital role in delivering various services during and/or after a hurricane and should receive additional design attention to avoid or resist flood and wind loads.

4.4.1 U.S. Army Corps of Engineers Administration Building (Galveston, TX)

The USACE Administration Building (Figure 4-60), constructed in 1991, is located in Galveston, TX. Although the building was not damaged by flooding, floodwater surrounded the building during Hurricane Ike. Had the water been a few inches higher, it would have wetted the first (lobby) floor. The building experienced wind damage from Hurricane Ike. The exterior walls are precast concrete. According to ASCE 7-05, the basic wind speed for this location is approximately 132 mph. The estimated maximum wind speed during Hurricane Ike was approximately 108 mph.

Figure 4-60.
General view of the USACE Administration Building in Galveston, TX

General Wind Damage. Some minor leakage occurred at a few windows; facility staff reported that minor leakage had also occurred during previous thunderstorms. Additionally, some fan cowlings and louvers at condensers were blown off, and some of the LPS conductors detached from the roof membrane. A sheet metal cover over a curb was blown off (Figure 4-61). The presence of the 3-foot 2-inch high parapet was the likely reason the sheet metal was not blown from the roof. The roof membrane is a mineral-surface modified bitumen membrane (which is relatively tough and one of the membrane types recommended in FEMA 543). Although the sheet metal scuffed the roof, the membrane was not punctured or torn.

Figure 4-61.
The black material on top of the curb is a temporary covering to replace the sheet metal covering originally on the curb; shown in the red circle and inset

Functional Loss. The emergency generator for the facility is fueled by natural gas. The gas supply was shut down prior to the storm by the gas supplier. The facility was without power until a portable generator was supplied by FEMA on September 21. Municipal power was restored on September 30. Additionally, the building was without potable water until October 2. The building was reoccupied on October 6.

Vulnerabilities and Other Observations. The incorporation of many sound design elements (e.g., precast concrete walls, a modified bitumen membrane, and a parapet in excess of 3 feet) makes this a relatively wind-resistant building. However, strengthening the attachment of the rooftop equipment and the LPS, constructing a wind- and debris-resistant enclosure around the exposed emergency generator, and providing a contingency for future natural gas interruption (see Chapter 7, Recommendations) would be prudent.

4.4.2 Federal Courthouse and Post Office (Galveston, TX)

The Federal Courthouse and Post Office (U.S. Postal Service) facility (Figure 4-62), constructed circa 1935, is located in Galveston, TX. The facility received some flood damage. The facility also had minor wind damage. According to ASCE 7-05, the basic wind speed for this location is approximately 132 mph. The estimated maximum wind speed during Hurricane Ike was approximately 107 mph. The upper level roof is composed of two types. The steep-slope portion is tile. All of the tails of the tiles are hooked (red circle in Figure 4-63). The sloped roofs surround a low-slope area that has a mineral-surface modified bitumen membrane.

This building is on the site of the former Federal Courthouse and Post Office designed by Nicholas Clayton, a prominent Galveston architect (the first professional architect in the State), and was built between 1888 and 1892. In 1993, during construction of 4- to 5-foot deep foundation trenches for the new generator building, the upper portions of a 3- to 5-foot foundation and the remains of a marble floor were exposed. The exposed foundation and marble floor were determined to be the northwest corner of the former courthouse/post office/customs building.

Figure 4-62. General view of Federal Courthouse and Post Office; some flashing damage occurred during Hurricane Ike (shown by red arrow)

Figure 4-63. All of the tile tails were hooked

General Flood Damage. Floodwater inundated the basement, which caused major damage to mechanical equipment and the main electrical switchgear room.

General Wind Damage. In one of the offices, there was damage to ceilings and interior partitions. The MAT assumption is that the damage was caused by wind entering the office through a window that became unlatched and opened during the storm.

No roof covering damage was observed. Some roof flashing damage occurred along a small area on the front of the building (red arrow, Figure 4-64) and similarly along the back of the building. Minor rooftop equipment damage was observed. An access panel at a condenser was nearly blown off (red arrow, Figure 4-64). The condenser had two supplementary anchor straps (yellow arrows). Supplementary anchor straps are recommended in FEMA 543.

Figure 4-64.
The access panel (red arrow) nearly blew away; the yellow arrows indicate supplementary anchor straps

Functional Loss. At the time of the MAT visit, the facility was closed due to flood damage to the mechanical equipment and switchgear in the basement.

Vulnerabilities and Other Observations. A good practice observed at this facility is the location of the emergency generator in a wind- and windborne-debris-resistant building and elevation above the floodwater level (Figure 4-65). Hence, although flooding damaged the switchgear in the basement, the emergency generator was functional and, therefore, able to be reconfigured to power portable equipment used to dry the interior of the building.

Figure 4-65.
The emergency generator is housed in a separate wind- and windborne-debris-resistant building (red arrow)

4.4.3 Tiki Island City Hall (Tiki Island, TX)

The Tiki Island City Hall (Figure 4-66), constructed around 1986, is located on Tiki Island, a barrier island between the mainland and Galveston Island. In the aftermath of Hurricane Rita, the building was mitigated in 2008 using HMGP funds. The mitigation work consisted of adding motorized shutters at all glazed openings. The facility received wind and flood damage during Hurricane Ike. According to ASCE 7-05, the basic wind speed for this location is approximately 130 mph. The estimated maximum wind speed during Hurricane Ike was approximately 103 mph.

Figure 4-66.
One of the shutters at the Tiki Island City Hall is shown in the red oval; blue arrows indicate breakaway walls that performed successfully by breaking away

General Flood Damage. Breakaway walls failed under flood forces and ground level space was inundated (blue arrows in Figures 4-66 and 4-68).

General Wind Damage. A portion of the ridge flashing was blown off the metal roof (Figure 4-67). Leakage did not occur, so the roof underlayment was apparently correctly lapped over the ridge. However, loss of flashing can make roof panels more susceptible to blow-off.

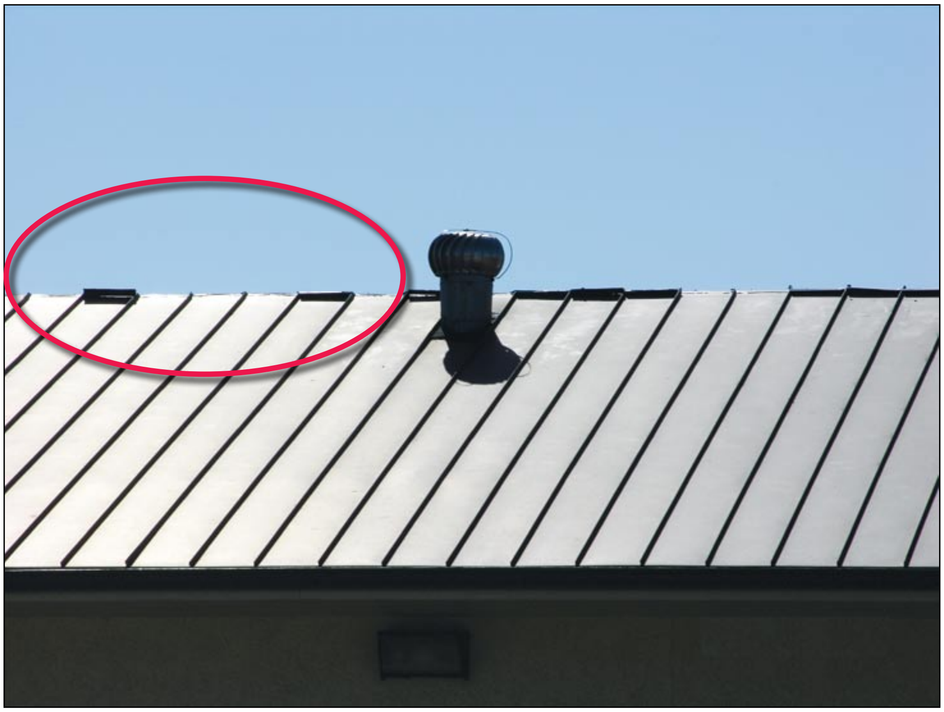


Figure 4-67.
The oval shows where ridge flashing blew away

Functional Loss. There was no loss of function at this facility. A few of the breakaway walls broke away as intended, but that damage did not significantly affect facility operations.

An exposed emergency generator that powers the City's sewage treatment facility failed due to corrosion in the electronic controls. This was an older generator that was scheduled for replacement in a year or two, so less attention had been given to maintenance. Municipal power was restored within 5 or 6 days, which allowed the sewage treatment facility to come back online. This generator also supplied power to the City Hall.

Vulnerabilities and Other Observations. The building design incorporated a very sound practice regarding entrance of electrical service. Normally when power is provided by overhead lines (as is the case with this building), the lines come into a weatherhead that penetrates the roof. If nearby power poles collapse or move significantly, the power lines pull the weatherhead, which often tears the roof and allows leakage. However, at this building, the conduit from the weatherhead (circled in Figure 4-68) runs along the wall and then enters the building through the wall (red arrow). With this installation, movement of the power lines may have caused some damage at the wall penetration had the power lines moved significantly; but if wall damage had occurred, leakage would have been much less problematic than if the conduit penetrated the roof.

Performance of HMGP Mitigation Work. When the facility undertook mitigation work, it would have been prudent to conduct a comprehensive vulnerability assessment and then mitigate the significant vulnerabilities, or alternatively, recognize the residual remaining risk (see FEMA 543). The addition of shutters via the HMGP mitigation project was prudent; however, other building vulnerabilities (i.e., the roof ridge flashing and emergency power) were not addressed.

Figure 4-68.
The electrical service entered through the wall rather than the roof; the blue arrows indicate missing breakaway walls

4.4.4 Terrebonne Parish Criminal Justice Complex (Houma, LA)

The Terrebonne Parish Criminal Justice Complex located in Houma, LA, houses approximately 600 inmates. It is a relatively new facility but received approximately 18 to 24 inches of flooding due to Hurricane Ike (Figure 4-69).

The facility was also flooded during Hurricane Rita in 2005. The 1985 FIRM showed the site as being in flood Zone C (outside the limits of the 500-year flood), but the February 2006 (post-Rita) flood recovery map shows the area as advisory flood Zone A with an advisory flood elevation of 6 feet NGVD, approximately comparable to the elevation of Hurricane Rita flooding.

General Flood Damage. Utility service, which runs beneath the slab foundation, was damaged and disrupted by Ike's flooding. In addition to the inundation problems, the facility became unusable because controls were either damaged or inoperable (virtually all of the functions of the prison are operated by electric switches, relays, and motors, including the communications, prison monitors, lights, and cell doors). Parish records also indicate that the criminal complex electronic security system was damaged by Hurricane Rita and required repair and replacement in 2006.

Functional Loss. Flooding damaged essential equipment and required that prisoners be relocated to a State corrections facility.

Vulnerabilities and Other Observations. ASCE 7-05 and ASCE 24-05 designate jails and detention facilities as Category III facilities, which require additional design consideration beyond building code requirements for typical commercial and residential construction. Correctional facilities should be located outside the floodplain or elevated to the 500-year flood elevation. If 500-year flood elevations are not available, elevate above the BFE with sufficient freeboard to prevent damage and loss of use. Some States have mandated special permit requirements and freeboard for correctional facilities located in or near flood hazard areas (e.g., Commonwealth of Pennsylvania, 2001). Federal agencies with involvement in funding, permitting, and constructing critical facilities should follow these guidelines for protecting correctional facilities in accordance with Executive Order 11988 Floodplain Management.

The U.S. Department of Justice (DOJ), National Institute of Corrections provides specific guidance for planning for emergencies, including natural disasters. All correctional facilities in hazardous areas can conduct a self-audit using the convenient checklists in the DOJ publication (Schwartz and Barry, 1996), and should identify retrofit opportunities and procedures to reduce damage and overcome operational issues related to natural disasters.

Figure 4-69. Terrebonne Parish Criminal Justice Complex