7. Performance of Critical and Essential Facilities

Critical and essential 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 Katrina had a significant impact on these facilities, totally destroying many of them and devastatingly affecting others.

Many of the observed facilities were impacted by flooding, and most experienced wind damage, even though they were subjected to winds that were below current design wind speeds. Most critical and essential facilities did not perform any better than the commercial buildings, and several performed worse. 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 and essential facilities are Category III and IV buildings as defined in ASCE 7 and the 2003 IBC (Section 1604, 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, Emergency Operations Centers (EOCs), schools, shelters, and power stations and other facilities required in an emergency. In addition to the buildings listed in Categories III and IV, there are other buildings that can play vital roles in recovery after an event. Examples of these buildings are discussed in Section 7.4.

Most of the building damage was to envelope systems and older facilities, although a few structural and new building failures did occur. Buildings that sustained damage from flooding had not been designed to account for the level of flooding that occurred. 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.

Sections 7.1 through 7.4 describe the performance of some of the critical and essential facilities (EOCs, fire stations, hospitals, and airports and military bases) observed by the MAT.

Special Requirements for Critical and Essential Facilities

The 2003 edition of the IBC has only one special flood-related provision pertaining to Category III and IV buildings. That provision concerns elevation requirements that exceed the NFIP minimum requirements. IBC references ASCE/SEI 24 for the specific elevation requirements.

The 2003 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 1.0, which is used for most other types of buildings. The effect of requiring the use of the 1.15 importance factor is that the design loads for the main wind force resisting system (MWFRS) and components and cladding (C&C) are increased by 15 percent.
- **Windborne debris loads:** For buildings located within windborne debris regions (as defined in ASCE 7) of hurricane-prone regions, exterior glazing is required to be impact-resistant. For Category III and IV buildings, the glazing is required to resist a larger energy missile load than the glazing on most other types of buildings.

7.1 Emergency Operations Centers

EOCs are key buildings in preparing for and responding to an event at both local and state levels. The MAT observed three EOCs.

7.1.1 Jackson County EOC (Pascagoula, Mississippi)

7.1.1.1 General Damage

Figure 9-15 shows a general view of the two-story building (constructed in 1977). The EOC is located on the second story of this building, which has a reinforced concrete frame, walls and roof deck, and an aggregate surfaced built-up roof (BUR). The membrane had been mopped to perlite insulation, which was mopped to the concrete deck. Polycarbonate shutters had been permanently mounted over the exterior windows and glazed door.

Floodwater rose to about an inch below the first floor, which is approximately 4-1/2 feet above grade. Wind blew off a portion of the roof membrane and blew aggregate from the roof (see Figure 7-1). The roof blow-off initiated with the metal edge flashing, which had a 5-inch vertical face that was uncleated, making it susceptible to lifting and peeling. The communications tower was also toppled (see Figure 7-2). The rooftop condensers were strapped to their curbs (Figure 7-2 inset), but the straps and their connections appeared inadequate; the condensers would have likely blown away if the winds had approached the current design wind speed.

The 2003 edition of the IBC has only one special flood-related provision pertaining to Category III and IV buildings. That provision concerns elevation requirements that exceed the NFIP minimum requirements. IBC references ASCE/SEI 24 for the specific elevation requirements.

Figure 7-1. The roof membrane blew off at the far end and along a portion of the right side of the roof. Aggregate was also blown off. An emergency roof repair was made prior to the MAT's observation (estimated wind speed: 105 mph. Pascagoula, Mississippi).[1]

7.1.1.2 Functional Loss

The EOC was in a mapped floodplain, Zone A10. A map in the EOC indicated that it was located in an area that would be isolated by flooding during a Category 1 hurricane and inundated during a Category 3 event.[2] However, it was decided to not evacuate the building prior to the storm because it was believed that, because this area did not flood during Hurricane Camille, it would not flood during Hurricane Katrina. As floodwaters rose, there were safety concerns for the approximately 20 occupants; therefore it was decided to evacuate most of the occupants across the street to a building that was a few stories taller. Staff members waded through a few feet of water during the storm to reach the other building. Because of favorable wind direction,

[1] Estimated speeds given in this chapter are based on Figure 1-13. These are for a 3-second gust at 10 meters elevation for Exposure C. Unless otherwise noted, the buildings for which estimated speeds are given are located in Exposure B. See Table 1-4 for the estimated speed conversion for buildings located in Exposure B. For example, the 105-mph Exposure C speed given for Figure 7-1 is equivalent to 90 mph in Exposure B.

[2] See Section 2.1.1 for a description of flood zones.

aggregate that was being blown from the roof did not land in the evacuation path or injure the evacuees. Movement of staff to the other building reportedly did not have a significant impact on the EOC operations.

About 30 emergency vehicles brought to the EOC parking lot prior to the storm were flooded, and were not immediately available after the hurricane moved inland. After the water around the facility receded (which took several hours), the vehicles had to be serviced (which took several days) before they were operational. The lack of immediate availability of the vehicles hampered response efforts.

The roof membrane blow-off did not result in interior rainwater leakage because the reinforced concrete roof deck was capable of resisting water infiltration. With critical and essential facilities, incorporation of a secondary membrane (as described in FEMA 424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds*) is a prudent practice. Such redundancy reduces the potential for water infiltration if the primary roof covering is blown away or punctured. When sealed at penetrations and parapets, cast-in-place concrete decks can also perform as a secondary membrane, as in the case of this building. However, installation of a secondary membrane over the concrete is a more conservative practice.

Figure 7-2.
The communications tower toppled due to failure of its connection to the roof deck. The condenser units were superficially strapped to their curbs (estimated wind speed: 105 mph. Pascagoula, Mississippi).

Three other prudent practices were observed at this building: the robust construction of the roof deck and walls (i.e., the concrete provided excellent protection from windborne debris, and substantial and reliable wind resistance), the retrofitting of the glazing with shutters for protection from windborne debris, and sufficient elevation of the emergency generator to keep it from being inundated by floodwater.

7.1.2 Harrison County EOC (Gulfport, Mississippi)

7.1.2.1 General Damage

The EOC occupies a small portion of a large two-story courthouse building constructed in 1977 (see Figure 7-3). The building has a reinforced concrete frame, pre-cast twin-tee exterior wall panels and some brick veneer, concrete floor and roof decks, and an aggregate surfaced BUR. Roll-down metal shutters (Figure 9-12) had been installed in 2003 at the exterior windows and glazed doors. (This work was funded via the FEMA Hazard Mitigation Grant Program; see Section 9.3.1.)

Figure 7-3.
The EOC is located near the center of the first floor of the First Judicial District Courthouse. A portion of one of the communications towers was damaged by wind (estimated wind speed: 130 mph. Gulfport, Mississippi).

Even though there was a parapet, aggregate was blown from the roof and broke the windows of a large number of vehicles in the parking lot. The parapet height varied; at the roof highpoint, the parapet was 14 inches high. A few sections of coping blew off the parapet, but a progressive roof membrane failure did not occur. A small satellite dish was blown off the roof and it appeared to have been mounted on wood sleepers. Rather than anchoring the sleepers to the deck, small blocks of concrete had been placed over the sleepers. A portion of the communications tower was damaged by wind. Some rainwater leakage occurred along a portion of the east wall, but observations were not made to determine if it was related to sealant joints at the pre-cast wall panels or the windows.

7.1.2.2 Functional Loss

The EOC lost normal communications during the storm. However, ham radio operators were in the EOC during the storm and their communications equipment remained operational. The emergency generator shut down when a control relay within the unit failed, but was repaired within about an hour.

Three prudent practices were observed at this building: the robust construction of the roof deck and walls, the retrofitting of the glazing with shutters, and pre-positioning the ham radio operators and their equipment so that a backup was readily available when the primary communications failed.

7.1.3 Hancock County EOC (Bay St. Louis, Mississippi)

7.1.3.1 General Damage

Figure 7-4 shows general views of the one-story building that was built around 1960. The EOC occupies a small portion of a courthouse (the floor elevation of the EOC is about 2 feet lower than the floor elsewhere in the building). The portion of the building housing the EOC has a steel frame, with metal wall panels and a cementitious wood-fiber deck over steel joists, and an aggregate surfaced BUR. The roof membrane was attached to the deck with self-locking fasteners. The walls at the other portion of the building were CMU. The emergency generator was mounted outside (see Figure 7-5).

Figure 7-4.
The EOC lost a portion of its roof covering, and was flooded and totally isolated by floodwater. The EOC was located in the rear portion of the building (red oval) (estimated wind speed: 125 mph. Bay St. Louis, Mississippi).

Figure 7-5.
The EOC's emergency generator was exposed and inundated by floodwater (Bay St. Louis, Mississippi).

Floodwater rose to about 2 feet above the EOC floor. Wind blew off most of the roof membrane over the EOC and also blew aggregate from the roof (see Figure 7-6). The roof blow-off initiated with the metal edge flashing. It had a 5-1/4-inch vertical face that was uncleated; therefore, it was susceptible to lifting and peeling. Hardware on the exterior door to the EOC failed and the door blew inward. A communications tower buckled and a satellite dish was blown off its support post. The satellite dish was mounted to a wooden sleeper assembly that rested on the roof surface, with small blocks of concrete over the sleepers.

Note: Had the winds been stronger, it is likely that some of the cementitious wood-fiber deck panels would have been blown from the steel joists. (At the time this building was constructed, the typical attachment for this type of decking offered limited uplift resistance.) Some of the wall panels may have also been blown away.

Figure 7-6.
The blue tarp was used as an emergency repair where the roof membrane blew off the EOC. Although the membrane's base sheet fasteners were too far apart, the failure initiated with lifting and peeling of the metal edge flashing (estimated wind speed: 125 mph. Bay St. Louis, Mississippi).

7.1.3.2 Functional Loss

Based on direct communication with EOC personnel, thirty-five emergency workers were in the EOC at the time of the hurricane. As floodwater began to rise in the community, many residents who had not previously evacuated their homes tried to evacuate during the storm. The water was deep enough to float their vehicles. Emergency workers rescued several people and took them to the EOC (eventually about 30 people arrived at the EOC, bringing the total occupancy to about 65). The occupants reported that, during the height of the storm, they believed they would not survive and wrote their identities on their arms to aid in the identification of their corpses.

With inundation of the emergency generator, the EOC was without electrical power. Placing the generator in an exposed area was a poor practice. When exposed, a generator is susceptible to windborne debris damage. The generator was also susceptible to flooding, because it was mounted only a few inches above grade.

Blow-off of the roof membrane allowed a substantial amount of water to leak into the EOC. Aggregate from the roof broke windows of several vehicles in the parking lot, but no injuries from flying aggregate were reported. At the time of the MAT observations, there was significant mold bloom in the EOC.

A food distribution center (which included a walk-in freezer) was located within the EOC and it too was flooded.

Because the community remained flooded, including the area around the EOC, after the storm moved inland it was about a day before the EOC could be evacuated. The EOC operations were transferred to the alternate EOC *during the storm.*

The EOC was not in a mapped floodplain (it was in Zone C). However, the EOC was about 600 feet from Zone AE. A 2000 map posted in the building indicated the hurricane evacuation zones for Bay St. Louis. The area where the EOC was located was designated as an evacuation zone for Category 1 hurricanes.

An engineering evaluation completed in 2002 recommended that this facility not be used as an EOC, and that it not be used during events where flooding or isolation from floodwaters was anticipated. The evaluation report also made the following recommendations:

- Improve the connections between the roof deck and framing and between the roof framing and bearing walls, and augment the roof deck for improved windborne debris protection.
- Reinforce the walls to resist wind and windborne debris.
- Install shutters over exterior glazing.
- Perform a structural analysis on the communications tower and develop mitigation actions required to allow it to withstand a design wind event.

7.2 Fire Stations

If fire stations cannot remain operational during an event, the community loses a valuable and important part of its emergency response capability. Several fire stations in Louisiana and Mississippi were damaged from flooding and/or high winds during the hurricane. The MAT observed over 20 fire stations, several of which experienced enough damage to take them off-line for the event and for weeks or months following the event.

Many of the observed buildings were relatively inexpensive and quite old; therefore, they did not possess sufficient wind-resistance. The most common wind-induced damages were to the sectional doors at the apparatus bays, roof coverings, and collapsed communications towers. Notable and representative examples of the observed fire stations are presented in Sections 7.2.1 through 7.2.11.

7.2.1 Back Bay Fire Co. #4 (Biloxi, Mississippi)

7.2.1.1 General Damage

This is a relatively new one-story building with CMU and brick veneer walls and a standing seam metal roof with 16-inch rib spacing (see Figure 7-7). Floodwater rose to about 5-1/2 feet above the floor. The apparatus bay doors were bowed in (this was likely caused by floodwater, rather than wind pressure).

Figure 7-7. General view of Back Bay Fire Co. #4. Floodwater was about 5-1/2 feet deep inside the station (Biloxi, Mississippi).

7.2.1.2 Functional Loss

The building was occupied at the time of the hurricane. As floodwater began to rise in the community, several residents went to this station. With the influx of residents, there were a total of 19 people in the building. The occupants crowded onto the top of the fire engines to avoid the floodwater; however, there was insufficient room for everyone. One firefighter put on a self-contained breathing apparatus and stood in the water; the water rose to the middle of his forehead. Although there was extensive interior water damage, at the time of the MAT observation, the fire station was operational.

The fire station was in a mapped floodplain, Zone B/C. It was about 200 feet from Zone A9.

7.2.2 Gulfport Fire Station #1 (Gulfport, Mississippi)

7.2.2.1 General Damage

This two-story building was constructed in 1977 (see Figure 7-8). It has glue-laminated beams and wood columns, a cementitious wood-fiber deck, and an aggregate surfaced BUR.

The three windward (east-facing) sectional doors were damaged by wind (see Section 5.2.3). The door damage occurred before winds peaked. In response, fire engines were moved against the damaged doors to brace them, and the three westward doors were opened. Opening the doors likely prevented them from being damaged.[3] With the doors at each end of the apparatus bay open or partially open, uplift load on the roof assembly was likely reduced. Had the westward doors not been opened, there likely would have been sufficient wind load to cause uplifting of the cementitious wood-fiber decking. (At the time this building was constructed, the typical attachment for this type of decking offered limited uplift resistance.) One of the deck panels at an overhang had a major crack across its entire width; however, the panel may have been cracked before the storm.

Three of the 12 upper windows on the south side of the building were broken by aggregate blown from a BUR across the street (Figure 7-8 inset). One of the lower windows was also broken.

Aggregate was blown from the fire station's roof (the roof did not have a parapet).

Floodwaters rose to within inches of the base of the station's emergency generator, but the unit was not inundated during the event. The generator was located outdoors, similar to the one shown in Figure 7-5.

7.2.2.2 Functional Loss

The window and door damages caused minor disruptions.

The fire station was not in a mapped floodplain; it was in Zone X, about 1,000 feet from Zone AE.

[3] Generally it is best to keep doors in the closed position, as opening them can create high internal pressures. But in this case, where the building had already lost windward doors, opening leeward doors was beneficial because it reduced internal pressures.

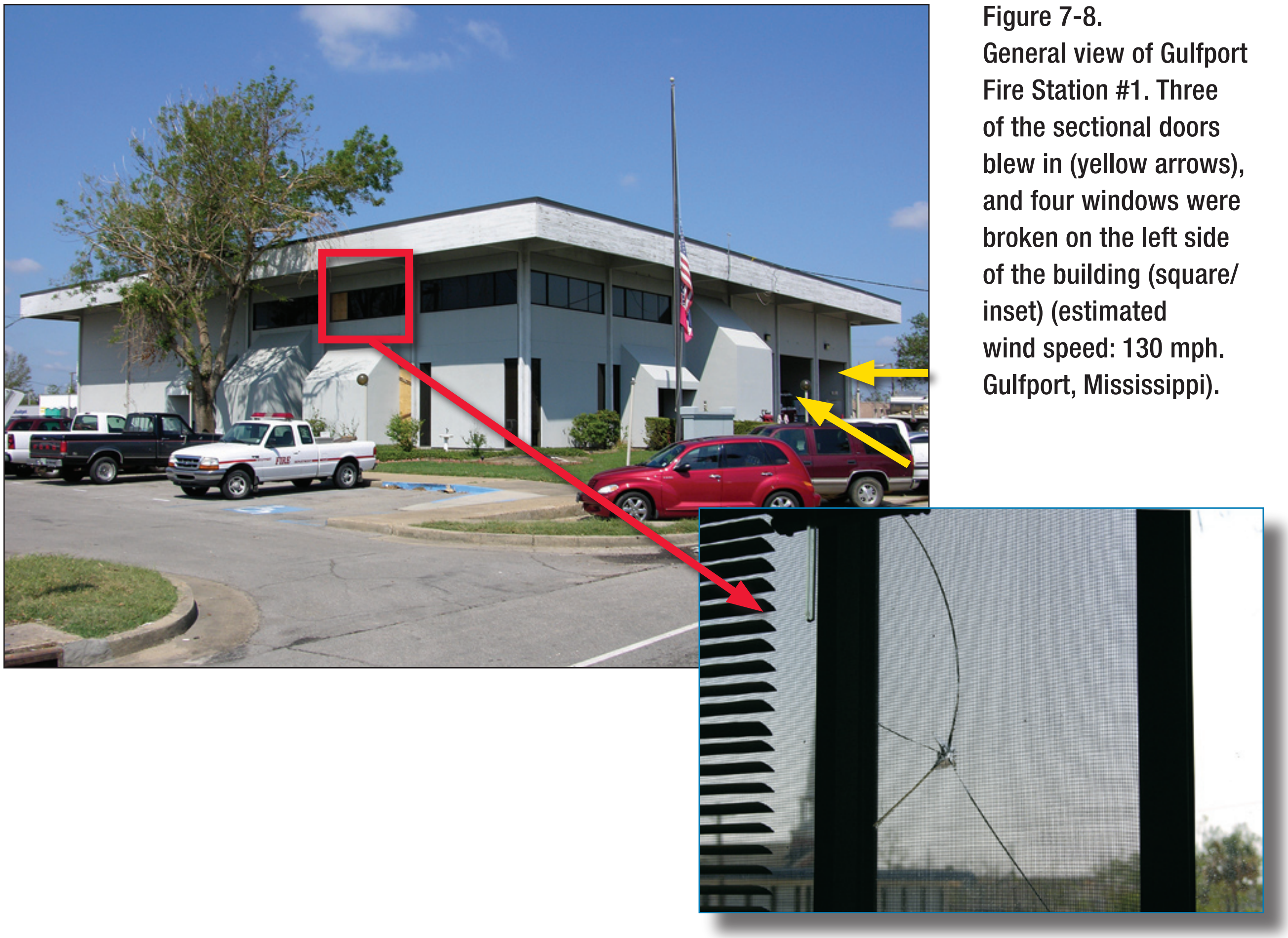

Figure 7-8.
General view of Gulfport Fire Station #1. Three of the sectional doors blew in (yellow arrows), and four windows were broken on the left side of the building (square/inset) (estimated wind speed: 130 mph. Gulfport, Mississippi).

7.2.3 Gulfport Fire Station #5 (Gulfport, Mississippi)

7.2.3.1 General Damage

Figure 7-9 shows a general view of the building. It has CMU and brick veneer walls, wood roof framing, plywood decking, and an asphalt shingle roof. A tree fell on the lower roof and caused modest damage to the shingles, decking, fascia, and soffit. Some of the shingle tabs were also blown off.

7.2.3.2 Functional Loss

The tree-fall caused minor disruptions. (Note: Many of the observed fire stations were located near very large trees. Falling trees can cause significant damage to buildings, particularly wood-framed and pre-engineered metal buildings (PEMBs), and injury to occupants.)

7.2.4 Gulfport Fire Station #7 (Gulfport, Mississippi)

7.2.4.1 General Damage

This PEMB was severely damaged by storm surge (see Figure 3-22).

7.2.4.2 Functional Loss

Evacuation of the station before the storm avoided injuries and fatalities. Storm surge pushed some of the apparatus out of the building, thereby making the equipment unavailable for response. Fire hoses and other equipment were also destroyed. The station was not functional after the hurricane.

The fire station was not in a mapped floodplain (it was in Zone X), nor was it adjacent to a floodplain.

Figure 7-9.
General view of Gulfport Fire Station #5. A tree fell on the left side of the building (the tree had been removed prior to the MAT's observations) (estimated wind speed: 130 mph. Gulfport, Mississippi).

7.2.5 Pass Christian Fire Department (Pass Christian, Mississippi)

7.2.5.1 General Damage

The Pass Christian Fire Department is a PEMB with metal wall panels and a structural standing-seam trapezoidal metal panel roof (see Figure 7-10). The emergency generator is housed in a free-standing PEMB. Although the walls and roof of the generator building could be penetrated by windborne debris, placing a generator in a marginal enclosure such as this is better than having it exposed as shown in Figure 7-5. Roll-down metal shutters had been installed around 1999 at the exterior windows. (This work was funded via the FEMA Hazard Mitigation Grant Program.) However, the glazing in the personnel doors was not protected from windborne debris. Some new steel columns were also located on the backside of the building; they were anchored to the structural frame to provide additional wind resistance to meet current wind loads.

In an effort to keep the doors from blowing inward, fire engines had been positioned so that they were in contact with the rolling doors. However, the slats from at least one of the rolling doors were blown out of the door track. Placing apparatus against bay doors does not increase the resistance of the doors to outward failure, nor does this practice necessarily keep doors from blowing inward on the apparatus. In lieu of using apparatus to buttress doors, doors that possess inadequate wind resistance should be replaced with doors that have sufficient strength to resist design wind loads.

7.2.5.2 Functional Loss

The door damage caused minor disruptions. The facility was in use at the time of the MAT observations.

Providing the structural upgrades and installing the shutters at the windows was perhaps prudent, but it appeared that a comprehensive building evaluation had not been performed before executing the upgrades. Had a comprehensive evaluation been made, it is likely that the rolling doors would have been upgraded (because this is typically one of the most vulnerable elements of fire stations), and the door glazing should have been protected. The roof covering, roof vents, gutters, and downspouts also looked like they had inadequate wind resistance.

Figure 7-10.
General view of the Pass Christian Fire Department. The building in the foreground houses the emergency generator (estimated wind speed: 130 mph. Pass Christian, Mississippi).

7.2.6 Cuevas Volunteer Fire Department (Pass Christian, Mississippi)

7.2.6.1 General Damage

This is a PEMB with an exposed fastener metal panel roof (see Figure 7-11). It appeared that floodwater rose to about 1 foot above the floor line; however, it was reported that the water rose to a depth of 2 to 3 feet. The slats from at least one of the rolling doors at the apparatus bay dislodged from the door track (this was likely caused by wind, but may have been initiated by floodwater). The communications tower was also toppled.

7.2.6.2 Functional Loss

The building was occupied at the time of the hurricane. The door damage caused minor disruptions. The facility was in use at the time of the MAT observations.

There was a large stand of tall trees near three sides of the building, including the side from which the primary winds were coming. The trees substantially reduced the wind loads during this event. However, the fourth side of the building had a long, open, flat fetch. A future strong storm with primary winds coming over the open fetch would likely cause significant building envelope damage.

The fire station was not in a mapped floodplain (it was in Zone C). It was about 100 feet from Zone A and about 2,500 feet from Zone A9.

Figure 7-11.
General view of the Cuevas Volunteer Fire Department. Note the damaged apparatus bay door (estimated wind speed: 130 mph. Pass Christian, Mississippi).

7.2.7 Northshore Volunteer Fire Department (Slidell, Louisiana)

7.2.7.1 General Damage

This is a PEMB with unreinforced CMU walls and metal wall panels. The building was severely damaged by storm surge and waves from nearby Lake Pontchartrain (see Figure 7-12).

7.2.7.2 Functional Loss

This station was not occupied during the storm (it was typically not manned). The station was not functional after the hurricane, and has since been demolished.

The fire station was in a mapped floodplain, Zone A10.

Figure 7-12.
General view of the Northshore Volunteer Fire Department. Exposure C (estimated wind speed: 115 mph. Slidell, Louisiana).

7.2.8 A. J. Champagne Fire Station (Slidell, Louisiana)

7.2.8.1 General Damage

This two-story building was constructed in 1952 and remodeled in 1989 (see Figure 7-13). It has a wood-frame structure, EIFS over unreinforced CMU and brick veneer, a cementitious wood-fiber deck, and asphalt shingles. Floodwater rose to several feet above the floor line. There was flood/flotation damage to pad-mounted mechanical equipment located outside the building. Several of the shingles were blown away, some rooftop exhaust fans were damaged, and the communications tower collapsed.

7.2.8.2 Functional Loss

The building was occupied during the hurricane; the second floor provided safe refuge for the occupants. Although there was substantial interior water damage, the building remained operational. The floodwater subsided in a little over a day. Communications were interrupted due to the tower failure.

The fire station was in a mapped floodplain, Zone AE.

Figure 7-13. General view of the A. J. Champagne Fire Station (estimated wind speed: 115 mph. Slidell, Louisiana)

7.2.9 Third District Fire Headquarters (New Orleans, Louisiana)

7.2.9.1 General Damage

This is a one-story, steel-framed building with brick veneer walls, metal fascia panels, steel roof deck, rigid plastic foam roof insulation, and metal roof panels (see Figure 3-55). The metal panels had standing seams with snap-on batten covers.

A large portion of the metal roof covering was blown off the apparatus bay. In some areas the panels were still in place, but the batten covers had blown away. In other areas the batten covers were still attached, but they had lifted and it appeared that fatigue cracks occurred along the standing seams (see Figure 7-14).

7.2.9.2 Functional Loss

This station was occupied at the time of the storm. Some equipment was destroyed. The station was not functional after the hurricane. For some time after the storm, operations were conducted from a modular unit furnished by FEMA.

The fire station was not in a mapped floodplain; it was in Zone B, about 50 feet from Zone A9.

Figure 7-14.
This portion of the roof was not blown off, but some of the batten covers lifted. It appeared that fatigue cracks occurred along the standing seams (estimated wind speed: 105 mph. New Orleans, Louisiana).

7.2.10 Port Sulphur Volunteer Fire Department (Port Sulphur, Louisiana)

7.2.10.1 General Damage

This is a PEMB with metal wall panels and a structural standing-seam trapezoidal metal panel roof (see Figure 7-15). Storm surge severely damaged the rolling doors and walls. Wind blew off a portion of the roof panels.

7.2.10.2 Functional Loss

The station was not functional after the hurricane.

The fire station was in a mapped Zone A99.

Figure 7-15.
General view of the Port Sulphur Volunteer Fire Department showing damage caused by storm surge and wind. Note the inundated apparatus in the foreground (estimated wind speed: 125 mph. Port Sulphur, Louisiana).

7.2.11 Buras Volunteer Fire Department (Buras, Louisiana)

7.2.11.1 General Damage

Storm surge severely damaged the rolling doors and walls (see Figure 7-16).

7.2.11.2 Functional Loss

The station was not functional after the hurricane.

The fire station was in a mapped Zone A99.

Figure 7-16.
General view of the Buras Volunteer Fire Department (estimated wind speed: 130 mph. Buras, Louisiana)

7.3 Hospitals

When a hurricane strikes, hospitals, 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 of the 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 receive an influx of women in their third trimester of pregnancy so that they will already 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.

Thirteen medical hospitals and one psychiatric hospital were observed by the MAT. Most of the observed hospitals experienced building envelope damage and a few were flooded. The flood and/or wind damage placed significant burden on several of the hospitals, and three of the observed hospitals were completely taken out of service. The hospital discussed in Section 7.3.1 is one of the newer facilities that was observed. (Note: see Section 7.4.2 for the Keesler Air Force Base Medical Center.)

7.3.1 Garden Park Medical Center (Gulfport, Mississippi)

7.3.1.1 General Damage

This 130-bed hospital was opened in 2000 (see Figure 7-17). The building has EIFS over metal studs, and ethylene propylene diene monomer (EPDM) membrane roof coverings (some were ballasted and some were fully adhered).

The nearby Flat Branch Creek (Figure 7-17 inset) rose above its banks and reached a depth of about 6 inches inside the hospital. The EIFS blew off the hospital in a few areas (detachment of the gypsum board from the studs was the primary failure mode). With loss of the EIFS, water was able to enter the wall cavities. A penthouse door was blown off its hinges (see Figure 5-5). The roof membrane lifted and peeled back in some areas, and in other areas it ballooned. Rubber walkway pads were blown away and the roof membrane was punctured in several areas (some of the punctures were likely caused by the lightning protection conductors and/or air terminals that became detached; see Figures 5-122 and 5-123). Some of the vents for the lightweight insulating concrete (LWIC) and an exhaust fan were damaged by windborne debris (see Figure 7-18). (Note: unless in a penthouse or protected by screen walls, rooftop equipment is vulnerable to debris damage.) Some fan cowlings were blown off (see Figure 5-114) and several of the storm caps over exhaust ducts were blown away (Figure 7-18 inset).

Figure 7-17.
General view of Garden Park Medical Center. EIFS repairs were underway at the time the photo was taken. The inset shows one of the hospital's lower roofs and Flat Branch Creek beyond (arrow) (estimated wind speed: 130 mph. Gulfport, Mississippi).

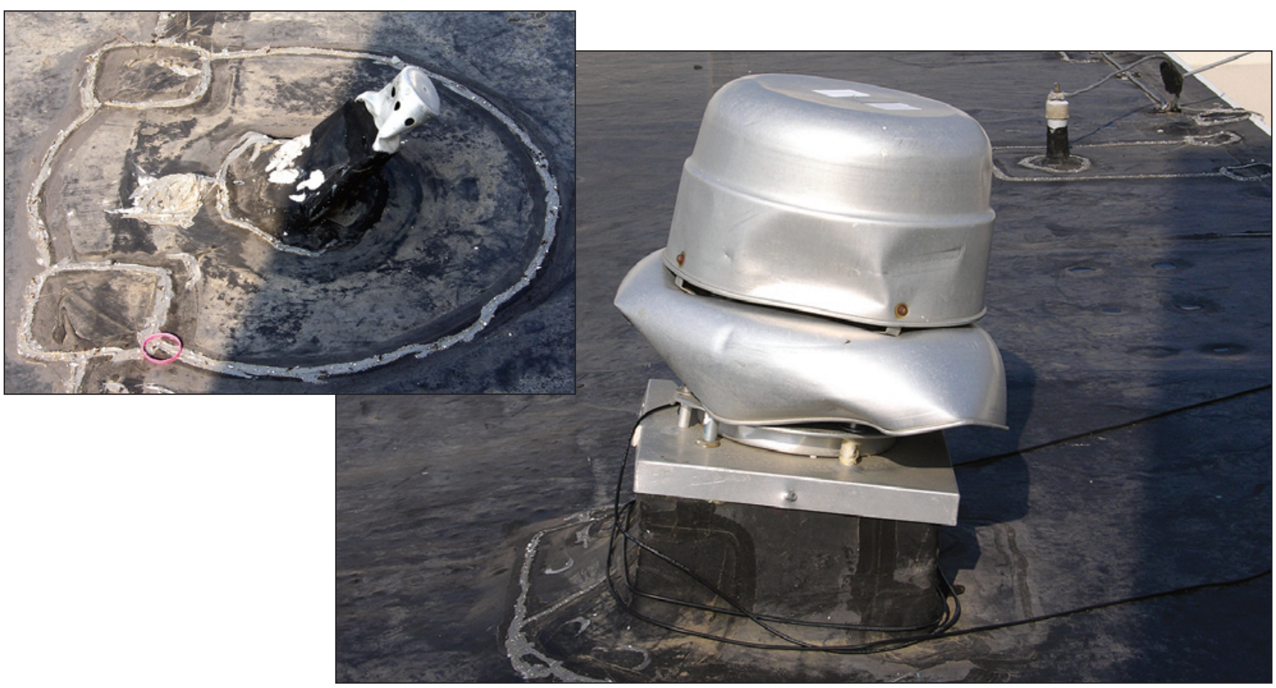

Figure 7-18.
This exhaust fan was struck by windborne debris. The inset shows a LWIC vent that was also hit by debris. Water could enter the roof where the vent cap was knocked off (estimated wind speed: 130 mph. Gulfport, Mississippi).

Although no exhaust fans were blown from their curbs, they were only marginally attached. At one fan that was on a 28 x 28-inch curb, the fan was only attached with one screw per side. Had the fan been attached in accordance with the guidance in the Hurricane Katrina Recovery Advisory section on attachment of rooftop equipment (Appendix E), there would have been six screws per side.

The municipal water supply was out of service for several days; therefore, the cooling towers were inoperable due to loss of water service, and the hospital was without air conditioning. The emergency power was also interrupted because the roof mounted air intake louvers blew off (see Figure 3-60). One of the communications towers was also damaged.

7.3.1.2 Functional Loss

Because of the flooding, the surgical suite was taken out of service for about 2 weeks. The entire fourth floor roof was temporarily reroofed after the storm. However, a substantial amount of water leaked into this floor (a nursing floor), and it was still being repaired nearly a month after the storm. Loss of air conditioning resulted in interior condensation and the warm/humid interior conditions interfered with the functioning of some of the electronic medical equipment.

A FEMA Disaster Medical Assistance Team (DMAT) was on site within 48 hours after the storm to assist with medical treatment.

The hospital was not in a mapped floodplain (Zone X).

7.4 Airports and Military Bases

Airports and military bases can provide valuable services in the aftermath of hurricanes. In the case of the Louis Armstrong New Orleans International Airport, after Hurricane Katrina the airport served to evacuate a large number of citizens from the New Orleans area. ASCE 7 does classify some airport and military facilities as Category IV buildings; however, as discussed in Sections 7.4.1 and 7.4.2, ASCE 7 does not classify all airport or military facilities as Category III or IV buildings. Therefore, for those buildings that will play vital roles in response and recovery, it is prudent to voluntarily design them as critical and essential buildings even though it is not required to do so.

7.4.1 Gulfport-Biloxi International Airport

Airports are vital to hurricane response and recovery. After a hurricane strikes an area, the primary initial function of nearby airports is to receive supplies and emergency response personnel being airlifted into the impacted area. A functional airport within an impacted area also facilitates arrival of insurance adjustors, volunteers, and contractors. Damage to airport facilities often prohibits the use of airports within impacted areas for a few or several weeks. When this occurs, airports farther away from the impacted areas have to be used. A fully functional airport is also needed to support normal commerce as surrounding communities begin their recovery.

The only airport facilities that ASCE 7 designates as critical and essential are aviation control towers, air traffic control centers, and emergency aircraft hangars. However, passenger terminals are also vital to airport operations. Cargo buildings may also be vital; if their loss would hamper receipt of emergency supplies, they too should be voluntarily designed as critical and essential buildings.

The MAT observed the Gulfport-Biloxi International Airport. All buildings on the airport complex were significantly damaged by wind and water from Hurricane Katrina.

7.4.1.1 General Damage

Damage to the airport control tower is shown in Figure 7-19. Wind pressure and windborne debris broke about 30 percent of the tower wall glazing and damaged the metal wall cladding.

The commercial air terminal had four operational airline gates and two new gates under construction. The hurricane damaged two operational gates, leaving only two gates available for flights. Damage to the terminal included loss of some of its EIFS wall cladding (see Figure 7-20), damage to the built-up roof, and loss of two large window curtain walls (see Figure 7-21), by wind pressures.

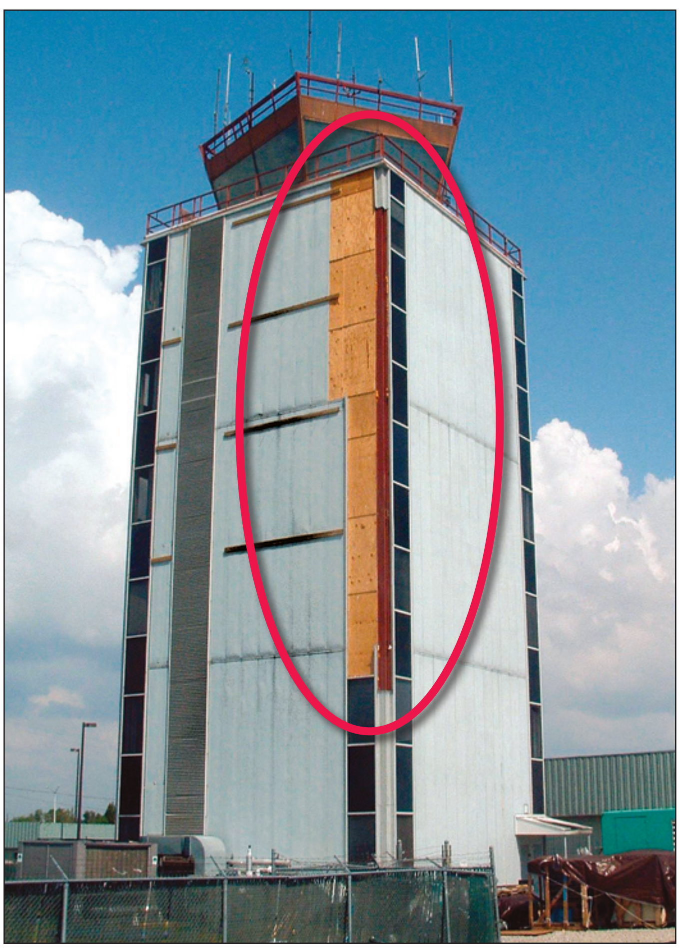

Figure 7-19.
Airport control tower. Note damaged glazing and cladding (circle) (estimated wind speed: 130 mph. Gulfport, Mississippi).

Figure 7-20. Damaged terminal gate at the Gulfport-Biloxi International Airport. Note the damaged roof coping (arrow) and the wind damaged EIFS (circle) (estimated wind speed: 130 mph. Gulfport, Mississippi).

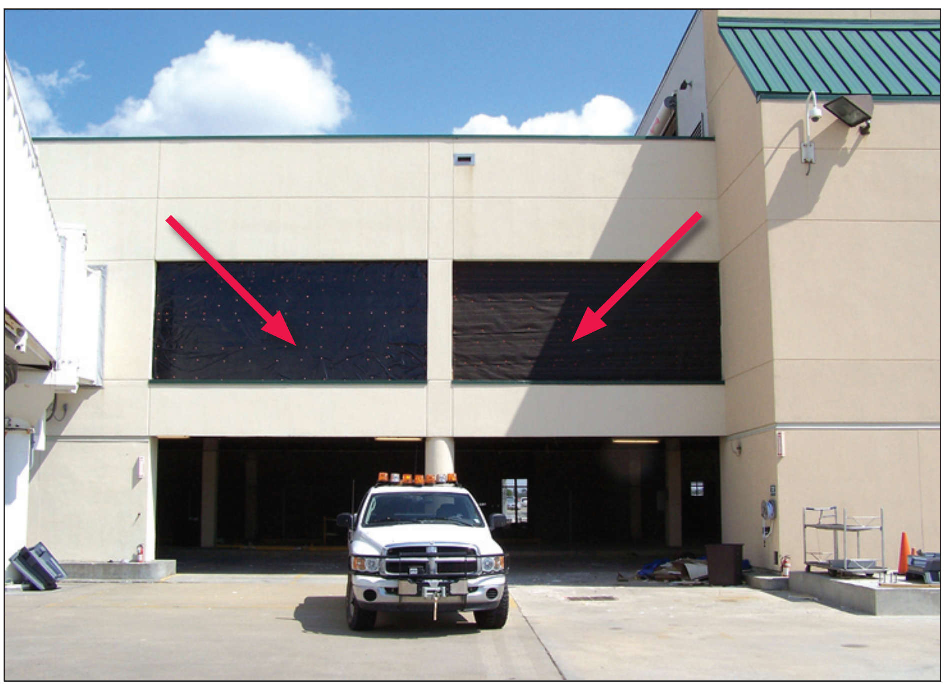

Figure 7-21. Glazed curtain wall pushed inward by wind pressure. Note the location of damaged curtain walls with temporary weather seal (arrows) (estimated wind speed: 130 mph. Gulfport, Mississippi).

Figures 7-22 and 7-23 portray the wind damage to the airport cargo building. The building was constructed with a pre-engineered metal building frame with metal siding. Damage to the building resulted when positive wind forces pushed in the two large rolling doors. The building became internally pressurized, causing the loss of most of the wall panels on the west side of the building and some of the roof panels.

Figure 7-22.
Wind damage to the southwest corner of the airport cargo building. Note the pressure damaged rolling door (circle) and the west wall panels removed by combined internal and external pressures (arrow) (estimated wind speed: 130 mph. Gulfport, Mississippi).

Figure 7-23.
Roof and wall panel damage at the airport cargo building. Note the damaged rolling door at the southeast corner (circle) and roof and wall damage (arrows) (estimated wind speed: 130 mph. Gulfport, Mississippi).

The airport Fixed Based Operator (FBO) building servicing general aviation experienced roof decking and roofing removal when one of its large sliding hangar doors was blown into the building. This failure allowed the building to become internally pressurized. Figure 7-24, an aerial view, portrays the extent of the roof damage. Figure 7-25 shows the hangar door on the ground.

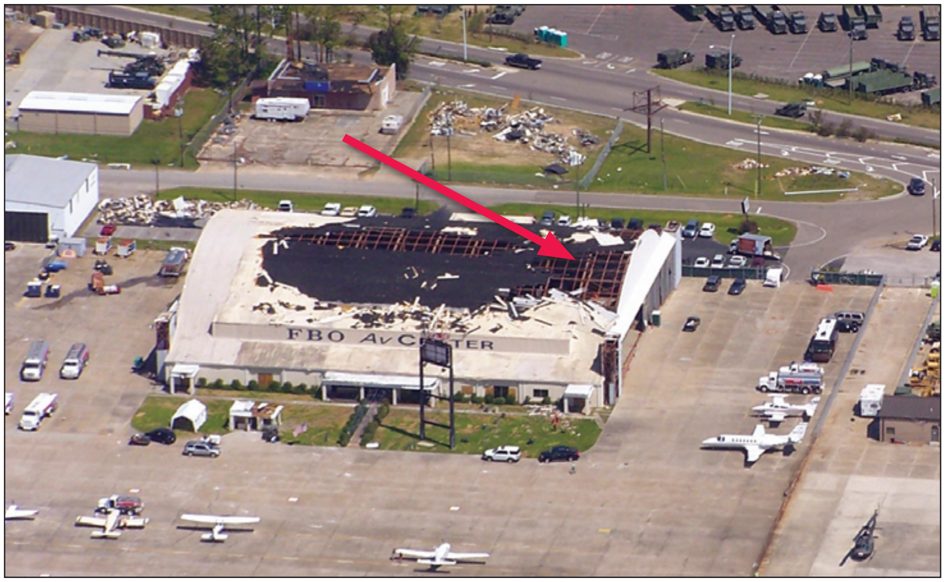

Figure 7-24.
Airport FBO building. Note the decking and roofing materials removed by wind pressure (arrow) (estimated wind speed: 130 mph. Gulfport, Mississippi).

Figure 7-25.
Sliding door blown into hangar (estimated wind speed: 130 mph. Gulfport, Mississippi)

7.4.1.2 Functional Loss

Prior to Hurricane Katrina, the Gulfport-Biloxi Airport handled 25 flights per day; after the storm, that number was reduced to 12 flights per day. The very high frequency (VHF) visual omnidirectional range (VOR) navigation system building was destroyed by the storm winds, thereby affecting direct navigation to the air field. The visual approach lighting system was damaged by floodwater at the ends of the runway, restricting the airport to daylight operation only.

The wind damage to the terminal building caused the loss of two functioning departure gates, and the winds damaged and slowed the construction completion of the two new gates. Wind damage to the cargo building left the airport without any large-scale cargo storage capabilities. Maintenance of general aviation aircraft was limited due to the FBO building damage.

7.4.2 Keesler Air Force Base

In addition to their national defense mission, military bases in hurricane-prone regions often provide needed response and recovery services. If key buildings on a base in an area impacted by a hurricane are damaged, the response can be impaired.

ASCE 7 states that buildings having critical national defense functions shall be designated as critical and essential facilities. Thus at any given military base, in addition to buildings normally classified as critical and essential (such as hospitals and fire stations), only those buildings that have critical defense functions need to designated as Category IV buildings. However, other buildings on a base in a hurricane-prone region that could also be vital to providing emergency response to surrounding communities should be identified and voluntarily designed as critical and essential facilities.

The MAT observed Keesler Air Force Base (AFB) in Biloxi. It is a primary military electronics and communications training center and medical training center. Home to over 8,000 military personnel, the base encompasses over 1,500 acres fronting Biloxi Bay on the north, and is located two city blocks from the Gulf of Mexico to the south (see Figure 7-26).

Figure 7-26.
Aerial of Keesler Air Force Base (estimated wind speed: 120 mph. Biloxi, Mississippi)

7.4.2.1 General Damage

Wind and water damage to the base buildings was extensive, with most buildings exhibiting some form of damage. Repair and reconstruction costs for Keesler AFB were estimated at $915 million. The types of buildings surveyed by the team included heavy engineered buildings, lightweight pre-engineered buildings, and residential buildings. The engineered buildings performed well structurally, but experienced loss of roof and wall coverings, resulting in water intrusion. The majority of the on-base housing was affected. Damage included loss of roof coverings, glazing damage, and water inundation. Flood levels varied from 2 feet to nearly 8 feet. (The majority of on-base housing is located in Zone C.)

The 81st Civil Engineering Squadron is responsible for carrying out design and construction responsibilities on Keesler Air Force Base. Programming personnel within the engineering flight typically develop programming documents that define the scope of work and estimate the cost for a given project. These documents are then sent to a review office, the Air Education and Training Command (AETC) in this case, and the Pentagon for purposes of project prioritization among other base projects in the given command and the Air Force, for funding.

The Keesler Civil Engineering Squadron uses the latest effective ASCE 7 criteria and model building codes for project design and bid documentation. Federal facilities, such as military bases, are self-insured. The Department of Defense (DoD) requests funding from Congress to repair or replace facilities damaged or destroyed by storms.

Military bases are not typically mapped or reviewed by FEMA for NFIP compliance because the Pentagon has this responsibility. Keesler AFB is mapped by the NFIP, but is not subject to local ordinance. As a Federal agency, the Pentagon is responsible for carrying out all the requirements noted above. This includes:

1. Executive Order 11988, Floodplain Management
2. Executive Order 11990, Protection of Wetlands

Both of these Executive Orders originated with the President of the United States and are codified and defined in:

1. The Code of Federal Regulations, Title 44
    a. Part 9, Floodplain Management and Protection of Wetlands
    b. Part 59, General Provisions
    c. Part 60, Criteria for Land Management and Use

7.4.2.2 Functional Loss

Most personnel were evacuated from the base prior to Hurricane Katrina. However, about 350 essential personnel remained and took shelter in Allee and Wolfe Halls (see Figure 7-27). During the storm, large portions of the roof covering blew off, resulting in major water leaks inside the building, and great anxiety for the building occupants.

The Keesler Medical Center (see Figure 7-28), which is used annually by 56,000 military retirees and active duty personnel, was flooded during the storm, with surge spilling into the basement of the building and inundating the emergency generators. The medical center was not expected (at the time of this report) to be fully operational until later in 2006. The hospital was not in a mapped floodplain (Zone C).

Figure 7-27.
Allee Hall, place of refuge for base essential personnel during the storm (estimated wind speed: 120 mph. Biloxi, Mississippi)

Figure 7-28.
Keesler AFB Medical Center (estimated wind speed: 120 mph. Biloxi, Mississippi)