6

Performance of Critical and Essential Facilities

Critical and essential facilities are needed to lead and manage response and recovery operations during and/or after an event. Hurricane Charley had a significant impact on critical and essential facilities within the path of highest winds; overall, the facilities experienced damages that resulted in these facilities being unable to be utilized for their intended function(s) for days, weeks, or several months after the hurricane.

According to Table 1606 of Section 1606 of the 2001 FBC, critical and essential facilities are facilities including, but not limited to, hospitals (and other medical facilities), fire and police stations, primary communication facilities, disaster (emergency) operations centers, and power stations and other utilities required in an emergency.[1]

[1] Schools are listed in the IBC and NFPA 5000, not the FBC.

Hurricane Charley produced a narrow band of winds from Charlotte Harbor to Orlando that can be said to have met or exceeded a design wind event for many buildings designed and constructed for use as critical and essential facilities. Although many of these facilities were older, they should have been designed to perform well at higher wind speeds.

Critical and essential facilities that were damaged include EOCs, fire and police stations, hospitals, schools, and shelters. Most damage was to older facilities; however, newer facilities experienced some failures in both their structural and envelope systems (see Chapter 5 for photographs and discussion of envelope damage). The MAT observed some structural damage (and isolated instances of collapse), significant cladding and equipment damage (resulting in water intrusion), and significant loss of function due to the hurricane at these types of facilities. Except for occasional shuttering of glazed openings, the investigated buildings did not appear to have been designed and constructed with wind-resistance enhancements to the building envelope and rooftop equipment.

6.1 Emergency Operations Centers

EOCs are key buildings in preparing for and responding to an event from the local to the state level. Due to the risk of hurricanes in Florida, there is a State EOC in Tallahassee and EOCs in almost every county in the state. Numerous local EOCs (fire or police stations) and a county EOC were impacted by Hurricane Charley. As the storm made landfall and moved inland, the hurricane tracked just west of the Charlotte County Sheriff's office/EOC, exposing the facility to the northeast (strongest) quadrant of the storm. Both the county Emergency 911 and EOC were relocated from the county administrative building to this pre-engineered metal building in 1999 and 2000, respectively. This building experienced significant damage and could not function, leaving Charlotte County without its Sheriff's office and EOC. Damage to numerous fire and police stations that function as local/community EOCs was also observed and is discussed in Section 6.2.

The metal building housing the Charlotte County Sheriff's office/EOC was constructed in 1991 and 1992 to the SBC for use by a private company. This building is a pre-engineered metal structure with a long span, shallow pitched gable end roof. The building roof covering and wall cladding (on the upper portion of the wall) is composed of metal panels attached to purlins (roof areas) and wood studs (wall areas). The lower portion of the building exterior is composed of masonry units.

Before moving into the building in 1999 and 2000, the county had consulted with the Florida Department of Community Affairs (FL DCA) for advice on design criteria for critical and essential facilities. FL DCA provided the county building hardening guidance used by the state to design and retrofit buildings for use as Enhanced Hurricane Protection Areas (EHPAs) since the mid-1990s. County emergency management staff was aware of the vulnerabilities and limitations of this facility; it was designed for office use with an Importance Factor of I = 1.0 as opposed to 1.15 for essential facility use. The county determined that mitigation of the existing structure to meet EHPA requirements was not cost-effective. To address these vulnerabilities, the county installed shutters on the existing facility to provide improved protection and performance and moved forward with a project to design and construct a new and hardened EOC adjacent to the existing facility. At the time the hurricane struck, architectural floor plans had been developed, but funding for the facility was still being secured.

6.1.1 General Damage

Most of the damage that was observed at the Charlotte County EOC (Figure 6-1) was to the building's envelope (i.e., the roof and wall coverings). Examples of this damage can be seen in Figures 6-1 and 6-2, which illustrate typical roof panel loss and wall panel loss, respectively. Roof damage appeared to center around the failure of the clips that either released from the purlins (Figure 6-2) or from a failure of the clip/panel connection. Additional roof failures were observed at the overhangs located at the rear of the facility at the two large rolling and sectional doors. Figure 6-3 shows the overhang on the southwest building corner.

Figure 6-1. Exterior wall and roof damage at Charlotte County EOC

Figure 6-2.
Failure of wood stud wall supporting wall panels above masonry wall (Charlotte County EOC)

Wind induced wall damage was limited to the upper portions of the exterior walls constructed of metal panels attached to the steel frame and to wood studs acting as purlins between the frame and the top of the masonry walls. Failures observed varied from clip and connection failures, similar to those observed with the roof panels, to complete failures of stud-supported sections (Figure 6-3).

Some isolated structural damage was observed in the roof framing. Damage to the frame was observed in areas where the roof panels were removed from the building by the wind. Damage was typically limited to deformed purlin members, but a few of the primary structural members were also damaged.

The damage to building components described above is avoidable and these systems can be designed and constructed to resist wind loads and windborne debris. The failure of the building envelope at the EOC should not have occurred. The damage around the site is consistent with a wind speed in the range of 120 to 140 mph 3-second peak gust. This wind speed is close to the design wind speed for this portion of the county for which at the time the building was designed in accordance with the 1991 SBC (110 mph fastest mile wind speed = 130 mph 3-second peak gust).

Figure 6-3.
Failure of roof and soffit panels at rear awning (Charlotte County EOC)

6.1.2 Functional Loss

The failure of the building envelope did not lead to an immediate or catastrophic failure of the structural framing system, but allowed damaging amounts of rain and debris to enter the facility. This slow failure of the building envelope allowed individuals within the building to take shelter elsewhere, but should not be considered a "success" for a critical or essential facility, especially an EOC. In addition to the loss of county records, documents, computer equipment, and communications equipment, the community lost its ability to respond to and manage the disaster without outside assistance. Unstable roof framing, missing roof and wall panels, and ponding water on the floor crippled the facility and the ability of the county to respond on its own. Only portions of the building could be used during the response and other county, state, and Federal resources had to be brought to the site to provide communications, assessment, and control functions.

Communities understand how important EOCs or other critical facilities are when they are lost. The damage and loss of function experienced at the Charlotte County EOC underscores the importance of proper design and construction of critical and essential facilities and also the appropriate selection of materials and building systems. This EOC was housed in a building that was constructed with a building system known for economy and not its redundancy or robust strength. Pre-engineered buildings with light-metal panel exteriors are

susceptible to damage and loss of function because they provide a relatively small factor of safety for the structural system (widespread use of one-third stress increase at least until 2002) that is reduced further by fastening the metal panels using fastener schedules that provide factors of safety.

Other building systems can be selected that provide larger factors of safety against structural failure and are more resistant to progressive collapse. Further, this building system utilized a combined roof deck and roof covering in the form of the metal roof panels. Thus, loss of the roof covering led to loss of roof deck and significant interior damage. When separate roof covering systems are used atop structural decks, additional and secondary levels of strength and protection are provided. Loss of the roof covering in buildings with separate structural decks and secondary layers of moisture protection would expose the roof deck to wind, rain, and debris. However, the separate roof deck and the secondary layer of protection on the deck would resist most water intrusion and likely prevent loss of function within the facility.

6.2 Fire and Police Stations

If fire and police stations cannot remain operational during an event, the community loses a valuable and important part of its emergency response capability. Several fire and police stations in Charlotte and Lee Counties were damaged during the hurricane from high winds and windborne debris. Of the nine stations documented in this section, five of them experienced enough damage to take them off-line for the event and for weeks or months following the event.

6.2.1 General Damage

The MAT observed significant damage in fire and police stations in the path of Hurricane Charley. Although older facilities tended to perform poorly, there were new buildings that sustained significant damage as well. With these types of facilities, it is expected that they will not only survive a hurricane, but remain operational throughout the storm. If damage does occur to the building, even seemingly insignificant damage (e.g., broken roof tiles or blown in sectional doors) can lead to an interruption in emergency services, thus affecting the post-disaster recovery. Table 6-1 summarizes the damages and loss of functions at the stations, and whether the facilities operations were interrupted as a result of the damage. Figures 6-4 through 6-7 illustrate some of the observations of the facilities. Additional photos taken at these sites are presented and discussed in sections of this report spe-

cific to the building structural type (Chapter 4) or the cladding or equipment damage (Chapter 5).

6.2.2 Functional Loss

Most of the fire and police stations that were damaged were unable to immediately respond to emergencies related to the hurricane. Further, many of these stations lost the ability to perform some or all of their functions. In many cases, service functions were returned within a few weeks through the repair of damaged equipment and dispatching and operational support provided from other facilities. However, long-term impacts to housing, response time, and loss of specialized equipment are being experienced and cannot be remedied until the fire and police stations are repaired or replaced.

Figure 6-4. Overview of west side of Port Charlotte Fire Station No. 12

Table 6-1. Summary of Fire/Police Station Damage and Functional Loss from Hurricane Charley

Fire/Police Station Year of Construction	Roof Covering Damage	Roof Deck Damage	Other Envelope Damage
Port Charlotte: Charlotte County Fire/ EMS No. 12 Early 1998	Metal panel roof covering loss in areas where structure did not fail. Primary damage was observed at hip flashing; additional damage at clip fasteners to deck. Clips were not installed at even spacing.	Loss of wood trusses and wood panel roof deck over apparatus bays (likely cause was pressurization of bay due to loss of rolling and sectional doors). See Figure 6-4 (note that clips/straps were used to secure trusses to walls).	Loss of all three bay doors on east side of station during period of positive pressure acting on doors. Two of the three doors' tracks remained in place. Broken windows around building exterior.
Port Charlotte: Fire Station No. 1 1980	BUR covering (mineral surface) was damaged due to uplift failure of deck system below. Base sheet of covering was attached to deck with tube-nails.	Numerous cement-fiber deck panels (secured with clips) failed from uplift forces. Openings and unstable sections of roof deck were located over apparatus bay and functional areas.	Two of three sectional doors (fully glazed) had broken glazing and were blown into apparatus bays. Windows and doors were broken or damaged. See Figure 6-5.
Fort Meade Fire Station	Tile roof covering loss and damage		
Punta Gorda: Fire Station No. 1 and Public Safety Complex 2002	Tile roof covering loss and damage. See Figure 6-6.		Soffit damage and failures. See Figure 6-7. Damage to rolling and sectional doors at several bays.
Punta Gorda: Aqui Esta Fire Station 2000	Minor damage to V-crimp metal roof panel system. Observed damage was noted at a hip lap.		Minor damage to V-crimp metal roof panel system. Observed damage was noted at a hip lap.
Port Charlotte: Charlotte County Fire and EMS Station No. 7 1976	Asphalt roof shingles failed across roof. Some covering loss was initiated due to gable end wall failure; however, other shingle loss was due to poor installation of shingles with staples, some observed to be at 45 degree angle to shingles.	Damage at gable included loss of wood panel roof decking	The two bay doors were in-place, but damaged. The rear bay door was blown into the apparatus bay and one personnel door was suctioned off the building. Window breakage and damage to perforated soffit was observed.
Punta Gorda Fire Station No. 2	Loss of some metal panel roof covering. Roof panels of this pre-engineered metal building were R-panel system.		Three of four sectional doors were blown into apparatus bays or were damaged. Undamaged newer door was heavily reinforced and attached to the wall at 18 inches on center with 1/4-inch lag bolts.
Matlacha/Pine Island Fire Department	Significant loss of V-crimp metal roof panels across most of roof	Loss of more than 50 percent plywood roof decking (attached with staples)	Three of four sectional doors were blown into apparatus bays. The door that did not fail was installed in 2002.
Cape Coral Fire Department	Isolated areas of shingle loss		Shutters prevented window damage. One bay door of six was damaged - track and door detached. Track was secured at 4 feet and greater on center with lag bolts. Failed door in apparatus bay appeared to be inadequately connected to wall.

Water Intrusion Damage	Structural Damage	Damage to Equipment	Off-line/Unable to Respond	Additional Comments
Primary water intrusion as a result of loss of bay roof and gable ends. Lower roof sections remained with minimal water intrusion issues. Additional water damage from pipe broken during roof blow-o ff.	Loss of gable roof structure over apparatus bays. Damage observed at bond beam above garage doors due to roof failure.	Equipment in apparatus bay was damaged. Broken windows and windshields were most prevalent. These vehicles were considered operational and moved to other fire stations.	The station was taken off-line during the hurricane, and remained off-line since the event.	This fire station was sheltering approximately 60 people during the storm and at the time of the roof failure. FEMA mitigation funding is being provided to assist with the reconstruction of this station.
Water infiltration occurred when building roof deck separated from building.	Structural damage appeared limited to roof deck loss. Steel joists and walls supporting decks appeared to experience only water damage.		The station was taken off-line during the hurricane and has remained off-line since the event.	This fire station was under contract for renovation when Charley struck. Repairs will be incorporated into the renovation project.
			The station remained operational.	
Significant water damage was observed related to the loss of soffits. Water damage in both roof and wall systems.		Approximately 40 to 50 police vehicles experienced body damage and glass damage from tile debris.	The station remained operational during the hurricane, but water damage limited some operations and response ability.	Functioned as town EOC during the event - approximate staff level was 100 personnel.
Significant water damage was observed related to the loss of soffits. Water damage in both roof and wall systems.	No storm induced structural damage was observed. Pre-cast concrete twin-tee roof structure over apparatus bay did not appear damaged.	Antenna structure was damaged.	The station was taken off-line during the hurricane and has remained off-line since the event.	Station is being evaluated for mitigation. Alternate site out of floodplain is being considered.
Building experienced significant water intrusion due to roof deck loss and soffit damage. Some light water damage due to debris impact that penetrated building exterior.	Loss of significant percentage of roof deck wood panels and structural roof members.	No damage to firefighting equipment. An outside compressor unit was damaged when it was displaced off its pad. Antenna unit collapsed onto roof of station.	The station was taken off-line during the hurricane and remained off-line for several months after the event.	Repairs and mitigation to existing station have been put on hold since the County is considering relocation of this station to improve community response.
Interior water damage due to loss of roof covering to operational areas.	Structural damage to walls and girts of the pre-engineered metal building at the main door area. Evidence of spalling failure between wall and slab connections was evident.	No damage to firefighting equipment. Antenna unit collapsed onto roof of station.	The station was taken off-line during the hurricane and remained off-line for several months after the event.	One of the two towers that collapsed just missed impacting the emergency generator.
Interior water damage due to loss of roof covering to operational and sleeping areas was sign ificant.	Loss of roof decking on upper levels; however, remainder of structure did not experience damage.	No damage to firefighting equipment moved prior to the storm's arrival. Two communications towers collapsed during the hurricane.	The station remained operational.	
Isolated water leaks due to roof shingle loss. Most water leaks occurred in the computer room of the facility.	No structural damage observed.	No damage to firefighting equipment. An outside compressor unit was damaged when it was displaced off its pad.	The station remained operational.	According to on-site fire station staff, the facility had been retrofitted for use as an EOC. Windows were protected with shutters.

Figure 6-5.
View of damaged garage door and interior of Port Charlotte Fire Station No. 1; note missing roof deck panels over apparatus bay.

Figure 6-6.
Overview of Punta Gorda Fire Station No. 1. The tile roof had been removed and a new roof was being installed. Note the damaged doors.

Figure 6-7. Damaged soffit at Punta Gorda Public Safety Complex

6.3 Hospitals

The MAT assessed a number of hospitals in Punta Gorda, Port Charlotte, and Arcadia. Structurally, these facilities performed well, with the exception of the collapse of a pre-engineered ancillary building at a hospital in Arcadia; however, the most significant damage resulted from water intrusion due to roof covering and rooftop equipment failure, and window damage from roof aggregate. The aggregate also caused damage to adjacent buildings and hospital staff vehicles.

6.3.1 General Damage

The most disruptive damage was caused by the loss of roof coverings and rooftop equipment, and the loss/breakage of unprotected glazing. This damage to the building envelope led to extensive internal damage in key hospital areas such as emergency rooms, intensive care units (ICUs), and general use areas (i.e., patient rooms and offices).

Each of the hospitals had sections of the facility built at different times, constructed with a variety of roof coverings, including aggregate surfaced built-up roof (BUR), modified bitumen, and single-ply

membranes. In many cases, failure was initiated with the metal edge flashing that led to the loss of the roof covering. Figures 6-8 and 6-9 show some of the damage.

Figure 6-8.
Aggregate damaged the windows to ICU rooms at a hospital (Arcadia)

The gutters lying on the lower roof in Figure 6-8 came from the right side of the upper roof and may have caused some of the glass breakage. However, the majority of the damage was broken by flying aggregate from the hospital's BURs.

Figure 6-9.
Roof covering damage resulting in water intrusion, which required evacuation of a skilled nursing facility (Arcadia)

6.3.2 Functional Loss

Hospitals experienced a significant loss of function. First, almost all critical care facilities were impacted and lost (taken off-line) during the hurricane and in the days immediately following the event. Extensive damage occurred at a number of the hospital facilities, affecting both urgent/critical care units and general patient care rooms. At the Charlotte County Regional Medical Center, temporary resources were required to restore critical care operations after the hurricane. Cost implications and impacts to all hospital operations had not been calculated at the time of this report.

6.4 Schools

The MAT evaluated nine schools in Charlotte, Lee, and De Soto Counties. The schools included elementary, middle, and high schools composed of one or more buildings, one- to three-stories high, and constructed between the mid-1920s and the present. In addition to their traditional role as educational facilities, schools often play an import role in providing space for emergency response and recovery after a hurricane; therefore, their loss can greatly impact a community.

This section provides a discussion of damages observed at the schools visited by the MAT. A more detailed discussion of schools specifically evaluated for and used as shelters is presented in Section 6.5.

6.4.1 General Damage

Damages to structural walls of schools evaluated by the MAT were limited to a few older buildings with walls or parapets constructed of URM or hollow clay tile. At one high school, the collapse of hollow clay tile walls and URM parapets caused extensive damage (Figures 6-10 and 6-11). Most exterior wall surfaces observed at school buildings did not suffer significant damage.

Damages to roof framing systems at schools occurred at large, gable end roofs with light-metal trusses where the gable end was pushed into the building due to inadequate lateral bracing and collapsed (Figure 6-12). A few plywood and OSB roof sheathing damages were also encountered along the edges and at the corners of older school buildings. Roof coverings and soffits were the most commonly damaged elements of school buildings evaluated by the MAT. Typical roof covering damages included loss of roof membrane systems due to inadequate connection to the roof deck, loss of edge flashing or coping,

or tearing of the membrane from debris impact. Metal roof coverings were lost or damaged due to inadequate connections or a loss of the edge flashing. Thin metal panel soffits and lightweight composite panel overhangs (which functioned as soffits) were often lost due to inadequate connections or excessive deflections caused by wind pressures along the edges and corners of the building (Figure 6-13).

Figure 6-10.
Hollow clay tile wall/ parapet damage to roof of a high school auditorium (Punta Gorda)

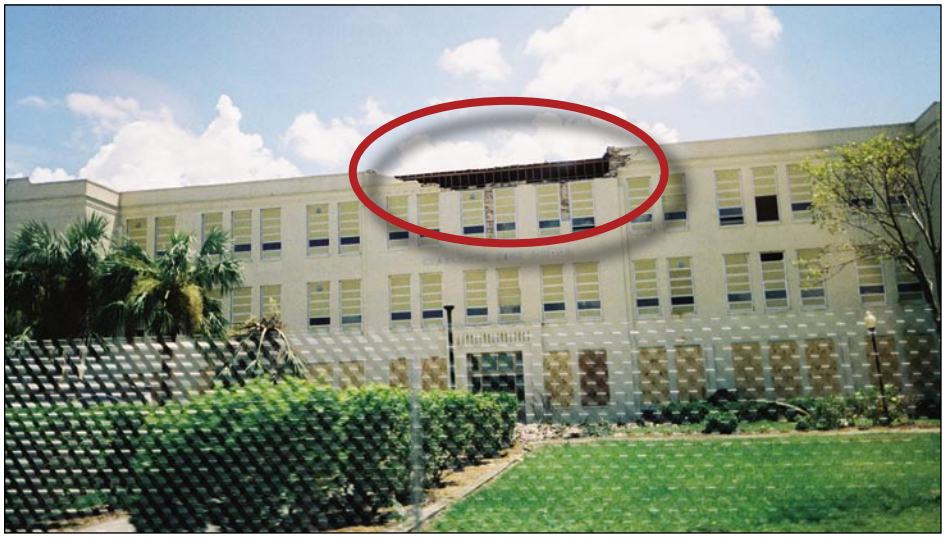

Figure 6-11.
URM parapet damage to front façade of a high school (Punta Gorda)

Figure 6-12.
Collapsed gable end wall at an elementary school (Deep Creek)

Figure 6-13.
Loss of lightweight composite panel overhang at an elementary school (Charlotte Harbor)

A few single and double metal entry doors in school buildings evaluated by the MAT were damaged due to inadequate locks or door frames that were not properly connected to the walls, which caused the doors to blow open or out during the storm. Some metal-framed windows constructed with annealed glass panes were broken due to debris impact and/or bending of the frames that supported the panels (Figure 6-14).

Figure 6-14.
Broken window damage at a high school (Punta Gorda)

Damages to rooftop mechanical equipment were noted at several schools. Most damages occurred when rooftop HVAC units and vents were knocked over or blown off by the wind, which caused tears in the roof coverings.

Many school buildings evaluated by the MAT suffered damage or collapse of metal awnings and walkway canopies, typically due to inadequate anchorage of the roof sheathing or the posts that supported the awnings and canopies (Figure 6-15). Several portable classrooms were damaged by debris impact or destroyed, presumably due to inadequate foundation anchorage (Figure 6-16). Some sections of chain-link fencing collapsed due to wind-blown debris that accumulated. A few pre-stressed concrete light poles at school athletic facilities were cracked or snapped due to inadequate steel shear ties.

Figure 6-15. Collapsed metal walkway canopy at a high school (Punta Gorda)

Figure 6-16. Damaged portable classroom unit at an elementary school (Charlotte Harbor)

6.4.2 Functional Loss

Functional losses to school buildings observed by the MAT included loss of building contents, loss or disruption of school functions and, in some cases, a loss of storm shelters. The majority of school building content damages and functional losses occurred when elements of the building envelope were breached. The most common damages observed by the MAT were roof covering loss or damage by wind pressures or torn by windborne debris and the associated water intrusion damage. In other cases, doors blown open by wind pressures or windows shattered by debris impact allowed wind and water to enter the building. Both events led to widespread water and wind damage to ceilings, lighting, floors and contents, and a disruption or loss of school operations. Because

most building envelope damages occurred over long span roofs or at entrances, the parts of the school that were most often impacted by building envelope damage included larger areas such as cafeterias, gymnasiums, auditoriums, and main entrance corridors.

Other school building content damages and functional losses occurred as a result of major structural failures from wind pressures and debris impact forces. Examples of major structural damages observed by the MAT included the collapse of older unreinforced masonry walls, failure of long span gable end roofs due to lack of bracing, and destruction of portable classroom units. These types of structural failures led to additional contents damages and long-term functional losses as damaged sections or units were repaired, redesigned, and/or replaced.

6.5 Shelters

Shelters can be defined in many ways, depending on their use. A shelter is a place where people go to take refuge during an event (often called storm shelters) or to recover when they cannot return to their homes immediately after an event due to widespread storm damage. For the purposes of this report, the term "shelters" refers to storm shelters or buildings where people went to take refuge from the winds and storm surge during Hurricane Charley. The MAT assessed the performance of these storm shelters to document how these critical and essential facilities performed and to provide feedback to FL DCA and local emergency managers who make decisions on opening and using shelters during storm events.

Further, because several school buildings evaluated by the MAT were designated as storm shelters, damages to schools in some communities led to a loss of shelters that could protect residents from injury during subsequent hurricanes. The loss of schools that function as storm shelters is particularly difficult in smaller communities where they often serve as convenient places to provide recovery assistance to residents in the days and weeks immediately after a disaster event.

The remainder of this section presents observations from site inspections of several shelters that were impacted by Hurricane Charley. Following these observations is a section that outlines the Florida Statewide Emergency Shelter Plan (SESP). This plan provides a listing of shelters that have been evaluated with minimum criteria for shelter performance, as well as the design guidance for the design and construction of hurricane shelters and EHPAs (also covered by the 2001 FBC in Section 423). Since the mid-1990s, FL DCA, through the Division of Emergency Management, has assessed and mitigated build-

ings for use as hurricane shelters and, since 2000, has increased shelter capacity in the state by over 500,000 spaces.

6.5.1 General Damage

The MAT was provided information on the shelters used in response to Hurricane Charley. Three buildings in Charlotte and De Soto Counties used as shelters during the event were visited to document their performance. These shelters include the recently constructed and largest shelter on the De Soto County shelter list (Turner Agri-Civic Center in Arcadia) and the only two shelters on the Charlotte County shelter list (Port Charlotte Middle School and Liberty Elementary School).

6.5.1.1 Turner Agri-Civic Center, Arcadia

Records from the FL DCA hurricane shelter program indicate that this building, which was completed in September 2002, was designed by an architect with a design wind speed of 140-mph 3-second peak gust per ASCE 7-98 with an importance factor of I=1.0. The intent was to design a facility to the minimum EHPA standards (see Table F-1 in Appendix F). The building was identified in the FL DCA 2004 SESP report as having 1,523 available shelter spaces and was providing shelter for approximately 1,400 people when it began to fail during the event (Figure 6-17). This shelter facility was included in the 2004 SESP shelter list because a letter from the architect of record stated that the shelter area was designed in compliance with the EHPA minimum requirements; in fact, this building had not yet been evaluated by FL DCA for compliance with the EHPA design requirements.

The MAT documented the damage observed at the shelter as a result of Hurricane Charley. Due to the limited access to the site, the MAT did not perform an analysis to evaluate the adequacy of the design assumptions used.

Figure 6-17.
Aerial view of Turner Agri-Civic Center damage caused by Hurricane Charley (Arcadia)
(FL DCA)

Based on the limited observations of the MAT at the site, the building is pre-engineered metal with a structural steel frame with reinforced masonry infill walls. The upper portion of the exterior walls and the roof are composed of structural standing seam trapezoidal panels (3-inch high ribs at 24 inches on center), over fiberglass batts over a plastic vapor retarder over light-gauge purlins. Steel frames support the purlins, creating the large, open area of the building. Maximum roof spans are approximately 200 feet. Exterior walls were reinforced masonry that extended from the foundation to a series of bond beams connected to the structural steel framing. At the end walls, intermediate steel framing extended from the top of the bond beam, up the gable end walls to steel frame elements at the top of the end wall. Figure 6-18 shows the building after it experienced a partial collapse during Hurricane Charley.

This building experienced damage to the cladding systems (evident at numerous places where panels were missing) and in the structural frame, which partially collapsed at one end of the facility. The MAT's inspection of the damage noted that, for the roof, the failure of the plane of the roof system was typically a separation of the two-piece clip that connected the panels to the purlins. A few clips were observed that were still intact, with clip screws pulled from the purlins. In addition, metal panels were observed to be missing from the soffit at

the entry canopy. The on-site representative meeting with the MAT reported that the roof panels were lifting off the frame prior to the collapse of the end wall.

Figure 6-18. End wall failure at Turner Agri-Civic Center (Arcadia)

Structurally, purlin spacing was observed to be the same at the perimeter, corners, and field of the roof. The roof structure was braced with rod x-braces. No roof bracing was observed at gable end walls or in the direction of the long, steel frames. Reinforced masonry walls at one end wall failed. The MAT observed reinforcing in the masonry end wall that failed, but insufficient information was available to determine if the construction was compliant with the applicable building code.

According to the on-site representative meeting with the MAT, after the partial collapse, shelter staff and inhabitants were moved to a nearby high school while the eye of the storm passed by and only one injury was reported. The MAT's observations of the high school, the middle school, and pre-engineered metal buildings in the vicinity of the Turner Agri-Civic Center (Figures 6-19 and 6-20, respectively) showed minimal damage and no structural failures. Estimated 3-second peak wind gust speeds for the area are between 110 and 120 mph for Exposure B terrain and between 125 and 140 mph for Exposure C terrain. The large open field upwind of the Turner Agri-Civic Center likely created Exposure C wind conditions for the building. Other organizations with greater access to the site and design and construction documents are investigating more deeply into the failure of this facility.

Figure 6-19.
Middle school with minimal roof covering damage (Arcadia)

Figure 6-20.
Pre-engineered metal buildings with minimal damage located near the Turner Agri-Civic Center (Arcadia)

6.5.1.2 Port Charlotte Middle School, Port Charlotte

Constructed in 1971, this school is one of two on the state shelter list for Charlotte County. The building is generally constructed of reinforced masonry walls (8-inch CMU) supporting metal roof joists (Figure 6-21). The walls are reportedly reinforced using two #5 reinforcing rods (vertical) in adjacent cells at 10 feet on center maximum spacing; there is also a bond beam at the top of the wall. The roof deck is metal with lightweight insulating concrete. The school is located in a Category 3 storm surge zone, making it vulnerable to storms with high surge levels. The school was used as a shelter during the storm for an unknown number of occupants. The building was evaluated for use as a school shelter and has an American Red Cross (ARC) 4496 compliant shelter capacity of 1,000 persons; another 500-person capacity was proposed, but was found to not be ARC 4496 compliant.

Figure 6-21.
Exterior view of Port Charlotte Middle School showing both gymnasium area (tall section) and typical classroom (lower section, rear of photo)

During the MAT assessment, no structural damage was observed and minimal damage was observed on the designated shelter areas of the facility. However, roof covering and exterior wall, trim, and coping damage was observed at the school (Figure 6-22). Damage to mechanically attached single-ply membrane roof coverings occurred on the gymnasium roof and one of two lower roof areas adjacent to the gymnasium (see Section 5.3 for further discussion). It is important to note that the gymnasium was not identified as usable shelter space and was not being used for shelter during the height of the storm.

Figure 6-22.
Edge flashing failure at Port Charlotte Middle School

A failure of the lightning protection system (LPS) cables was also observed. A failed and loose LPS can puncture and damage roof coverings, leading to leakage issues, although such damage was not observed at this school.

As was observed at numerous other commercial and critical/essential facilities, many HVAC units were blown off supports/curbs at the school; equipment access panels were also blown off. The units were displaced due to inadequate connection to their supports and curbs. Mechanical systems and equipment that remained on the roof were minimally secured, but were not displaced by the wind.

6.5.1.3 Liberty Elementary School, Port Charlotte

Shelter areas of this school were constructed in 1986; this school is the second of two shelters on the state shelter list for Charlotte County (Figure 6-23). The shelter areas of the building are generally constructed of reinforced masonry (8-inch CMU) with a brick veneer. There is a bond beam at the top of the walls and two #5 reinforcing rods were reportedly set vertically in a cell a maximum of 8 feet on center. The roof of the cafeteria shelter area is a lightweight insulating concrete deck with a maximum roof span of 54 feet. The school is located in a Category 3 storm surge zone, making it vulnerable to storms with high surge levels. The school was used as a shelter during the storm for an unknown number of occupants. The building was evaluated for use as a school shelter and has an ARC 4496 compliant shelter capacity of 500 persons; another 1,000-person capacity was proposed, but was found not to be ARC 4496 compliant.

Figure 6-23. Exterior view of Liberty Elementary (Port Charlotte)

During the MAT assessment, no structural damage was observed and minimal damage was observed on the designated shelter areas of the facility. There was no apparent structural damage to the shelter area and structural damage appeared to be limited to a failed canopy at a side entrance of the school. During the storm, electrical power to the school was lost. The school is not equipped with an emergency generator, so the day after the storm, the shelter staff and occupants were moved to another school that had power.

No significant roof covering or rooftop equipment damage was observed and there were no reported roof leaks in the shelter area; however, there were significant debris issues. The loss of metal panels over walkways between buildings and loss of aggregate surfacing from the BUR increased the debris hazard at this site and added to the debris field.

Some areas of the school have been retrofitted with shutters to protect windows from windborne debris. The shutters are roll-down, permanently installed systems that protect the windows during hurricanes. Although these shutters were not in place throughout the facility, they were placed on areas of the school that were identified for use as shelters. Figure 6-24 shows an example of a shutter system at the shelter area.

Figure 6-24. Shutters installed at openings at Liberty Elementary School shelter area (Port Charlotte)

6.5.2 Functional Loss

All shelters visited by the MAT performed well enough to prevent loss of life, which is the primary purpose for the shelters, though the partial collapse of the Turner Agri-Civic Center was undoubtedly terrifying for the occupants. Quick action by the staff at the Turner Agri-Civic Center to move occupants away from the areas of roof failure prior to the collapse of the end wall of the building avoided any deaths or serious injuries. However, the schools visited, as well as a number of recovery shelters that were also visited during the post-event assessment, sustained damages. Most of this damage was limited to loss of roof coverings, loss of or damage to rooftop equipment, glazing breakage, and wall and soffit damage as documented above. However, when these shelter and non-shelter areas sustain damage from water intrusion, the ability of the facilities to return to their pre-storm functions may be compromised.

Many of the shelters used during Hurricane Charley were designed or mitigated to resist extreme wind events. Although Charley was a design wind event for some normal use buildings constructed to the 2001 FBC, these shelters did not experience a "design event." In several of the examples cited here and in Section 6.4, the envelopes on parts or all of buildings being used as shelters failed to perform as designed. With the exception of the Turner Agri-Civic Center, shelters evaluated by the MAT did not experience significant structural damage. Water intrusion into shelter areas was the most commonly observed issue and, although this is not a desired result, criteria used by FL DCA do not identify water intrusion as an event that would categorize the performance of the shelter as a "shelter failure," although water intrusion could be very uncomfortable for shelter occupants.

All of the shelters observed by the MAT experienced blow-off of building components. When building components are blown-off, there is a risk that people arriving at a shelter during the hurricane may be injured or killed. It is for this reason that buildings selected for sheltering should be designed and constructed to avoid loss of components. Items particularly susceptible to blow-off include aggregate roof surfacings. Roof coverings and rooftop equipment are also susceptible if adequate attention was not given to wind-resistant design and construction for these elements.

During investigations, the MAT observed that, in many cases, reports of shelter building damage and failures required clarification. Many buildings used for shelters are located in portions of larger buildings or on sites with a campus environment with multiple

buildings. News media correctly reported that there was building damage at one site that was being used as a hurricane shelter. In a number of instances, this damage, however, did not occur at the area of the building being used as a shelter. For example, at the Port Charlotte Middle School, damage at the gymnasium and cafeteria was reported; however, these areas of the building are not designated for shelter use and were not being used at the time for this use. Thus, the damage reported at the site implied poor building performance with respect to the designated shelter space, which is not what actually occurred. This underlines the importance of properly identifying the shelter area at a building or campus prior to damage assessments to ensure the damage assessment is as accurate as possible.

It is important to recognize success and failure in buildings being used as shelters so that programs regulating the design, operation, and use of such facilities can be improved. In one disaster event, the Turner Agri-Civic Center had a loss of function that placed lives at risk. Nonfunctioning shelters or the reported poor performance of shelters may also result in the community's loss of confidence in shelter options provided for them. As a result, citizens in need of shelter may take undue risks and seek shelter at other inadequate facilities (or residences) or they may attempt to outrun the storm, both of which would increase their risk of injury during the event. Where shelters performed as expected, especially where the surrounding buildings or non-shelter portions of the building housing the shelter area received damage, it is important that the public understands that the shelters functioned properly to protect the inhabitants and perform as designed.

6.5.3 Buildings Selected for Shelter Use

Very few shelters were identified and opened in Charlotte and Lee Counties in response to Hurricane Charley because most of the shelters on the SESP listing are located in the storm surge inundation zones for Category 1 and 3 hurricanes. State and local emergency managers, in concert with the American Red Cross, work together to open and operate storm and recovery shelters during hurricanes. Further, FL DCA provides assistance to this decision-making process through its shelter program that culminates in the SESP shelter listing for the state. When a storm makes landfall, it is up to the communities and local emergency managers to assess the situation and open up shelters. Shelters are opened directly in the path of the hurricane if they are believed to be capable of providing safe refuge. Others, commonly called recovery shelters, are opened as a place for victims of the disaster to go who were forced to evacuate to areas outside the storm's projected path. Care should be taken to provide all available information at the

FL DCA has implemented a multifaceted program to assess shelters and work with communities to mitigate buildings to create and provide additional shelter space in their communities. This program includes: 1) survey of existing buildings, both public and private, to identify suitable shelter capacity; 2) where cost-effective (and practical), support mitigation and retrofitting of existing facilities to increase shelter capacity; 3) construction of new facilities to meet the public shelter design criteria; 4) shelter demand reduction through improved hurricane hazard models and behavioral studies; and 5) improve public information/education to reduce unnecessary "shadow" evacuations.

shelters and to protect operators during these events. Because Hurricane Charley was not categorized lower than a Category 2 hurricane as it approached Florida, it was reasonable for shelters in the projected path of Charley that were in storm surge inundation zones to not be opened as shelters.

The MAT visited the Diplomat Middle School in Cape Coral. This school was originally opened to displaced residents from the barrier islands of Fort Myers Beach, Sanibel Island, and Captiva Island. However, when the storm path changed, the building was affected by winds from Charley. Although the building was only slightly damaged (limited mainly to roof covering damage), school administrators were not aware that the school had been evaluated by FL DCA and had specific areas identified for use as shelter areas. This situation led to shelter occupants being placed in vulnerable areas of the building.

Although building strength and structural attributes of a facility are key elements in shelter selection during a disaster event, the location of the shelter is also critical. The state criteria for shelter space apply to both the building and the site. If the facility is in the 100-year floodplain, as defined on a FIRM, or in a storm surge zone identified by a SLOSH map, the site should not be used to host a shelter. In Charlotte County, there are only two shelters on the SESP listing, and both of these shelters are in Category 3 storm surge areas, vulnerable to flooding. Therefore, emergency managers had to make a subjective decision to open their only two shelters or to keep them closed because of the danger of surge flooding the shelters. Similarly, most of the shelters on the SESP listing for Lee County are in Category 1 and 3 storm surge zones and are vulnerable to flooding. For both counties, there is difficulty finding or siting shelters outside the storm surge inundation zones because of the flat geography of the counties and the underwater shelf offshore.

Hurricane Charley did not result in rising water across most of Charlotte Harbor and, therefore, very little coastal flooding was observed. It is important to note that most of the shelters on the Lee County list are in Category 1, 3, and 5 storm surge areas. Had the storm surge from Hurricane Charley remained at original forecasted heights, the shelters used in Charlotte and Lee Counties might have been flooded. This includes the many "recovery" shelters opened in schools in Lee

County (specifically in Cape Coral). These shelters were opened prior to Charley's landfall to support the evacuation of the barrier islands of Fort Myers Beach, Sanibel Island, and Captiva Island. Many of these shelters were opened, although they were in storm surge zones, because the track of the storm was forecasted to bring the eye of the hurricane over Tampa at landfall.[2] However, when the storm turned and the hurricane's eye made landfall in the Charlotte Harbor area (within the NOAA forecast landfall area), all of these shelters were at risk of flooding. Only the unique nature of Charley (a very compact storm prior to landfall) kept the damaging surge from occurring.

Questions regarding shelters and shelter evaluations should be directed to the Shelter and Retrofit Program administered by FL DCA and the State Emergency Management Office and information on this program may be found online at http://floridadisaster.org/DEMprograms.htm. Additional guidance on using shelters in or near floodplain or storm inundation areas is presented in the recommendations of Section 8.6.

6.5.4 The Florida SESP

Across Florida, shelter surveys and evacuation studies have determined that significant hurricane shelter space deficits exist in nearly all regions of the state. These regional deficits can have a significant impact on the ability of local agencies to protect citizenry when a major hurricane threatens or strikes Florida. Pursuant to Section 1013.372(2), Florida Statutes, FL DCA is responsible for preparing an SESP to guide local planning and provide consultative assistance with the construction of educational facilities that provide public shelter space. The purpose of this plan is to meet the statutory responsibility outlined in Section 1013.372(2), Florida Statutes. In accordance with the statute, the plan must:

- Identify the general location and square footage of existing shelters by Regional Planning Council regions;
- Identify the general location and square footage of needed shelters by Regional Planning Council regions for the next 5 years;
- Identify the types of facilities which should be constructed to comply with the public shelter design criteria; and
- Recommend an appropriate and available source of funding for the additional cost of constructing emergency shelters within those public facilities.

[2] Even when Hurricane Charley was forecast to track over Tampa, the Port Charlotte area was still included in the "zone of uncertainty."

Furthermore, FL DCA has statutory responsibility and authority to administer a statewide program to eliminate the deficit of "safe" hurricane shelter space. To ensure consistency with state and national standards, guidelines, and "best practices," the Division has recognized *Standards for Hurricane Evacuation Shelter Selection* (ARC 4496) as the minimum hurricane shelter survey and evaluation criteria. Therefore, at a minimum, meeting ARC 4496 criteria is a required condition for a public facility to be described as "safe," "suitable," or "appropriate" for use as a public hurricane shelter.

Cumulatively, since 1995, the FL DCA's hurricane shelter survey and retrofit program has identified, created, or otherwise documented approximately 434,000 hurricane shelter spaces that meet ARC 4496 guidelines. The total list of shelter space evaluated is compiled in the SESP plan of that year and identifies space meeting the ARC 4496 criteria as well as space evaluated, but not meeting the ARC 4496 criteria. Buildings on this list may not have been designed to the criteria now specified, but have areas in the buildings that meet the criteria of "safe," "suitable," or "appropriate" for use as a public hurricane shelter.

New public school construction programs have created an additional 209,654 hurricane shelter spaces. These spaces are in buildings that were designed to meet EHPA requirements as defined in Section 423, State Requirements for Education Facilities, of the 2001 FBC and as outlined in the state statutes presented in Appendix G of the SESP. The design requirements as presented in the code are provided below. Additional discussions regarding shelter design requirements of the FBC and FEMA 361 are provided in the SESP and Appendix F of this report.

From the 2001 FBC Section 423 (24), Public Shelter Design Criteria:

> **"(d) Structural Standard for Wind Loads.** At a minimum, EHPAs shall be designed for wind loads in accordance with ASCE 7-98, "Minimum Design Loads for Buildings and Other Structures, Category III (Essential Buildings)." Openings shall withstand the impact of windborne debris missiles in accordance with the impact and cyclic loading criteria per SBC/SSTD 12-99. Based on a research document, "Emergency Shelter Design Criteria for Education Facilities," 1993, by the University of Florida for the DOE, it is highly recommended by the Department that the shelter be designed using the map wind speed plus (40) mph, with an importance factor of 1.0."