# 7 Conclusions

*The conclusions presented in Sections 7.1 through 7.6 are based on the MAT's observations; evaluations of relevant codes, statutes, and regulations; and meetings with state and local officials, building associations, contractors, and other interested parties. The conclusions presented in Sections 7.1 through 7.6 are based on the MAT's observations; evaluations of relevant codes, statutes, and regulations; and meetings with state and local officials, building associations, contractors, and other interested parties. These conclusions are intended to assist the State of Florida, local communities, businesses, and individuals in the reconstruction process and to help reduce future damage and impact from natural events similar to Hurricane Charley. Observed mitigation successes are presented in Section 7.7.*

## 7.1 General Conclusions

Hurricane Charley was a powerful hurricane when it made landfall as a strong Category 3 or borderline Category 4 hurricane in southwestern Florida. Although waves and coastal surge caused erosion and damage along the beaches of the barrier islands in Charlotte and Lee Counties (including the breach that was cut across North Captiva Island), Hurricane Charley will be remembered mostly for its winds and wind-induced damage. In addition to the estimated 145 to 155 mph (3-second peak gust) winds associated with the eye of Hurricane Charley as it passed over North Captiva Island, communities around Charlotte Harbor, including Port Charlotte and Punta Gorda, were impacted with winds estimated at 125 to 140 mph (3-second peak gust) in densely populated areas. Hurricane force winds (with 3-second peak gust winds as high as 105 mph) in densely populated areas of Orlando continued to induce damage across the peninsula of Florida until Hurricane Charley exited into the Atlantic Ocean near Daytona Beach, still categorized as a hurricane.

The need for hardening, providing backup power, and data storage to the NOAA/NWS surface wind and weather monitoring system was demonstrated by Hurricane Charley. The assessment of the performance of buildings and infrastructure is tied to the estimates of wind speeds experienced throughout the area of impact. None of the Automated Surface Observing Systems (ASOSs) and other systems, as far inland as Orlando, that were impacted by the strongest winds continued to report wind information throughout the storm. In many cases, the ASOS operates more like an early warning system for hurricane force gusts (because the power is typically lost when wind gusts approach hurricane force) than as a reliable source of data on the winds during the heart of the storm.

The categorization of the storm by a single hurricane classification also has limited use in the post storm assessment and may lead people in the impacted areas to draw incorrect conclusions about the event they actually experienced at their site and the strength of their building. The development of wind field estimates and resulting wind speed swath maps (Figures 1-4 and 1-5) are critical to the proper assessment of an event and its implications for building construction and code development.

The response of buildings to the high winds varied due to their location in the wind field, building code in effect at the time of construction, level of code compliance, quality of construction, and mitigation efforts implemented on the building. The most severe damage and structural failures occurred along the path of the eyewall of the hurricane, where most of the structural collapses and severe damage to the structural elements of buildings was observed. However, based on MAT observations, the number of structural failures from the winds associated with Hurricane Charley was generally less than has been observed during damage assessments following previous hurricanes with similar wind speeds.

Performance of building envelope elements such as roof coverings, rooftop mounted equipment, unprotected glazing, soffits, and siding was generally poor and led to widespread damage to the interiors of residences, businesses, and critical/essential facilities. In the windborne debris regions (areas identified in the 2001 FBC with 3-second peak gust design wind speeds of 120 mph or greater), where glazing was not protected, debris often broke the unprotected glazing and resulted in damage to building interiors (and, in some cases, structural failure from an uncontrolled increase in air pressure). Damage to the contents of residential and commercial buildings, and critical/essential facilities is preventable, as are the resultant costly losses and claims.

## 7.2 Building Performance and Compliance with the Building Codes, Statutes, and Regulatory Requirements of the State of Florida

Most structural failures observed by the MAT appeared to be the result of inadequate design and construction methods commonly used before the 2001 FBC and other modern building codes and standards were adopted and enforced; some failures may be explained by lack of maintenance or poor condition of the building and its structural elements. Code changes implemented in response to Hurricane Andrew in 1992, such as improvements to the SBC and the adoption of the 2001 FBC, can be credited with improving the wind resistance of buildings that have been designed and constructed over the past 12 years. In addition, the improvements in ASCE 7, including the addition of windborne debris protection requirements and the elimination of the one-third stress factors, are further refining the loads that new buildings must resist, thus ensuring better performance in wind events.

Buildings constructed in accordance with older codes were typically vulnerable to envelope and equipment damage, because older codes lacked or had inadequate criteria (refer to Chapter 2). Where buildings were designed and constructed to newer codes and standards (such as the FBC, the SFBC, or ASCE 7-98 or later) with improved building envelope and equipment design criteria, some of the observed failures were due to failure to comply with code provisions in both the design and construction phases. Other failures were the result of installed materials and systems that are known to lack the ability to perform under high-wind loads (i.e., the use of unsecured soffit panels). These components either do not meet the new criteria or there is a lack of evidence, through either realistic laboratory testing or observed performance during hurricanes, that the product will work under high-wind loads. Because these components are not considered “structural elements,” their design and construction is often overlooked during design, permitting, construction, and inspection. Therefore, improvements are needed in the design requirements of the codes themselves and with enforcement and code compliance to ensure that components and cladding (C&C) elements are being engineered and designed per the code requirements. The MAT’s observations are presented in Chapters 4, 5, and 6, and provide details in support of this statement.

The 2001 FBC and the recently completed 2004 FBC (to be adopted statewide by administrative rule effective July 1, 2005) include several improvements to the structural design of buildings and attached structures, as well as improvements for the design of building envelope and equipment provisions. Based on the observations outlined in this report, design guidance provided by the code with regard to the design and construction of the building envelope and attached structures and equipment needs to be expanded and improved. Guidance for some of these issues is provided by current model codes and standards, including the International Building Code/International Residential Code (IBC/IRC), NFPA 5000, and ASCE 7-02.

Finally, performance of manufactured housing was also observed to be a function of age of the building and the regulations to which the units were designed, constructed, and installed. Widespread damage was observed to manufactured housing designed and constructed prior to the 1976 HUD regulations. The performance of units installed between 1976 when the first HUD regulations were enacted and the implementation of the 1994 HUD regulations was observed to be somewhat improved, but significant improvements in performance were observed in the units designed and installed to the HUD regulations implemented after 1994 in response to Hurricane Andrew. Although some instances of structural failure were observed, the newer manufactured housing units typically sustained minimal structural damage and remained secured to their foundations when installation followed state requirements (e.g., enforced by the Division of Motor Vehicles, Department of Highway Safety and Motor Vehicles, etc.) of unit tie-downs (anchors) at 5 feet 4 inches on center (if no ancillary structures were attached to the unit). Much of this improved performance was difficult to observe due to widespread damage caused by the failures of improperly designed and constructed attached structures (including screen enclosures, carports, and accessory structures). The failure of these attached structures, in many places occurring where wind speeds were below the design wind speed for the area, resulted in extensive damage to roof coverings, siding, windows, and doors of the manufactured units, and generated significant amounts of debris. Very few manufactured homes had glazing protection and, as a result, numerous unprotected windows on units along the path of the eye of the storm were damaged and broken. Had the Zone II and Zone III homes installed in areas where debris protection is required for site-built one- and two-family dwellings been shipped with appropriate glazing protection, these homes would have been protected from windborne debris.

## 7.3 Performance of Structural Systems (Residential and Commercial Construction)

Buildings designed and constructed to resist wind loads prescribed in the 2001 FBC and to the requirements of ASCE 7-98 performed well and showed how improvements to the building codes have been successful in Florida. Structural damage, however, is still occurring during code level events such as Hurricane Charley.

### 7.3.1 Internal Pressures

Breach of the building envelope through broken windows, failed doors, or loss of sheathing led to rapid and uncontrolled increases of the internal air pressure in buildings, which sometimes resulted in structural damage or failure. Research suggests that internal pressures are affected by openings as small as 1 percent of the wall area and that the internal pressure generally becomes equal to the external pressure at the opening when the area of the opening reaches or exceeds 5 percent of the wall area. Consequently, the loss of a large window, a sliding glass door, a double-entry door, or a garage door can expose the interior of a building to the full effect of the external wind pressure. When openings are breached on the windward face of the building by direct pressure-related failure or by impact from windborne debris, the internal pressure in the building rises toward and tends to follow the fluctuations in positive pressure that would have occurred on that window, door, or panel had it not failed. Because air is essentially incompressible at the wind speeds encountered in even the most severe wind storms, the pressure builds without the need for much wind flow through the opening. However, if other openings in the building are present, including panels covering ceiling access holes in attics, air pressure can escape from the building, but does so as rapidly moving air that whips through the building. Failures of windows and doors on the windward face of a building have been correlated with subsequent failures of partition walls, windows, and doors on side and leeward walls, attic access panels, roof sheathing, and even whole roof structures (refer to Chapter 4 for details of these types of failures).

The MAT found examples of all of these types of failures in Hurricane Charley. A number of newer homes had double-entry swinging doors that failed. Because these homes were built with reinforced masonry and had adequate roof strapping, the roofs remained intact, but the sliding glass doors on the leeward side of the homes came out of their tracks, opening the house to the hurricane winds. It was not uncommon to find furniture blown out of these homes. A church sanctuary in Punta Gorda was reduced to rubble when the entire roof separated from the walls and a house on Pine Island lost most of the roof over a central area with a cathedral ceiling when a window blew in on the windward side. The widespread failure of low-slope roof systems may have been impacted by the build-up of internal pressures after a window or door failed, but the roof was probably compromised and the internal pressure just hastened the failure.

### 7.3.2 Wind Mitigation for Existing Buildings

To minimize damage or prevent failure of older buildings (residential, commercial, and critical/essential facilities), mitigation to create a continuous load path from the roof to the foundation must be implemented. This type of mitigation can be expensive because it often requires demolition and replacement of interior building finishes, and may require displacement of occupants while the mitigation is performed. Justifying the cost may also be difficult because the building code or local ordinance may not require that the building be upgraded to current code requirements.

For homeowners, opportunities to perform mitigation retrofits that improve the building's continuous load path would be optimal during renovation work or roof replacement projects, when significant invasive work is already being performed and the cost to install extra clips, screws, or nails to secure decking to rafters/trusses would be minimized. Access to the roof structure/top of wall connection is often made accessible during these projects, and clips and straps may be installed to help with the creation of a continuous load path. Additional anchorage of the bottom of the walls may still be required to develop a complete load path. Mitigation projects stated above would address the roof decking and roof structure failures observed after Hurricane Charley.

In commercial and critical/essential facility buildings, mitigation retrofit costs may be minimized if these types of projects are performed during tenant fit-out projects or major capital improvement projects. Prioritization can be given to mitigating space used for critical and essential functions. Public schools are examples of where these types of mitigation projects have occurred. As part of their efforts to increase safe public shelter space, FL DCA has evaluated schools, and sponsored structural and non-structural mitigation projects to strengthen buildings and provide debris impact protection to mitigate existing buildings once vulnerable to damage from wind and windborne debris.

## 7.4 Performance of Accessory Structures/ Attachments

Historically, aluminum accessory structures have had little rigorous engineering applied to them because they have been regarded as auxiliary and even expendable structures. Since the mid-1970s, the design of aluminum accessory structures has been most often accomplished through the use of prescriptive guidelines promulgated by a few professional engineers apparently without adequate formal peer review or industry consensus. Consequently, the widespread failure of these structures observed after Hurricane Charley (refer to Chapter 4) was unfortunate, but not surprising.

Another issue affecting the survivability of aluminum accessory structures is that, in general, installers and building department personnel (plan reviewers or inspectors) may not be sufficiently knowledgeable about the design of aluminum accessory structures. Although attention has been given to the size and spacing of members, little effort seemed to be focused on the connection details between the members and anchoring. Field observations point to connection detail failures, inadequate bracing as being frequent initiation points, and overturning/sliding for the ultimate failure of these aluminum accessory structures.

In addition to the damage and failures of the structures themselves, damage occurred to the site-built and manufactured housing to which they were attached. The failure and destruction of accessory structures and attachments contributed large pieces of windborne debris that impacted the surrounding homes. Manufactured homes that had a collapse or partially collapsed attached structure, significant damages to roof covering, roof decking, and siding were commonly observed. Further, the widespread failure of these structures created large amounts of debris that had to be cleaned up and disposed.

Sound guidance for the design of these types of structures was developed with the preparation of the 2001 FBC. The Aluminum Association of Florida (AAF) commissioned research that involved wind tunnel testing of both screened structures with screened roofs and screened structures with solid roofs. This research established wind design pressures that should be applied to these aluminum structures and these results are included in Table 2002.4 of the 2001 FBC. The AAF document, *Aluminum Design Manual*, referred to in the code in Section 2002.2, should be used by engineers and building officials to learn the engineering properties of the components that comprise a completed structure. The document does not deal with particular extrusions or assemblies of parts, but rather with the criteria for evaluating the connections.

It is important to note that Table 2002.4 of the 2001 FBC (submitted by the AAF) does not address the issue of the particulars of the design, just the applied pressures. In recognition of the limited guidance available and in preparation for the 2004 FBC, the *AAF Guide to Aluminum Construction in High Wind Areas* was developed. Although it is not a consensus standard, this guide is based on wind tunnel testing and rigorous engineering that has been constructively peer reviewed, making it the best guidance available at the time of issuance of this report. Designs based on this guide would substantially address the shortcomings in the current way aluminum accessory structures are being designed and the way they will ultimately perform. The results contained in the AAF document have been incorporated into the 2004 FBC. However, because most attached structures and pool enclosures were constructed prior to the 2001 FBC code, the MAT could not determine if the industry has moved to fully support the guidance in the existing FBC code and the 2004 Edition.

In addition to the guidance from the aluminum structure industry, changes in wind loads for open and partially enclosed canopy roofs are set to appear in the next edition of the wind load section of ASCE 7 (2005). Furthermore, the ASCE 7 standard has been revised to make it very clear that the one-third stress increase frequently used for short duration loads, such as wind loads, should not be applied unless it can be clearly demonstrated that the material capacity clearly increases as the load duration decreases. Thus, the common practice of reducing safety margins for metal or concrete structures by taking a one-third increase in allowable stress is no longer allowed. This should lead to stronger frames for screen enclosures and stronger carports and metal roof canopies in the future.

## 7.5 Performance of Building Envelope, Mechanical and Electrical Equipment

Although structural system failures tend to be perceived by the public and the building industry as the dominant issue of concern, the greatly improved performance of houses built in accordance with the FBC 2001 and other model codes have, in general, resolved many structural performance issues. Now, the arena in which improvements can and must be made are those related to rain water intrusion and protection of the building envelope (refer to Chapter 5). Protection of the building envelope is important in minimizing losses and damages to building contents, but also because of the importance of the building envelope with respect to internal pressurization of a building.

Poor performance of building envelopes and rooftop equipment was common on residential, commercial, and critical/essential buildings. Envelope and equipment damage was more widespread and significant on older buildings, although new buildings were also damaged in many cases. Damage was noted throughout all areas observed. Ramifications of poor performance include:

- **Property damage.** Property damage was extensive, requiring repair and/or replacement of the damaged envelope and equipment components; repair and/or replacement of interior building components; and mold remediation and furniture and equipment replacement as a result of rain water and/or wind damage in the interior of the building. Even when damage to the building envelope or equipment was limited, such as blow-off of a portion of the roof covering or broken glazing, substantial rain water damage frequently resulted because of the heavy rains accompanying the hurricane and rains occurring in the following days and weeks. Rain water entered the buildings through the breaches in the building envelope.
- **Loss of function.** Depending upon the magnitude of the wind and rain water damage, repairs can take days or months. As a result, residents may not be able to return home, businesses may not be able to reopen, and critical/essential facilities may be incapable of providing their vital services. In addition to the costs associated with repairing the damage and/or replacing the damaged property, other financial ramifications related to interrupted use of the building can include rental costs of temporary facilities or lost revenue due to business interruption. These additional costs can be quite substantial.

## 7.5.1 Building Envelope

Poor performance was a function of both inadequate wind resistance and damage from debris impact. Inadequate resistance to high-wind pressures on building envelopes and rooftop equipment was responsible for much of the damage caused by Hurricane Charley. In addition, windborne debris caused significant envelope damage (and virtually all of the glazing damage) that the MAT observed where wind speeds from the event were thought to be 120 mph 3-second peak gust and greater. Damaged and fallen trees, and failed building envelope components and rooftop equipment (such as roof coverings, gutters, HVAC equipment, and wall coverings) also became windborne debris that damaged the buildings they blew off of, as well as other buildings in the vicinity.

### 7.5.1.1 Roof Coverings, Wall Coverings, and Soffits

Observations showed that roof coverings of all types continue to fail at unacceptable rates during hurricane events. Some of these failures were due to the age of the coverings (coverings that were never considered for their ability to resist what is now understood as design level wind loads) while other failures were due to design and construction related issues or debris impact. With respect to roof coverings, wall coverings, and soffits, the MAT concluded that

- Wind damage to roof coverings and wall cladding was widespread, even with wind speeds below design levels. Improved performance of roof and wall coverings was generally observed on the newer buildings and is likely due to improved codes and standards, product and test method improvements, a more educated designer and contractor workforce, and reduced detrimental effects of weathering (on newer buildings).
- Asphalt composition roof shingles continued to fail at or below design level winds. In general, it appeared that shingles installed within the past few years performed better than shingles installed prior to the mid-1990s. The enhanced performance is likely due to product improvements and less degradation of physical properties due to limited weathering time. In most cases, observed shingle failures were attributed to inadequate self-seal adhesive bond strength or installation that did not comply with recommended methods for resisting blow-off in high-wind areas. Failures of shingle roof systems applied over previously installed shingles were frequently observed.
- Tile roof systems experienced varied levels of performance from complete resistance to wind to substantial loss of tiles. Variation in performance was primarily related to installation and attachment methods with mortar-set tile system failure most frequently observed

as compared to foam set and mechanically attached tiles. Tile failures on roofs with foam-adhesive were observed, in most cases, to not comply with manufacturers' installation recommendations. All types of tile (concrete and clay) are vulnerable to breakage from debris impact, regardless of installation methods used. Tiles lifted by wind or broken from windborne debris often lead to cascading failures. Tiles on hips, ridges, and edges of the roof were a frequent point of failure. Hip and ridge tiles rarely were attached using mechanical anchors.

- Aggregate roof surfacing continued to cause debris damage when aggregate was blown off the roofs by high winds.
- For all roof systems, inadequate attention was typically given to edge flashing, coping, and gutter/downspout design and installation despite being located in the roof areas subject to the highest wind pressures. Failure of these roofing components often initiated roof membrane lifting and peeling.
- Wall cladding of all types (EIFS, vinyl and aluminum siding, masonry, etc.) appeared to have typically received minimal attention during design and construction, and continues to be an initiation point for progressive failures leading to interior contents damage or pressurization of the building.
- In numerous buildings, wind-driven rain was driven into attic spaces because of soffit failures. Widespread loss of soffits was observed in residential construction. In many of these instances, water intrusion occurred from wind-driven rain through areas where soffits were displaced or lost.

### 7.5.1.2 Windows, Doors, and Shutters

Windows and glazed doors can be protected in all wind regions using shutter systems, laminated glazing systems, and other means of opening protection. Large amounts of debris and loss of many unprotected windows and doors in areas along the path of the eye of Charley support the required protection of these openings in areas within the FBC windborne debris region. Further, many buildings in the areas outside the windborne debris regions would have benefited had the glazing been protected. Using glazing protection to prevent internal pressurization and wind-driven rain water intrusion protects interior contents from being damaged. Specifically; with respect to windows, doors, and shutters, the MAT concluded :

- The benefits of shutters are two-fold. First, they minimize an inrush of air that might cause a building not designed for internal pressures to fail structurally and they protect against the intrusion of wind-driven rain that could enter an unshuttered broken window. Although the public generally understands the importance of minimizing the inrush of air that might damage or cause a structure to fail, it is not clear that the public appreciates the dramatic damage that can be caused by rain entering a residence. Code prescribed shutters capable of withstanding penetration by windborne debris and both negative and positive wind pressures would eliminate water intrusion that would otherwise result from broken windows.

- Many homes and businesses that experienced only contents damage could have prevented these losses if their openings had been protected. Success in designing the structural frame to resist wind loads and internal pressures was negated by significant losses to building interiors and contents.
- Most shutters observed on buildings performed well during Hurricane Charley.

#### 7.5.1.3 Attached Equipment (Rooftop and Ground Level)

Much like the building envelope systems already discussed, rooftop and ground level equipment is not typically receiving the design, installation, or code attention needed. Design guidance in ASCE 7-02 provides basic information to calculate wind loads on these elements to determine connection and support anchoring systems, but detailed guidance is needed. The lack of design and installation attention caused displacement or damage to these units across the wind field of the hurricane. This not only resulted in the loss of function associated with the damaged units, but in many cases led to the loss of function of the occupied space due to rain water infiltration at displaced rooftop equipment.

### 7.5.2 The Need for High-Wind Design and Construction Guidance

Designers, contractors, and building officials need additional education and resources to promote wind-resistance design and construction. Although many successes of design and construction were observed across the path of Hurricane Charley, it was apparent that the load path concept was not fully understood in all cases. It was also clear that many designers, contractors, and building officials do not fully understand the devastating effects that hurricanes can have on envelopes and equipment. It was common to see fasteners spaced too far apart, fasteners that were too small, and weak connections. Enhanced details were seldom seen. In contrast, there were numerous examples of failure to follow well established basic construction practices such as minimum edge distances for fasteners. Unless wind resistance issues are understood by designers, contractors, and building officials, envelope and equipment failures will continue to occur. In part, the envelope and equipment problem is due to lack of high-wind design guides for various envelope assemblies and various types of rooftop equipment.

## 7.6 Performance of Critical and Essential Facilities (Including Shelters)

Critical and essential facilities must remain operational before, during, and after significant hazard events, such as hurricanes, to serve their communities. As stated in Chapter 6, buildings that were considered critical and essential facilities were EOCs, fire and police stations, hospitals, schools, and shelters.

In general, buildings functioning as critical and essential facilities did not perform any better than their commercial-use counterparts. Despite codes of the past 10 years that require high design loads be used in the design of these facilities, the same flaws in construction, such as poor wall cladding, poor attachments of roof covering, and improper anchorage of rooftop mechanical equipment, were observed in critical and essential facilities. As a result, the operations and response at many critical and essential facilities discussed in Chapter 6 were hampered or shut down and taken off-line after the hurricane. In Charlotte County alone, over a half-dozen fire stations, three hospitals, numerous police stations, and the county EOC were significantly damaged and some were unable to respond in the days, weeks, and sometimes months after the event.

Most critical and essential facilities (shelters excluded) were housed in older existing buildings and most, if not all, apparently were not mitigated to resist known hurricane risks. If these critical and essential operations were housed in buildings constructed to the 2001 FBC, the 2004 FBC, or the model codes such as the IBC or NFPA 5000, designs for the structural and building envelope systems (including debris impact resistance) are required to provide levels of protection from wind and windborne debris. As a result, these design requirements may have prevented enough damage to allow these buildings to remain operational after the event. Alternatively, if key areas of the building had been mitigated or retrofitted for wind and windborne debris design requirements that are specified in the current code, building damage and loss of function would have most likely been reduced.

Widespread damage to large rolling and sectional doors and roof systems at fire stations is preventable. If these older buildings had been designed or mitigated to the 2001 FBC for 120 mph (3-second peak gust) winds and associated windborne debris impact protection over openings applicable in most of Charlotte County, the observed damage may have been avoided. Furthermore, many critical facilities were housed in lightly engineered buildings such as pre-engineered metal buildings. When this was the case, few if any of these lightly engineered structures were mitigated or retrofitted to design levels other than minimum code requirements for general use buildings in place at the time of construction.

The performance of buildings used as hurricane shelters also varied widely during Hurricane Charley. In Charlotte County, the MAT visited the two shelters (schools) on the state approved list that tracks and identifies shelters (the yearly Statewide Emergency Shelter Plan [SESP]); these shelters are on the list despite being located within the storm surge inundation zone for a Category 3 hurricane. At these two schools, the county was operating shelters in the areas of the school designated by the SESP. These areas only experienced minor roof covering (with some water leakage problems) damage during the storm; the structural systems, roof deck, and shutter systems performed without failure.

However, in De Soto County, the new multi-purpose Turner Agri-Civic Center designed for use as a shelter experienced a partial end wall/roof collapse. In Lee County, the county opened shelters for residents of the barrier islands with the belief that these shelters were "recovery shelters" that would not be impacted by hurricane force winds; most of these shelters were also located in Category 3 storm surge inundation zones, but these buildings experienced tropical force winds (with gusts near hurricane strength) and roof covering damage with associated rain water intrusion damage. Fortunately, due to the compact size of Hurricane Charley, only limited significant storm surge was generated by the hurricane and none of shelters in Charlotte and Lee Counties were flooded.

The building damage to critical and essential facilities experienced during Hurricane Charley led to a significant, and avoidable, loss of function. Specific conclusions for critical and essential facilities based on these observations are:

- When older buildings are used as critical and essential facilities, damage will likely occur to the roof covering, wall coverings, window and door systems, and rooftop equipment. This damage will often lead to significant loss of function at the facilities.

- Some buildings designed to critical and essential facility requirements experienced damage and partial failures during the hurricane due to lack of protection from windborne debris. Lack of protection of windows was common at hospital and medical buildings, and led to window failures and severe damage to building interiors and contents.
- Large rolling and sectional doors at fire stations can be purchased and installed to provide protection from high-wind and debris impact, but catastrophic failure of the doors can occur when these systems are not installed correctly and when track systems are not reinforced for the larger wind loads. These door failures led to pressurization of the buildings and, in some cases, roof collapse that should have been prevented by proper installation of the high-wind rated doors.
- Rooftop equipment loss such as loss of HVAC units and vents, antennas, communication dishes, and lightning protection systems was prevalent. All of these failures caused damage to roof coverings (and sometimes supporting structural systems) that often resulted in rain water intrusion into the facilities.
- Critical facilities housed in lightly engineered buildings such as pre-engineered metal buildings will continue to experience damage and loss of function unless the designs are substantially improved and close attention is given to all connections of the structure and the building envelope.
- Windborne debris could injure or kill first responders at fire and police stations, as well as EOCs, late arrivers at shelters, or those seeking medical attention at hospitals. Although people are not usually outdoors during hurricanes, buildings used as critical and essential facilities can be the exception. It is common for people to arrive at these facilities during a hurricane and additional efforts should be made to reduce the potential for windborne debris at these sites.
- In some communities, shelters sited in a storm surge inundation zone and located in the projected landfall area were used during the hurricane. Only the unique nature of this storm with a small radius of maximum winds and landfall near low tide kept the shelters from being flooded. Shelters located in the projected landfall area and sited in storm surge zones place large numbers of individuals at risk of injury or death due to flooding from the storm surge.
- Designing to minimum Enhanced Hurricane Protection Area (EHPA) requirements does not guarantee that a building being

used as a shelter will be properly designed and constructed to resist extreme wind events.

- ARC 4496 provides a baseline for a shelter's integrity and performance, but meeting this criterion does not guarantee that the building will resist wind and windborne debris associated with all hurricanes.
- Peer review of the design of critical and essential facilities would greatly improve the likelihood that a building has been adequately designed to resist extreme winds.
- Special inspections for key structural items and connections, and for installation of envelope components would help ensure the performance of critical and essential facilities.

## 7.7 Observed Mitigation Successes

In addition to the successful performance of structures built to the 2001 FBC, successes in older structures and structures mitigated to resist wind and flood loads were observed. Examples of successful residential, commercial, and critical/essential facility mitigation are provided in this section. In addition to these observed mitigation successes, additional examples of mitigation successes can be found on the DHS/FEMA Mitigation web site at http://www.fema.gov/fima/bp.shtm.

### 7.7.1 Mitigation Success in Residential Construction

Two examples of well-executed mitigation against flood and wind were observed. First, on North Captiva Island, where Hurricane Charley battered buildings with estimated winds in excess of the 130 mph (3-second peak gust) winds required by the 2001 FBC, many homes withstood the winds with minimal damage. Figure 7-1 shows a residence constructed to the design requirements of the 2001 FBC. This building had a well-secured standing seam metal roof that performed well and only experienced some light trim damage (shown in the center of the photo). The windows and doors were protected with a combination of impact resistant, laminated glazing products and shutters. In addition, the residence was elevated above the predicted 100-year flood level on an open pile foundation.

Second, many residences and businesses on the north end of Fort Myers Beach have been elevated on pile foundations to allow water to pass beneath these V-zone structures. In one of the few areas investigated by the MAT that experienced flooding and overwash, Fort Myers Beach experienced storm surge from Charley. The house in Figure 7-2 is one of eight residential units located along the beach in this small development. During Charley's storm surge, water approximately 2 to 3 feet deep washed through the development (see water mark on door of enclosure below house). These older residences, however, were atop pile foundations that allowed the floodwaters to pass safely beneath the houses. As a result, only minor damage to enclosures and access stairways was experienced. This success illustrates the use of best practices on older homes that has been recommended by FEMA in publications such as FEMA 55, *Coastal Construction Manual*.

**Figure 7-1.**
**Residence constructed to the design requirements of the 2001 FBC performed well and only experienced some light trim damage (shown in the center of the photo) (North Captiva Island).**

Figure 7-2.
Older residence atop pile foundation that allowed floodwaters to pass safely underneath, resulting in only minor damage to enclosures and access stairways (Fort Myers Beach)

### 7.7.2 Mitigation Success in Commercial Construction

When Hurricane Charley hit Fort Myers Beach, the Lighthouse Resort Inn and Suites shown in Figure 7-3 remained dry, undamaged, and full of customers, while other hotels and motels on the island were damaged or flooded, and closed. In the past, the Lighthouse Resort would also have been closed. Over the last two decades, seven hurricanes have caused flood and wind-related damage to the resort, resulting in nearly $100,000 in repair costs per event. The resort, which sits 200 feet from the beach, had been elevated as part of a joint State of Florida, Federal, and local mitigation project. In approximately 1 year, the owners have saved nearly $200,000 in repair costs alone, almost 50 percent of their mitigation investment.

At the Charlotte County South Annex building, significant damage and loss of function was prevented when new shutters were installed to protect the building during Hurricane Charley. The galvanized metal shutters were funded in part by a grant to the State of Florida under FEMA's Hazard Mitigation Grant Program (HMGP). With the shutters in place, the Annex suffered only minimal damage. An investment of less than $10,000 saved the taxpayers over half a million dollars in losses avoided in just one hurricane event.


**Figure 7-3.**
**Exterior view of the elevated Lighthouse Resort Inn and Suites, which remained dry and undamaged after Hurricane Charley (Fort Myers Beach)**

The county's grant application was approved in 2003. Shutters were purchased for $9,546, using a combination of local funds and the HMGP grant and installed for the first time on August 11, 2004, in anticipation of Hurricane Charley. Two days later, they were severely tested when 125 mph winds slammed the coastal city.

"If it wasn't for the shutters," said George Dahlke, Charlotte County Facilities Construction and Maintenance Project Manager, "all the glass in the building would have been gone. Without the windows, we feel that the uplift [of the wind] would have taken the roof off." (Figure 7-4)

Only one shutter was damaged. Hit hard by flying debris, the shutter panel was dented, breaking the glass behind it, but remained in place and prevented the wind from penetrating the building and causing major wind and water damage. Although windborne debris damaged the roof, creating some leaks and damaging some of the building's contents, this damage was minimal in contrast to other buildings according to Charlotte County Facilities Manager, Michael Sheridan.

Figure 7-4.
Exterior view of the galvanized shutters that protected the Charlotte County South Annex (Punta Gorda)

"The Health Department Building, without shutters, located about a mile away, is badly damaged—broken glass panels, roof and ceiling uplifted—they're still not in service [nearly 5 weeks later]. It may cost $500,000 to repair," he related. Mr. Sheridan credited the shutters on the 20,000-square foot South Annex building with saving the county approximately $600,000 in repairs. That is the amount that would have been needed had the glass panels been broken, allowing wind and rain water to penetrate the building. The total repair estimate for the South Annex is $80,000. Eighty percent is earmarked for roof repairs due to damage from windborne debris. The remainder is for damage to the contents from the roof leaks. The monetary loss avoided by installing the shutters is $520,000.

Employees and the community also avoided losses in time off from work and interruption of services due to lengthy repairs. Just 2 days after Hurricane Charley, with minimal repairs still in progress, the South Annex was up and running. Employees were back at work, providing much-needed services to Charlotte County residents.

### 7.7.3 Mitigation Success in Critical and Essential Facility Construction

A success in school design and construction that resulted in no loss of function was observed at the Sanibel School on Sanibel Island (Figure 7-5). Dedicated on August 10, 2004, less than a week prior to the landfall of the storm, this school was designed and constructed to the 2001 FBC. Although the school building likely experienced wind speeds that were below the 130 mph (3-second peak gust) design wind speed for the site, the building did experience hurricane force winds around the level of Category 2 winds and sustained little damage.

Damage at the school was limited to loss of gutters on the east side of the building and some wind-driven rain issues. At the time of the MAT visit, the school was preparing for an on-time school opening and did not experience a loss of function as a result of the hurricane. In addition to avoiding significant damage to the school building itself, the successful performance of the design allowed residents of Sanibel Island to move forward with their rebuilding process because the school was functioning.

**Figure 7-5.**
**Courtyard of the newly constructed Sanibel School that was operational immediately after Hurricane Charley passed**