4 Conclusions and Recommendations

The following conclusions and recommendations are based on the most significant damages observed by the MATs and Rapid Assessment Teams deployed after Hurricanes Charley, Frances, and Ivan. Additional conclusions and recommendations are included in the individual reports for these hurricanes. The following sections outline the most significant conclusions and recommendations. Detailed recommendations are included in four matrices presented at the end of this Summary Report.

4.1 Wind-Related Conclusions and Recommendations

Houses built in accordance with the FBC 2001 or the IBC 2000/2003 generally avoid most wind-related structural issues. At this time, improvements must focus on preventing rain water intrusion and protecting the building envelope. Protection of the building envelope is important in minimizing losses to building contents.

General

NOAA/NWS Monitoring System

None of the Automated Surface Observing System (ASOS) and other systems that were impacted by the strongest winds of Hurricane Char-

ley (as far inland as Orlando) continued to report wind information throughout the storm. Assessment of structure and infrastructure performance is keyed to wind speed estimates experienced throughout the area of impact. Based on performance during Hurricane Charley, National Oceanic and Atmospheric Association (NOAA)/NWS surface wind and weather monitoring systems in areas of the U.S. threatened by hurricanes must be hardened and provided with backup power and better data storage.

Hurricane Classification

Building performance across the paths of the hurricanes varied significantly by location in the wind swath area. The categorization of a storm by a single hurricane classification has limited use in post storm assessment. Wind field estimates and wind speed swath maps (refer to Figures 2–5 for examples) are critical to properly assess storm events and their implications for building design, construction, and code development.

Structural

To minimize damage or prevent failure of older buildings (both residential and commercial), mitigation actions that create a continuous load path from the roof deck to the foundation must be undertaken. Specific recommendations are included in Matrix #2, Building Code and Regulations Recommendations.

Accessory Structures

Historically and typically, aluminum structures have had little rigorous engineering applied to them because they have been regarded as auxiliary and even expendable structures. As such, the widespread failure of these structures observed after the 2004 hurricane season was anticipated.

Connection detail failures and inadequate bracing were frequently the initiation points for the ultimate failure of accessory structures indicating that, in general, designers, installers, and building department personnel may not be sufficiently knowledgeable about the design and construction of wind resistant aluminum structures. Attention is generally given to the size and spacing of members, but not to connection details. Revised guidance associated with Table 2002.4 (FBC 2001), prepared by the Aluminum Association of Florida (AAF) should be used until the adoption of the 2004 version of the FBC. Specific recommendations relating to accessory structures and attachment are cited in Matrix #1, Design and Construction Recommendations.

Building Envelope

Poor building envelope performance resulted in extensive property damage and substantial loss of function. Poor performance was a function of both inadequate wind resistance and damage from debris impact.

- Inadequate resistance to large wind pressures on building envelopes (particularly roof systems and soffits) and rooftop equipment was responsible for much of the damage incurred by the hurricanes.
- Windborne debris, especially during Hurricane Charley where wind speeds in some areas were 120 mph 3-second gust and greater, caused significant envelope damage.

Recommendations to improve building envelope performance include: modifications to building codes, Florida statutes, and regulatory requirements (refer to Matrix #2); specific recommendations by building envelope element (Matrix #1); and additional/new guidance materials and public education (Matrix #3, Public Outreach Recommendations).

Building Codes, Florida Statutes, and Regulatory Requirements

Buildings built in accordance with older codes are typically vulnerable to envelope and equipment damage because older codes had inadequate criteria or no criteria at all. Where buildings were designed and constructed to newer codes (FBC or IBC/IRC), some of the observed failures were due to failure to comply with code provisions in the design and/or construction phases. Other failures were the result of installing materials and systems that cannot perform under high-wind loads (i.e., the use of inadequately secured soffit panels). Because these elements are not considered "structural elements," their design and construction is often overlooked during design, construction, and code enforcement. Therefore, improvements are needed in the design requirements of codes themselves and with code enforcement. Specific code change recommendations are included in Matrix #2.

Building Envelope Systems

Certain building envelope components reported on in previous MAT reports continue to be initiation points for substantial interior damage and/or progressive failure. The following elements require additional guidance and design; specific recommendations by element type are included in Matrix #1.

- **Roof systems.** Many roof coverings of all types continue to fail at unacceptable rates during hurricane events, even when wind speeds

are below design levels. Failure is 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), debris impact, and design and construction related issues. Inadequate attention has typically been given to edge flashing, coping, and gutter/downspout design and installation despite their roof area locations, which are subject to the highest wind pressures.

- **Exterior Mechanical and Electrical Equipment Damage.** Displacement or damage to these units resulted in loss of function associated with the damaged units and, in many cases, loss of function of the occupied space serviced by the equipment. Rooftop and ground level equipment is not receiving the design, installation, or code compliance needed.
- **Soffits.** In numerous buildings, wind-driven rain intruded into areas where soffits were displaced or lost. Widespread loss of soffits was observed in residential construction.
- **Wall Covering.** Wall coverings continue to be an initiation point for progressive failures leading to interior contents damage or pressurization of the building.
- **Doors.** As building performance has improved and resolved many of the large structural issues, increased attention can be focused on doors and wind-driven rain infiltration. Weatherstripping and vestibules are recommended to minimize interior damage from wind-driven rain.
- **Windows and Shutters.** The required protection of windows and glazed doors in areas within the ASCE 7 windborne debris region appeared justified based on the amount of observed windborne debris from Hurricanes Charley, Frances and Ivan. The FBC windborne debris provisions in the panhandle should be changed to match those in ASCE 7. Most shutters observed on buildings performed well. Many homes and businesses that experienced only contents damage could have prevented these losses if their building envelope openings were protected.

4.2 Flood-Related Conclusions and Recommendations

The most severe flood-related damages experienced during the 2004 hurricane season were associated with Hurricane Ivan. Several general conclusions were drawn based on damage observations by the MAT.

General

Flood levels several feet higher than the mapped BFEs on the FIRMs were recorded. Several reasons could account for this: Ivan may have been a storm with a higher return period than the 100-year event shown on the FIRMs; there may have been changes in the topography over the 20 to 25 years since the storm surge modeling was initially performed; or older storm surge modeling methodologies may have failed to produce accurate estimates. Recommendations based on these observations are:

- **Re-evaluate the hazard identification/mapping approaches in Coastal A/V Zones.** Re-evaluate the methodology to determine flood zones and flood elevations in coastal high hazard areas to address the inconsistencies of observed damages versus anticipated damages based on mapped flood zones. Flood hazard mapping procedures and methodologies in coastal areas (especially on barrier islands and on mainland, open coast shorelines) may need revision to capture anticipated future coastal conditions (for instance, the possible effects of multiple storm events and long-term erosion).
- **Re-evaluate the storm surge modeling.** Re-analyze the storm surge modeling, which provides the storm surge elevations for the mapping analysis, because of significant changes in the barrier islands since the modeling was first performed.
- **Reconstruction Guidance.** Use Hurricane Ivan tide levels, inundation limits, and areas subject to wave effects as proxies for reconstruction guidance until such time as new, up-to-date regulatory studies and maps can be prepared and adopted.

Structures and Foundations

Pile Foundations. Although pile foundations generally performed well, their performance varied depending on the level of detail followed during building construction. Additionally, flood-borne debris contributed significantly to the structural damages that were observed by creating unanticipated loads on pile foundations. Recommendations to address these issues are presented in Matrix #1.

Shallow Foundations. In areas subject to coastal erosion and scour, shallow foundation damage was extensive and the structural failures dramatic. The most extreme cases were building failures due to erosion of supporting soil under shallow foundations. Shallow foundations are not appropriate for supporting structures in coastal areas

subject to scour and/or erosion and should not be permitted. Specific foundation design measures related to barrier island construction and bay/sound shoreline area construction are provided in the Matrix #1.

General recommendations on the foundations are:

- **Elevate the bottom of the lowest structural member above the BFE for Coastal A Zones.** Damages to lowest floor elevations were widespread in the flood damaged areas. All new construction (including substantially improved structures and replacement of substantially damaged structures) in Coastal A Zones should be elevated with the bottom of the lowest horizontal structural member at the base flood level.
- **Freeboard.** Require freeboard for all structures in all flood hazard zones with the amount varying with building importance and anticipated exposure to wave effects. Recommendation is based on ASCE 24-05, which addresses freeboard and elevation requirements for flood resistant materials and equipment. Specific recommendations are provided in Matrix #2.
- **V Zone standards.** Require V Zone foundations for new construction in Coastal A Zones subject to erosion, scour, and/or wave heights greater than 1.5 feet. Require deep pile or column foundations in areas mapped as Zone B, C. or X, where erosion and/or scour are possible.
- **FEMA 55 *Coastal Construction Manual*.** Emphasize best practices contained in FEMA's *Coastal Construction Manual* and in the latest flood resistant codes and standards.

Accessory Structures and Construction Features Beneath Elevated Structures

Accessory structures such as stairs and enclosures built beneath elevated buildings were totally destroyed. Most of this damage is preventable by limiting the construction of these enclosures and other systems built beneath elevated buildings. Not only are the enclosures, stairs, utilities, and other systems severely damaged, but they become a significant source of flood-borne debris, as were docks and piers. Once dislodged by storm surge, wave action, or wind, these features can act as obstructions and create unanticipated loads on the foundations and increase the potential for structural failure. Refer to Matrix #1 for specific recommendations related to these structures.

To discourage construction that results in this type of damage, flood insurance claims payments for stairs and building access structures should be limited to a reasonable fraction of the policy limit and

claim procedures should be modified to ensure flood insurance policy ratings are correct, particularly with regard to enclosures and obstructions.

4.3 Critical and Essential Facilities/Shelters, Conclusions and Recommendations

Poor performance of numerous critical/essential facilities and shelters occurred in the fall of 2004 during Hurricanes Charley, Frances, Ivan, and Jeanne. The building damage these facilities sustained during the hurricanes led to significant, yet avoidable, loss of function.

Many essential and critical facilities (excluding shelters) were housed in older buildings and most apparently were not mitigated to resist known hurricane wind risks. If these critical and essential operations were housed in buildings constructed to current code (which provides levels of protection from wind and in some cases to windborne debris), some of these buildings could have then remained operational. Alternatively, many of these facilities could have remained operational if key areas of the buildings had been mitigated or retrofitted for wind and windborne debris design requirements for their locations as specified in the current code. Code improvements are also needed. The current practices for designing, constructing, retrofitting/mitigating, and maintaining critical/essential facilities can be improved.

In addition, the continuity of critical facilities needs to be ensured. In some cases this means designing beyond the existing code minimums (e.g., remove or replace roof-top aggregate). A vulnerability assessment should be performed to assess the building performance and utilities that service critical facilities. This would provide the building owner a better understanding how the building will be impacted during a storm and how the operations will be impacted by limited utility services. As an example, electrical service may provide power to lift stations for sewage; if the building were used as a shelter and electrical service is disrupted during a storm, backup systems would likely be required, but certain portions of the building may not need to be operational.

The performance of buildings used as hurricane shelters also varied widely. Performance varied from numerous successes to an instance of a partial building collapse. Although only minor injuries were reported, large numbers of people within shelters were traumatized because of poor building performance or perceived poor performance when comfort issues were compromised. In Charlotte and Lee Counties in

Florida, shelters used during Hurricane Charley were located within the storm surge inundation zone for a Category 3 hurricane; luckily, due to the compact size of the hurricane, typical storm surge was not generated and the shelters were not flooded; however, if typical surge had occurred, this shelter would have been flooded.

To achieve building performance during hurricanes that will preserve the facility function, the following are recommended in addition to the specific recommendations provided in Matrix #2 and Matrix #4, Critical and Essential Facility Recommendations.

- **Expand the use of the critical/essential facility designation.** Buildings other than those defined by ASCE 7 Table 1 may be vital in the response or recovery after a hurricane, or they may house functions that need to remain operational during or after an event. For example, damage to a medical office building, though not necessarily a Category III or IV building, could adversely affect the hospital functions. Additionally, skilled nursing homes, Alzheimer's units, and perhaps independent living or assisted living facilities could benefit from this designation.
- **Prioritize the critical and essential facilities.** Although all critical and essential facilities are important, some are more critical than others. Buildings sheltering large numbers of people (e.g., greater than 1,000) and buildings that have regional importance (e.g., a county EOC or regional hospital) should be designed, constructed, and maintained more conservatively than normal critical and essential facilities. Existing critical and essential facilities should also receive the highest priority for mitigation (retrofit). Designers should also remember that codes and standards recommend the minimum design requirements for facilities (even critical and essential facilities). Designers should implement known best practices for high-wind design above the minimums required.

4.4 Design Guidance and Public Education Recommendations

Design and Construction Guidance

Many building component failures observed during the 2004 hurricane season were the result of the failure to implement well-established basic construction practices. Designers and contractors need additional guidance to understand wind-resistance issues and to provide methodologies and best practices when code guidance is vague or unclear or does not exist. Based on the MATs' observations, specific design, test-

ing, and construction guidance is needed for the several areas listed below. Detailed recommendations are included in Matrix #3:

Design Guidance

- Roof coverings, gutters, and downspouts
- Rolling and sectional doors
- Soffits
- Rooftop equipment
- Other exterior devices and equipment such as pool equipment, swing sets, and storage sheds
- Electrical and communications equipment

Testing Guidance

- Test methods: Most of the methods used to test envelope assemblies are static tests, which are inadequate for some assemblies. The development and application of dynamic tests are recommended.

Construction Guidance

- Manufacturer's instructions: There were numerous instances of significant deviation from manufacturers' installation instructions. Manufacturers need to ensure adequate instruction (bilingual instructions would be advantageous) and training.

Public Education and Outreach

Much has been learned in the past three decades regarding practices that need to be implemented to achieve good building performance during strong hurricanes. Although improvements are still needed with respect to design guides, test methods, building codes, and construction/inspection practices, many designers, manufacturers, building officials, and contractors did not fully implement the current state of knowledge (e.g., FEMA 55, FEMA 361, FEMA 424, ASCE 24-05) with respect to buildings located in hurricane-prone regions. A renewed, comprehensive educational effort is needed to avoid the hurricane building damage cycle, wherein buildings are constructed, damaged, repaired, or rebuilt—to a condition often no better than the initial damage—and then damaged again in a future weather event. Specific recommendations for the following audiences are included on Matrix #3.

- Building owners and homeowners
- Architects/engineers/consultants
- Building officials
- Contractors
- Manufacturers
- Associations

The greatest educational challenge is to get those in need to take advantage of educational materials that are available. To the extent possible, materials and seminars should be free or of minimal cost. To achieve this goal, governmental funding or private sponsorship may be necessary. However, the ultimate incentive likely lies with building owners and homeowners, and the decisions they make in selecting design and construction teams that will produce the best product for their dollar.

Matrix #1.
Design and Construction Recommendations

BUILDING COMPONENT	RECOMMENDATION	ACTION REQUIRED BY[1]
WIND HAZARD		
ACCESSORY STRUCTURES		
Attached & detached	Add additional anchors at corner post connections to concrete.	D, C
Attached & detached	Use AAF *Guide to Aluminum Construction in High Wind Areas* until FBC 2004 is adopted.	D
Attached & detached	Increase wind resistance of accessory structure walls parallel to primary building (e.g., tension cable, solid 'K' bracing).	D
Attached & detached	Provide lateral bracing in roof planes using rigid diagonal structural members.	D, C
Attached	Ensure attached building and primary building can withstand equal wind pressures.	D, C
Attached	Determine implications to primary building if attached structure collapses.	D, C
Detached	Determine ability to withstand windstorm events to reduce windborne debris.	D, C
BUILDING ENVELOPE		
Roof systems	Testing: Roof assemblies susceptible to dynamic loading should be dynamically tested to obtain realistic measure of their wind resistance. Higher safety factors should be used for those assemblies requiring dynamic testing, but for which dynamic test methods are not available.	D, C, G
Re-roofing	Tear off old roof (do not re-cover) in areas where basic wind speed is 110 mph or greater.	D, C
Re-roofing	Install additional sheathing fasteners if existing sheathing attachment is not in compliance with current building code.	D, C
Asphalt shingles	Ensure manufacturers' installation instructions are followed (i.e., starter strips and nail locations) and use Recovery Advisory Nos. 1 and 2.	D, C
Asphalt shingles	Re-evaluate attachment of factory-laminated tabs.	M
Metal panel roof system	Ensure that chalk-line clip locations for panels with concealed clips are not excessively spaced.	C
Metal panel roof system	Base uplift resistance on ASTM E 1592.	M, D
Metal panel roof system	Specify close spacing of fasteners at eaves, and hip, and ridge flashings.	D
Tile roof system	Use Recovery Advisory No. 3.	D, C
Tile roof system	Develop tiles with improved ductility via internal or backside reinforcement or bonding film in hurricane-prone regions (e.g., develop tile similar to laminated glass).	M

[1] Action required by: Designer (D), Contractor (C), Manufacturer (M), Government Official (G), Building Owner (O)

BUILDING COMPONENT	RECOMMENDATION	ACTION REQUIRED BY[1]
Tile roof (foam-set) system	For foam set tile, simplify number of installation options and clarify requirements.	M
Tile roof (foam-set) system	Modify training and certification programs to ensure that foam-set roof installers are adequately trained.	M, C
Tile roof (foam-set) system	Use a higher safety factor (e.g., 4) to account for application and testing issues.	M, D
Mechanically attached roof systems	FRSA/TRI re-evaluate use of safety factor of 2. Either develop dynamic test method or use existing test method with higher safety factor (e.g., 3).	M, D
Built-up roofs	Develop and codify technically-based criteria for aggregate surfacing on built-up and sprayed polyurethane foam roofs.	M, G
Edge flashings & copings	Comply with ANSI/SPRI ES-1 (2003). Use safety factor of 2 - 3.	D
Edge flashings & copings	Install edge flashings on top of membrane to clamp it down.	D, C
Edge flashings & copings	Place a bar over roof membrane near edge of flashing and coping to provide secondary protection.	D, C
Gutters & downspouts	Use professional judgment to specify and detail gutter uplift resistance.	D
Gutters & downspouts	Design Guidance: Develop design guide, test method, and code criteria for gutters, including attachment of downspouts.	M, C
Rooftop walkway pads	Research wind resistance of roof walkway pads.	M, G
Soffits	Design Guidance: Develop design guidance for attaching soffits, including design of baffles or filter media to prevent wind-driven rain from entering attics.	M, G
EXTERIOR EQUIPMENT		
General	For all exterior equipment, recommend safety factor of 3 due to uncertainties pertaining to wind load.	D
General	Design Guidance: Develop guidance and code criteria for attaching condensers and rooftop mechanical equipment (including ductwork).	D, G
General	Evaluate the need to better secure exterior devices, such as pool equipment and roof-mounted solar heaters.	D, C, O, CF
Cowlings	Anchor cowlings on exhaust fans to curbs using cables.	M, D, C
Access panels	Modify access panels attached by manufacturer to ensure secure attachment (see FEMA 424).	M, D, C
Lightning protection systems	Attach lightning protection systems, per FEMA 424.	M, D, C

[1] Action required by: Designer (D), Contractor (C), Manufacturer (M), Government Official (G), Building Owner (O)

BUILDING COMPONENT	RECOMMENDATION	ACTION REQUIRED BY[1]
Lightning protection systems	Design Guidance: Develop guidance and code criteria for attaching lightning protection systems. Anchor communication towers and satellite dishes.	D, C, M, G
Vinyl siding	Design Guidance: Develop design guidance for attachment.	M, G
EIFS	Design Guidance: Develop design guidance for attachment and re-evaluate existing test method.	M, G
DOORS		
Exterior doors	Specify wind-driven rain resistant weather-stripping at exterior doors (see FEMA 424).	D
Entrance vestibules	Design entrance vestibules in areas where basic wind speed is greater than 120 mph.	D
Rolling & sectional doors	Consider type, size, and spacing of door, frame, and frame fasteners to withstand wind loads. If frame is attached to wood blocking, then consider blocking attachment.	D, C
Rolling & sectional doors	Maintain adequate edge distances for frame fasteners.	C
WINDOWS AND SHUTTERS		
General	The window industry should re-evaluate current test procedures to better represent dynamic wind loading produced by hurricane and tropical storm winds.	D, C, M, G
General	Develop window assemblies that are more wind-driven rain water-resistant.	M
FLOOD HAZARD		
FOUNDATIONS AND STRUCTURES		
General	Design foundations and structures to withstand loads from flood-borne debris during a base flood event (100-year).	D
Foundations on barrier islands	Require V Zone foundations for new construction in Coastal A Zones subject to erosion, scour, and/or subject to wave heights of 1.5 feet or higher during a base flood event.	G
Foundations on barrier islands	Use pile or column pier foundations for A Zone areas not subject to erosion and not subject to 1.5 foot (or higher) wave heights to minimize flood-borne debris damage. Stem wall foundations may be appropriate for areas subject to shallow flooding, but foundation walls are not recommended.	D, C
Foundations on barrier islands	Require deep pile or column foundations in areas presently mapped as Zones B, C, or X, where erosion and/or scour is possible.	G
Foundations on barrier islands	Require use of self-supporting lowest floor system that will not collapse if undermined for high-rise construction in areas outside the V Zone.	G
General	Use flood and corrosion resistant materials below the BFE as recommended by American Society of Civil Engineers (ASCE) 24-05 and the *Coastal Construction Manual* (FEMA 55).	D, C

[1] Action required by: Designer (D), Contractor (C), Manufacturer (M), Government Official (G), Building Owner (O)

BUILDING COMPONENT	RECOMMENDATION	ACTION REQUIRED BY[1]
Foundations in bay and sound shoreline areas	Require V Zone foundations for new construction subject to erosion and/or scour in bay areas outside mapped V Zones.	G
Foundations in bay and sound shoreline areas	Require V Zone foundations for new construction subject to wave heights of 1.5 feet or higher in bay areas outside mapped V Zones.	G
Foundations in bay and sound shoreline areas	Use pile, column, or pier foundations for A Zone areas that are not subject to erosion, scour, or 1.5-foot (or higher) wave heights to minimize flood-borne debris damage. Stem wall foundations may be appropriate for areas subject to shallow flooding, but foundation walls are not recommended.	D, C
First floor elevation	Elevate all new construction (including substantially improved structures and replacement of substantially damaged structures) in A Zones with the bottom of the lowest horizontal supporting member above the base flood level. Freeboard for all structures in all flood hazard zones is desirable; the amount will vary with building importance and anticipated exposure to wave effects.	D, C
ACCESSORY STRUCTURES AND CONSTRUCTION BENEATH ELEVATED STRUCTURES		
Dock and Piers	Implement design requirements for docks and piers that minimize damage to other structures.	D

[1] Action required by: Designer (D), Contractor (C), Manufacturer (M), Government Official (G), Building Owner (O)

Matrix #2.
Building Code and Regulations Recommendations

WIND HAZARD	
BUILDING COMPONENT	**RECOMMENDATION**
BUILDING ENVELOPE	
Edge flashing and coping	**FBC Section 1503** (Weather Protection) should require compliance with ANSI/SPRI ES-1 for edge flashings and copings.
Gutters	**FBC Section 1503** (Weather Protection) **and IBC/IRC**: Develop and add criteria regarding uplift resistance of gutters.
Metal panel roof system	**FBC Section 1504** (Performance Requirements): Require compliance with ASTM E 1592 for testing the uplift resistance of metal panel roof systems.
Roof system	**FBC Section 1510.3** (Recovering vs. Replacement) **and IBC/IRC**: Require removal of existing roof covering down to the deck and replacement of deteriorated sheathing in areas where basic wind speed is 110 mph or greater. If existing sheathing attachment does not comply with loads derived from Chapter 16, then require installation of additional fasteners to meet loads.
Asphalt shingles	**FBC Section 1507.2** (Roof Covering Application) **and IBC/IRC**: Require compliance with UL 2390. Also require six nails per shingle and require use of asphalt roof cement at eaves, rakes, hips, and ridges where basic wind speed is 110 mph or greater (refer to Recovery Advisory No. 2).
Mortar-set tile roof system	**FBC Section 1507.4** (Clay and Concrete Tile) **and IBC/IRC**: Provide an alternative to the use of mortar to attach field tiles and hip/ridge tiles.
Built-up roof	**FBC Section 1508** (Roof Coverings with Slopes Less Than 2:12): Add technically-based criteria regarding blow-off resistance of aggregate on built-up and sprayed polyurethane foam roofs.
Ridge vents	**FBC Section 1503** (Weather Protection) **and IBC/IRC**: Add criteria regarding wind and wind-driven rain resistance of ridge vents. Attachment criteria require development, but TAS 110 could be referenced for rain resistance.
Soffit	**FBC/IBC/IRC:** Criteria regarding wind resistance of soffits should be added, and wind-load criteria for soffits require development. Wind-driven rain resistance of ventilated soffit panels should also be added. TAS 110 may be a suitable test method, modified as necessary.
WINDOWS AND SHUTTERS	
Shutters	**FBC Section 1606.1.4** (Protection of Openings): Add requirement to label shutters (other than wood) because without labels, building owner does not know if shutters are suitable.
Windborne debris region	**FBC:** Revise the Florida panhandle criteria to match ASCE 7.
Shutters	Revise Chapter 15C of the Rules and Regulations of Florida to provide window protection systems (and a strengthened structure around openings) on Zone II and Zone III units being installed in the windborne regions defined by Chapter 16 of the FBC.
EXTERIOR EQUIPMENT	
General	**FBC Section 1522.2** (Rooftop Mounted Equipment): Make applicable throughout the State of Florida for all wind speeds. Develop and add criteria that pertain to attaching lightning protection systems. Provisions also included in mechanical and electrical codes.

BUILDING COMPONENT	RECOMMENDATION
CRITICAL AND ESSENTIAL FACILITIES	
General	For hurricane shelters and EHPA, adopt wind speed recommended by Florida Department of Community Affairs (FL DCA) in the SESP and the ASCE 7-02/2001 FBC wind speed map design wind speed plus 40 mph using Performance Criteria 3. Currently this is a *recommended* best practice in the FL DCA shelter design guidance and in FBC Section 423, Part 24; change to a *requirement*. This criterion should be required by the SESP and should be used until the International Code Council's High Wind Shelter Standard is completed in 2006/2007 and available for adoption.
General	Minimum debris impact protection should be per ASTM E 1996 Category E for a 9-pound 2x4 (nominal) missile traveling at 50 mph. This criterion should be required by the SESP and should be used until the International Code Council's High Wind Shelter Standard is completed in 2006/2007 and available for adoption.
General	As an alternative to designing shelters to the SESP or ASCE criteria, design or retrofit buildings to be used as shelters to the design guidance provided in FEMA 361, *Design and Construction Guidance for Community Shelters.*
FLOOD HAZARD	
FOUNDATIONS AND STRUCTURES	
General	Adopt ASCE 24-05 for elevation requirements and flood resistant materials, equipment.
General	Re-evaluate the hazard identification/mapping approaches in Coastal A/V Zones (refer to glossary for definitions).
General	Re-evaluate the storm surge modeling methodology.

Matrix #3.
Public Outreach Recommendations

WIND HAZARD	
EDUCATION TOPIC	**OUTREACH METHOD**
BUILDING OWNERS AND HOMEOWNERS	
Plan and budget construction projects that incorporate natural hazard mitigation measures. Select design and construction teams knowledgeable in effective construction methods in hurricane-prone areas. Prepare and protect building prior to hurricane landfall. What to do after hurricane passes (building inspection for damage, emergency repairs, and drying out building interiors). Rebuild damaged structure in manner that protects against future damage. Inspect exterior connections and fasteners for wear, corrosion, and other deterioration. Educate building owners on how wind-driven rain water enters buildings, the resulting implications (loss of electricity, mold), and prevention methods.	✔ Tailor informational pamphlets to homeowners and building owners. ✔ Develop strategy to distribute information (e.g., standardized information sheets during sale of building). ✔ Enlist assistance of real-estate companies and organizations such as the Building Owners and Managers Association. ✔ Provide public service notices at start of each hurricane season. ✔ Develop informational materials on how wind-driven rain water enters buildings, the resulting damage, and prevention methods.
ARCHITECTS, ENGINEERS, CONSULTANTS	
Improve the technical proficiency of building envelope design. Provide adequate level of design details for connecting rooftop equipment, including mechanical, electrical and lightning protection. Share post-disaster building performance information to maximize the value of lessons learned.	✔ Prepare monographs for trade-wide distribution. ✔ Prepare web-based tutorials and seminars. ✔ Encourage colleges and universities to augment existing curriculum with hurricane-resistant design instruction.
BUILDING OFFICIALS	
Share post-disaster building performance information to maximize the value of lessons learned. Train building officials to identify structural weaknesses that may cause structure or building component failure during a hurricane (e.g., unbraced gable ends, missing truss bracing, truss' anchorage, window/door anchorage). Implement effective enforcement techniques to maintain a high construction quality.	✔ Conduct annual seminars for building officials and plan reviewers in coastal areas to share lessons learned. ✔ Implement hurricane disaster building inspection training program and "train the trainer" program.

EDUCATION TOPIC	OUTREACH METHOD
CONTRACTORS	
Educate contractors who construct building envelopes and install rooftop equipment on hurricane resistant fastening and anchoring systems. Educate contractors on how wind-driven water enters buildings, the resulting implications (loss of electricity, mold), and prevention methods.	✓ Develop and distribute visual tools such as instructional videos or DVDs. ✓ Conduct on-the-job training to highlight failures that occur when simple anchoring techniques are not applied. ✓ Encourage trade schools in hurricane-prone areas to augment their curriculum with courses on state-of-the-art hurricane-resistant construction.
MANUFACTURERS	
Educate manufacturers of building envelope materials and rooftop equipment on the performance of their products during hurricanes. Encourage manufacturers to provide special guidance for use of their products in hurricane-prone areas. Develop improved products and systems for hurricane-prone areas. Manufacturers should educate designers and contractors on their products.	✓ Develop and distribute informational notices to manufacturers.
ASSOCIATIONS, INSTITUTES, AND SOCIETIES	
Advocate hurricane-resistant design and construction to their membership.	✓ Develop educational materials for distribution to their members and industry.
FLOOD HAZARD	
BUILDING OWNERS AND HOMEOWNERS	
Educate building and homeowners in the risks of natural hazards and best practices for mitigating damages. Educate homeowners on the risk of constructing enclosures and accessory structures beneath the first floor and emphasize the significant damage that will result during a severe coastal flood event.	✓ Tailor informational pamphlets to homeowners and building owners.
ARCHITECTS, ENGINEERS, CONSULTANTS **BUILDING OFFICIALS** **CONTRACTORS**	
Share post-disaster building performance information to maximize the value of lessons learned. Emphasize best practices such as *Coastal Construction Manual* (FEMA 55). Emphasize importance of strong structure-to-beam connections to prevent structure detachment from the foundations while piles and beams are still intact.	✓ Prepare monographs for trade-wide distribution. ✓ Prepare web-based tutorials and seminars. ✓ Encourage colleges, universities, and trade schools to augment existing curriculum with hurricane-resistant design and construction instruction.

Matrix #4.
Recommendations Specific to Critical and Essential Facilities[1]

WIND HAZARD		
COMPONENT	**RECOMMENDATION**	**ACTION REQUIRED BY[2]**
GENERAL		
Detailing and notations on the building plans	Facility plans should delineate the facility area designed to function as a shelter or hardened area. Details of the shelter or hardened area and the envelope elements should be provided to ensure that the construction requirements are clearly understood by the builder and building official. Provide facility design criteria and maximum design pressures for the main wind force resisting system (MWFRS) and for components and cladding.	D, C, CFO
Material selection	Reinforced concrete roof deck and reinforced concrete and/or reinforced and fully-grouted concrete masonry unit (CMU) exterior walls are recommended. FEMA 424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds,* and FEMA 361, *Design and Construction Guidance for Community Shelters,* provide detailed guidance on material selection for structural and building envelope systems.	D, C, CFO
General	Develop additional criteria to help insure continuity of function. See FEMA 424 and FEMA 361.	CFO
General	Emphasize best practices for schools and shelters described in FEMA 424 and FEMA 361 respectively, and in the latest codes and standards for wind resistance (ASCE 7).	CFO
Design guidance	Develop a comprehensive design guide to complement FEMA 424 for mitigating existing facilities.	D, G
Perform vulnerability assessment	Perform vulnerability assessment to ensure continuity of operations. The assessment should evaluate the building performance and utilities that service critical/essential facilities so that the building owner understands impacts to the facility during a storm and operational impacts due to limited utility services.	CFO
STRUCTURAL		
General	Implement mitigation measures or structurally retrofit critical/essential facilities to design levels other than minimum code requirements for general use buildings. Do not house critical facilities in lightly engineered buildings such as pre-engineered metal buildings.	CFO, D
General	Educate designers: buildings designed to minimum EHPA requirements does not guarantee that building used as shelter will be properly designed and constructed to resist extreme wind events. Emphasize best practices for shelters described in FEMA 361.	D, C
General	Educate designers: American Red Cross 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 hurricanes. Emphasize best practices for shelters described in FEMA 361.	D, C

[1] Refer also to other matrices
[2] Action required by: Designer (D), Contractor (C), Manufacturer (M), Government Official (G), Critical Facility Manager/Owner (CFO)

COMPONENT	RECOMMENDATION	ACTION REQUIRED BY[2]
General	Conduct special inspections for key structural items and connections to ensure performance of critical facilities.	CFO, C
General	Design critical and essential facilities with wind loads using an importance factor of 1.15 in accordance with ASCE 7. For some facilities, design using the 40-mph increase with importance factor of 1 (recommended for shelter EHPA design in FBC Section 423, Part 24).	D
General	Incorporate hazard mitigation peer review into design approval process to ensure that critical and essential facilities are adequately designed to resist extreme winds.	D
ACCESSORY STRUCTURES		
Detached	Strengthen the anchorage of structures and portable classroom buildings at schools.	D, C, G, CFO
BUILDING ENVELOPE		
General	Contract drawings and specifications for new construction and remedial work on existing building envelopes and rooftop equipment should undergo rigorous peer review, submittal review, field observation (inspection), and testing prior to construction.	D, C, G
General	Implement mitigation measures in buildings not built to current building codes to protect roof coverings, wall coverings, window and door systems, and rooftop equipment.	D, CFO
General	Conduct special inspections for key building envelope components to ensure performance of critical/essential facilities. Inspect roof top equipment twice a year. Inspect doors, windows, and wall coverings at 5-year intervals. Conduct special inspections of the entire facility (both structural and building envelope systems) after storms with wind speeds in excess of 90 mph 3-second gust winds.	CFO
Roof structure	Install hurricane clips or straps on inadequately connected roof beams and joists in those buildings that will be occupied during a hurricane.	C, CFO
Roof decks	Strengthen inadequately attached roof decks.	CFO
Roofing	Replace aggregate-surfaced roof systems with non-aggregate systems.	D, C, CFO
Roof system	Design roof system that will prevent water infiltration if roof is hit by windborne debris.	D
Edge flashings and copings	Install exposed fasteners to weak metal edge flashings and copings.	D, C, CFO
Gutters and downspouts	Install tie-down straps on gutters to avoid membrane blow-off.	D, C, CFO
Rooftop equipment	Anchor all rooftop equipment.	D, C, CFO

[2] Action required by: Designer (D), Contractor (C), Manufacturer (M), Government Official (G), Critical Facility Manager/Owner (CFO)

COMPONENT	RECOMMENDATION	ACTION REQUIRED BY[2]
DOORS		
Door	Design or mitigate to the 2001 FBC for the 120 mph (3-second gust) design wind speed.	D
Rolling and sectional doors	Purchase and install high wind-rated, sectional/rolling doors to protect against high wind.	D, CFO
Rolling and sectional doors	Ensure sectional rolling doors are properly installed and reinforced to prevent catastrophic door failure and building pressurization. Replace or retrofit existing doors that lack adequate resistance.	D, CFO
WINDOWS AND SHUTTERS		
Shutters	Install shuttering system on all exterior glazing that is not windborne debris resistant. Install power-operated shutters or laminated glass, or apply an engineered film system to the glazing and frame on upper-level floors,	D, C, CFO
Windows	Implement window protection systems to protect critical facilities from windborne debris.	CFO, D
FLOOD HAZARD		
FOUNDATIONS AND STRUCTURES		
General	Do not open shelters located in potential storm surge inundation zones until after the hurricane makes landfall.	G, CFO
General	Elevate new structures in floodprone areas to the 500-year (0.2% annual exceedance) flood level, or higher based on ASCE 24.	D, C, G, CFO

[2] Action required by: Designer (D), Contractor (C), Manufacturer (M), Government Official (G), Critical Facility Manager/Owner (CFO)