8 Recommendations

The recommendations in this report are based solely on the observations and conclusions of the MAT, and are intended to assist the State of Florida, local communities, businesses, and individuals in the reconstruction process and to help reduce damage and impact from future natural events similar to Hurricane Charley. The general recommendations presented in Section 8.1 relate to policies and education/outreach that are needed to ensure that designers, contractors, and building officials understand the requirements for disaster resistance construction in hurricane-prone regions. Proposed changes to codes and statutes are presented in Section 8.2.

In addition to these general and code related recommendations, specific recommendations for improving the performance of the building structural system and envelope, as well as the protection of critical and essential facilities (to prevent loss of function) are provided later in this chapter. Implementing these specific recommendations in combination with the general recommendations of Section 8.1 and the code and statute recommendations of Section 8.2 would significantly improve the ability of the built environment to resist damage from hurricane force winds. Recommendations specific to building structural and envelope issues, critical and essential facilities, and education and outreach have also been provided.

8.1 General Recommendations

As the people of Florida rebuild their lives, homes, and businesses, there are a number of ways they can avoid the effects of future natural hazards, including:

- Design and construct facilities to at least the minimum design requirements in the 2001 FBC and the 2004 FBC (after it becomes effective in the summer of 2005)
- When renovating or remodeling for a building's structural or envelope improvements (both residential and commercial), involve a structural engineer/design professional/licensed contractor in the design and planning
- Assure code compliance through increased enforcement of construction inspection requirements such as the Florida Threshold Inspection Law or the IBC Special Inspections Provisions
- Perform follow-up inspections after a hurricane to look for interior moisture that may affect the structure or building envelope
- Use the necessity of roof repairs to damaged buildings as an opportunity to significantly increase the future wind resistance of the structure

The following recommendations are specifically provided for state and Federal government agencies:

- The government should place a high priority on and allocate resources to hardening, providing backup power and data storage to NOAA's/NWS's surface weather monitoring systems, including ASOSs located in hurricane-prone regions. Continued support is also needed for maintenance, expansion, and deployment of stand-alone unmanned surface observation systems that can be safely and reliably placed in advance of a landfalling hurricane. Support should be provided for the real-time communication of data from all these systems to forecasters and wind field modeling efforts.
- The government should place a high priority on continuing to fund the development of several different tools for estimating and mapping wind fields associated with hurricanes and for making these products available to interested parties as quickly as possible after a hurricane strikes.

8.2 Proposed Changes to Codes and Statutes

Buildings constructed in accordance with 2001 FBC (and those that had been mitigated to resist high-wind loads) were observed to perform substantially better than typical buildings constructed to earlier codes, but their performance was not without exception. The study of buildings and their interaction with high winds associated with hurricanes is a continuous process and much has been learned since the current FBC was developed and adopted. Incorporating these recommendations into the next available code cycle is key to setting the new standard in hurricane-resistant construction in Florida and all hurricane-prone regions.

The following is a list of recommendations specific to the codes and statutes currently adopted and being enforced in the State of Florida. If these recommendations are not codified by the state in response to the hurricanes of 2004, the design changes recommended herein should be considered "best practices" in hurricane-resistant construction and incorporated in all new construction and mitigation projects to the maximum extent possible. The preliminary conclusions and recommendations from this MAT report were presented to the Florida Building Commission and to FL DCA in December 2004 at the Hurricanes Charley, Frances, Ivan, and Jeanne Workshop sponsored by the Commission and IBHS.

In response to Hurricane Season 2004, the Florida Building Commission established a Hurricane Research Advisory Committee composed of researchers, engineers, academics, material suppliers, code officials, and the insurance industry. The Commission invited FEMA to be a member of the Committee. At its first meeting on March 15, 2005, the various members of the Committee made presentations to the Commission on their observations of building performance and the status of their various studies and reports; FEMA also delivered its comprehensive report FEMA 490, *Summary Report on Building Performance 2004 Hurricane Season*. The report provides the Committee with the recommendations of the MATs on design and construction, building code and regulations, public outreach, and critical/essential facilities issues. With FEMA's input and that of its other members, the Committee will produce a report that presents consensus recommendations on needed changes to Florida's building codes, standards, and statutes. The Florida Building Commission will consider these changes as it begins its building code update cycle in the summer of 2005.

8.2.1 Statutory Building Code Provisions

The following design criteria are recommended for inclusion into statewide design requirements for all construction. The criteria are addressed in Ch. 553.71 and Ch. 2000-141 of the *Laws of Florida* (and presented in Section 2.2 of this report).

- Evaluate and adopt updated versions of ASCE 7 for design-load determination of building structures, building envelope systems, attached equipment, accessory structures, and critical and essential facilities. Specific improvements related to the design of building envelopes, attached structures, and open structures that could mitigate damage observed in Hurricane Charley are not available in ASCE 7-98.
- Adopt the windborne debris region defined in ASCE 7 2005 and the debris-impact design criteria provided in ASCE 7 2005. The findings of this MAT and the Hurricane Ivan MAT determined that these code improvements would have a significant effect in reducing damage from windborne debris to buildings and contents when a high-wind event strikes.
- Review the exemption in windborne debris regions that allows for residences to be designed as "partially-enclosed" structures with unprotected openings. The MAT observed numerous instances where the breach of unprotected glazing led to significant damage to building contents that would have been prevented if the damaged buildings had been equipped with protected glazing to resist windborne debris. The next version of the IRC does not allow for the design of partially enclosed structures without protecting glazing. Based on observed damages in Hurricane Charley, this exemption should not be allowed for any use (residential or commercial) in windborne debris regions.
- Define the Exposure Categories used in design in a manner consistent with ASCE 7. Refinements to design guidance for Exposure Categories have been included in the most recent revisions of ASCE 7. Use of the proper Exposure Category would help ensure that full-wind loads are calculated in open areas (Exposure C) where speed reductions are not appropriate.
- 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.

8.2.2 General Code Changes Proposed for FBC Consideration

The MAT observed damages across the hurricane wind field that may have been prevented had existing code sections been enforced for all design wind speed regions or if the code had provided additional design or testing guidance with respect to the building envelope and attached structures and equipment. In response to the observations, the following items are recommended for inclusion in future updates of the FBC and consideration should also be given to incorporating applicable modifications into the national model building codes for other areas of the country exposed to high-wind speeds:

- Develop and adopt wind resistance and wind-load criteria regarding wind resistance for soffits. Wind-driven rain resistance of ventilated soffit panels should also be added. Testing Application Standard (TAS) 110 may be a suitable test method, although it may require modification.
- FBC Section 1503 (Weather Protection) should require compliance with American National Standards Institute (ANSI)/Single Ply Roofing Industry (now just known as SPRI) ES-1 for edge flashings and copings.
- Develop and adopt criteria regarding uplift resistance of gutters and add to FBC Section 1503 (Weather Protection)
- Criteria regarding wind and wind-driven rain resistance of ridge vents should be added to FBC Section 1503 (Weather Protection). Attachment criteria need to be developed, but TAS 110 could be referenced for rain resistance.
- FBC Section 1504 (Performance Requirements) should require compliance with American Society for Testing and Materials (ASTM) E 1592 for testing the uplift resistance of metal panel roof systems.
- FBC Section 1507.2 (Roof Covering Application) should require compliance with Underwriters Laboratories (UL) 2390 and six nails per shingle where the basic wind speed is 110 mph or greater, and it should require use of asphalt roof cement at eaves, rakes, hips, and ridges (refer to FEMA *Hurricane Recovery Advisory No. 2* in Appendix D for details).
- Technically-based criteria regarding blow-off resistance of aggregate on built-up and sprayed polyurethane foam roofs should be added to FBC Section 1508 (Roof Coverings with Slopes Less Than 2:12).
- In areas where the basic wind speed is 110 mph or greater, FBC Section 1510.3 (Recovering vs. Replacement) should require

removal of the existing roof covering down to the deck and replacement of deteriorated decking. In addition, if the existing decking attachment does not comply with the loads derived from Chapter 16, installation of additional fasteners to meet the Chapter 16 loads should be required.

- FBC Section 1522.2 (Rooftop Mounted Equipment) pertaining to anchoring rooftop equipment should be applicable throughout the State of Florida for all wind speeds. Criteria should be added that pertain to attaching lightning protection systems; however, the criteria need to be developed. These provisions should also be included in the mechanical and electrical codes.
- Where shutters other than wood are provided to comply with FBC Section 1606.1.4 (Protection of Openings), a requirement to label the shutters with code described performance information should be added to this section. Without a label, is it difficult for building owners to know if their shutters are suitable.

8.2.3 Code Changes Proposed for Critical/Essential Facilities and Shelters

To address the poor performance and loss of function of critical and essential facilities during Hurricane Charley, the following code changes are recommended. Some changes in this section are not directly attributed to damage observed from the hurricane, but rather to the resulting loss of function that was observed. These types of facilities are expected to perform better than standard construction (i.e., these buildings are expected to withstand design events such as Hurricane Charley with minimal damage or loss of function). These facilities are expected to be functional and operational after hurricanes of significant magnitude.

For shelters and Enhanced Hurricane Protection Areas (EHPAs), the need for assurance against failure is significant because these facilities are opened and people are invited into a building deemed capable of preserving life and protecting against harm during an event. Recommended design guidance and best practices for the critical and essential facilities, in addition to the code changes cited below, are presented in Section 8.6.

- Critical and essential facilities, at a minimum, should be designed with wind loads using an importance factor of 1.15 in accordance with ASCE 7. In addition, all code changes proposed in Section 8.2.2 should be required (if they are not adopted for all buildings).

- In the SESP, the FL DCA recommends that the design wind speed used for the design of hurricane shelters and EHPAs should be the 2001 FBC basic wind speed plus 40 mph (Performance Criteria 3, shown in Table F-1 in Appendix F). This is also the *recommended* best practice for shelter design provided in the 2001 FBC, Section 423, Part 24 (State Requirements for Educational Facilities–Public Shelter Design Criteria). To better ensure the adequate performance of shelters, the MAT recommends that this guidance be changed to a *requirement*.
- For shelters and EHPAs, the minimum debris impact protection should be per ASTM E 1996 Category E for a 9-pound 2x4 (nominal) missile traveling at 50 mph. These criteria should be required by the SESP and should be used until the International Code Council's (ICC's) High Wind Shelter Standard is completed in 2006/2007 and available for adoption.

8.3 Structural (Residential and Commercial Construction)

The generally good performance of structural systems implies that the structural design of buildings in high-wind areas has been improved. This improvement is the result of implementation of code requirements that better account for the forces acting on buildings from wind and windborne debris. In addition to considerations recommended in Section 8.2, the following best practices regarding the design of new structures and mitigation of older structures are strongly recommended.

8.3.1 New Residential and Commercial Structures

It is essential that new buildings be constructed to the 2001 FBC and then to the revised 2004 Edition. In addition to the proposed changes to codes and statutes presented in Section 8.2, the following should also be considered during the design and construction of new buildings:

- Detailing for connections that clearly specifies the continuous load path through a building should be provided on residential construction drawings.
- Structural attachments, such as carports, and additions to manufactured homes should only be constructed when properly designed and permitted documents show the addition is capable of withstanding the wind loads generated. If the addition or attachment

is not free-standing and is connected to the manufactured home for structural support, plans should be prepared that clearly detail the connection between the unit and the structure being attached. The design and construction should be approved, permitted, and inspected by building officials.

- Design professionals, building officials, and contractors need to work together to improve quality control and inspections during the design and construction of buildings in high-wind areas. Codifying additional inspections does not guarantee improved construction unless building officials are provided the resources or funds for these inspections. All parties need to look at ways to ensure buildings are constructed as designed and permitted in hurricane-prone regions.

8.3.2 Wind Mitigation for Existing Residential Buildings

Some of the existing residences that performed well in Hurricane Charley were older residences that had been retrofitted to resist wind and windborne debris. In many instances, the mitigation measures observed by the MAT in these older homes were key to the improved performance of the structures. However, in some cases, these retrofits were incorrectly performed or were incomplete, and damage or failure occurred.

The most common mitigation measure for existing residential buildings observed was the installation of metal framing connectors such as clips and straps between rafters/trusses and bearing walls. However, in each of the observed buildings, the mitigation effort did not address other connections between the roof deck and the rafters/trusses. Therefore, only part of the load path between the roof covering and the foundation was strengthened.

At many other existing residences, the attachment of the roof covering system to the roof structure below had not been upgraded along with other mitigation efforts; most of the houses inspected experienced roof covering damage and subsequent damage to their interiors and contents from rain. The MAT concluded that mitigation measures should have been part of an overall mitigation plan and each measure should have been completely, rather than partially, carried out.

The IBHS (http://www.ibhs.org) and the Federal Alliance for Safe Homes (FLASH) (http://www.flash.org) have comprehensive guidelines and plans for retrofitting existing homes for wind resistance. The mission of both organizations is to reduce the loss of life and property

damage from natural disasters by promoting construction techniques that typically exceed those of the minimum adopted building code. Their guidelines are strongly recommended and highly relevant for mitigating damage from events such as hurricanes. The programs provide recommendations for retrofitting existing buildings from the roof deck to the foundations. Some of the highlights and focuses of their mitigation programs are outlined below.

For wall openings:

- Windows – Cover windows with impact-resistant shutters or replace them with impact-resistant windows
- Garage doors – Replace garage doors with wind and impact-resistant garage doors or have a design professional specify bracing for the garage door and strengthen methods for the track. Figures 8-1 and 8-2 show a plan view of a typical garage door and a recommended reinforced horizontal latch system for a typical garage door, respectively.

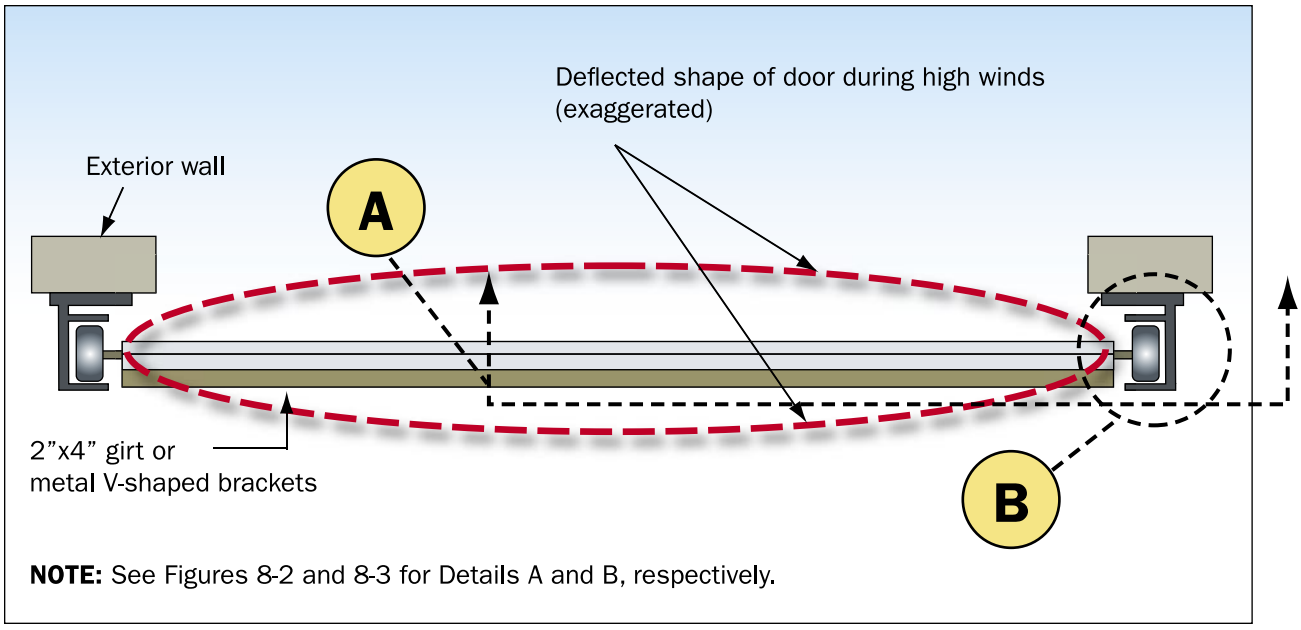

Figure 8-1. Plan view of a typical garage door

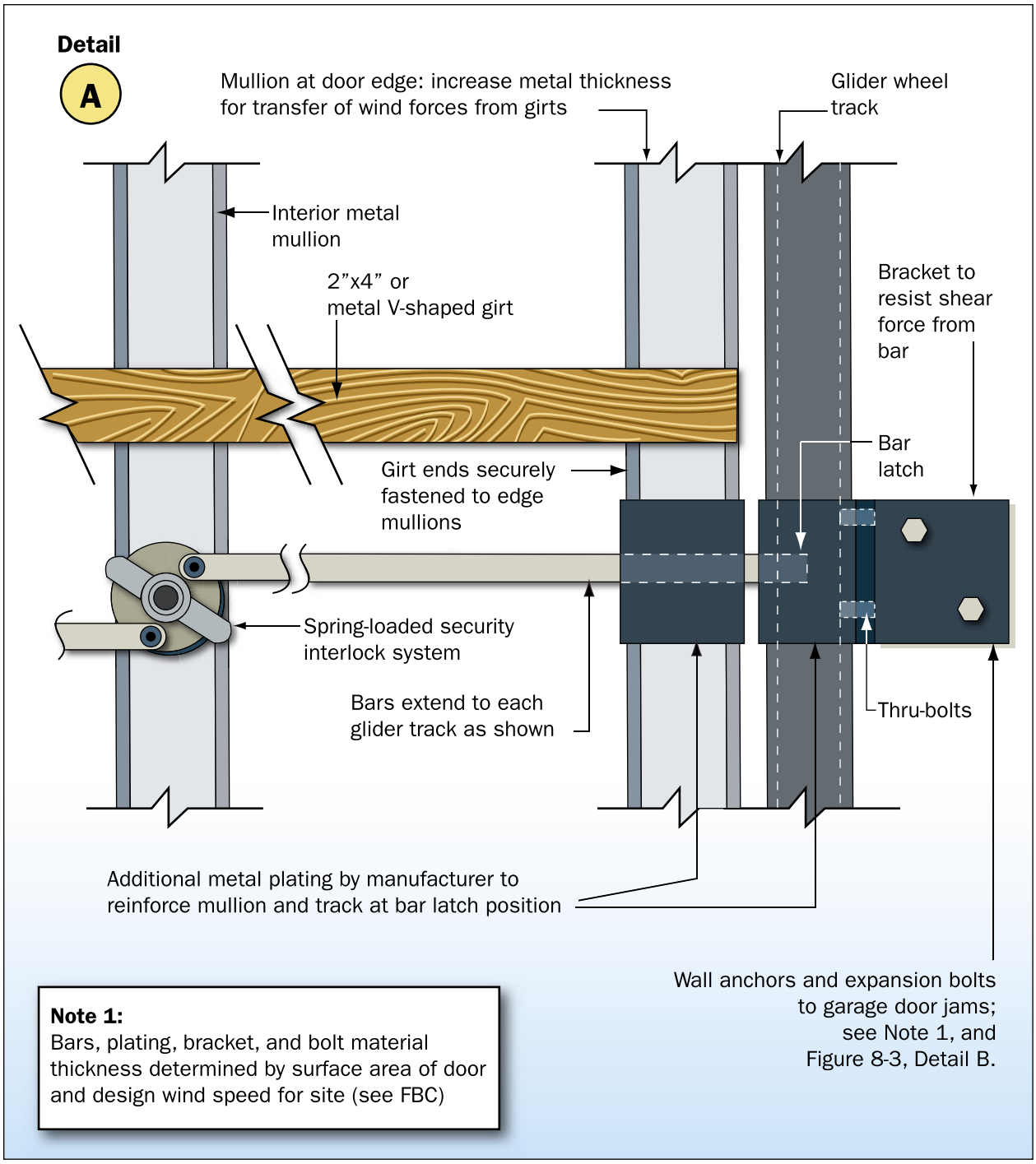

Figure 8-2. Detail A – recommended reinforced horizontal latch system for a typical garage door

- Replace doors with wind and impact-resistant doors or install head and foot bolts to engage door frames with a longer throw length (a minimum of 1 inch); use additional connectors to secure door frames to supporting walls

For roof coverings and roof decks (see FEMA *Hurricane Recovery Advisories Nos. 1 and 2* in Appendix D):

- When installing new asphalt shingle roof covering, perform the following activities:
  - Remove the existing roof covering to expose the roof sheathing
  - Remove the bottom row of sheathing at the eave
  - Install straps/clips at the roof-to-wall connections
  - Brace the gable end walls
  - Replace any damaged or deteriorated sheathing panels
  - Refasten all sheathing with 10d common or 8d ring shank nails spaced at 4 inches on center on the edges and 6 inches on center in the field
- If the roof covering is not being replaced, perform the following activities:
  - Strengthen the roof deck from inside the attic by using a caulking gun to apply a 1/4-inch bead of wood construction adhesive (certified to AFG-01 or ASTM D 3498) at the intersection of the roof deck and truss/rafter on both sides
  - Brace the gable end walls and ensure the bottom chord of the gable end trusses are secured to the top of the wall
  - Install straps/clips at the roof to wall intersection from inside the attic or by gaining access from the exterior

8.3.3 Wind Mitigation for Existing Commercial Buildings

The MAT observed some existing commercial (non-residential) buildings that were mitigated to resist additional wind loads or to protect glazing from windborne debris. Although this report clearly states that significant contents damage claims may be reduced by installing protection systems for glazing, the building structure or other portions of the building envelope should still be evaluated. At the Charlotte

County Sheriff's office and EOC, the roof of this pre-engineered building was lost over the front third to half of the building, despite having shutters protecting the glazing. Even if this facility was not used for critical or essential operations, the end result for any tenant would have been the same; that is, the contents of the building were completely destroyed when the roof covering was lost and rain soaked the interior. It is important to remember when retrofitting existing buildings that the building will remain vulnerable unless all structural and envelope issues are addressed comprehensively.

The MAT observed many rolling and sectional garage doors on critical or essential facilities and at commercial and industrial buildings that failed during the hurricane, resulting in large openings in the building envelope. A typical failure point was the roller and track connection. Designers should ensure that wind-resistant doors, all tracks, closure mechanisms, and attachments to the building structure are properly designed and installed. For these doors, the tracks need to be reinforced (along with the attachment of the tracks to the wall and ceiling) or the door itself needs to be supported by removable columns or supports that will reduce the loads being transmitted through the roller/track connection. These removable supports should be installed on garage doors when a hurricane warning is issued. Figure 8-3 shows a typical garage door failure and recommended assembly improvements applicable for commercial and residential applications.

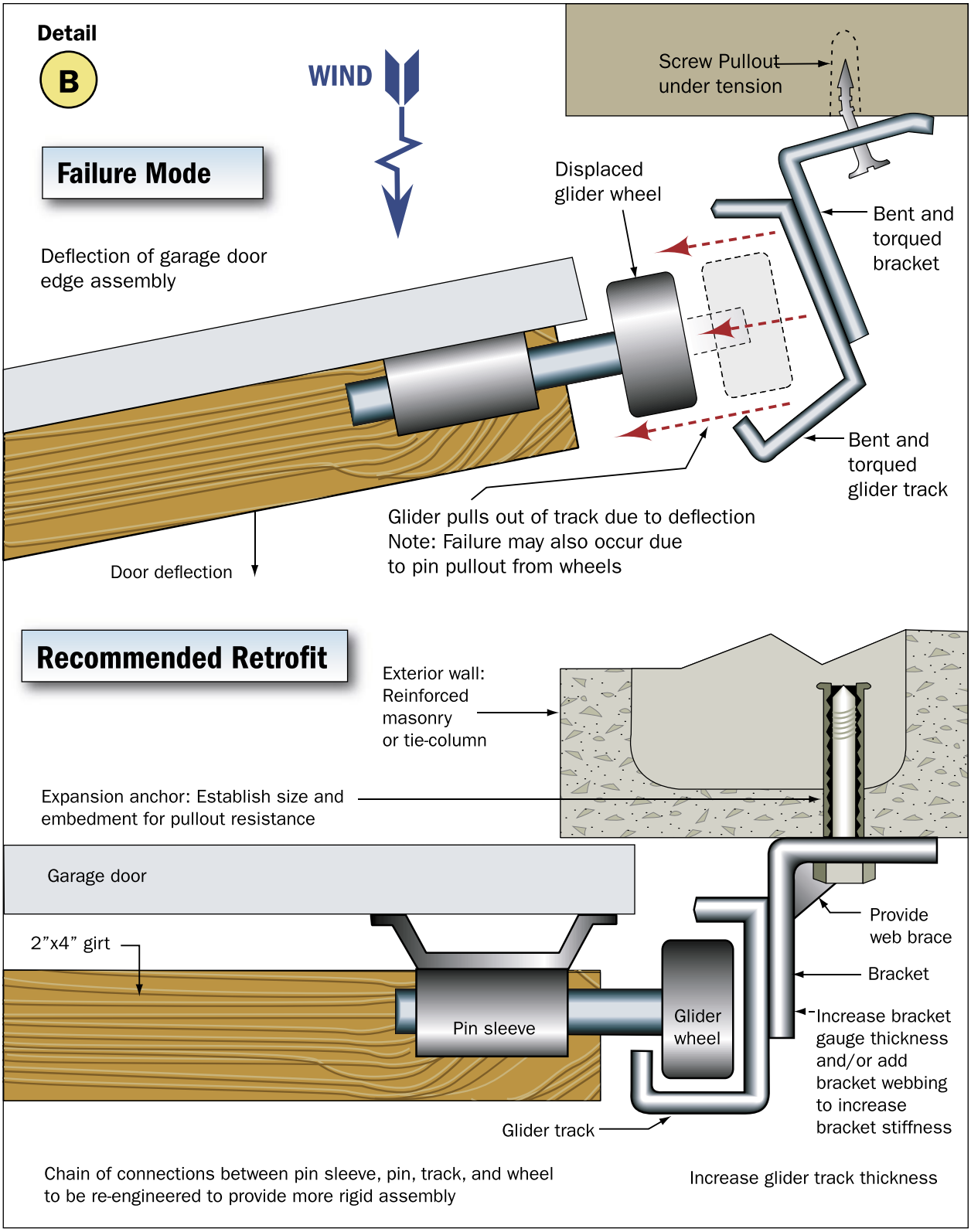

Figure 8-3. Detail B – typical garage door failure at the edge and recommended assembly improvements

8.4 Accessory Structures/Attachments

Given the prevalence of failures of aluminum structures (such as pool cages and carports), consideration should be given to improving their designs. Until the 2004 FBC is adopted (and statutes restricting the referencing of improvements to ASCE 7 and the IRC are rescinded), fabricators and engineers of aluminum structures can opt to use the readily available *AAF Guide to Aluminum Construction in High Wind Areas*. Alternatively, the MAT recommends the following: 1) provide additional anchors at the corner post connections to the concrete (these posts should be more securely fastened to the concrete than the intermediate posts); 2) ensure that walls parallel to the primary building are more resistant to wind forces parallel to those walls by using tension cable bracing, solid "K" bracing, or other methods; 3) provide lateral bracing in roof planes by using rigid diagonal structural members; and 4) use stainless steel screws to avoid commonly observed corrosion.

For existing attached structures, it is recommended that these structures be evaluated to determine if they are structurally sound for the wind region in which they are located. Because prescriptive analysis guidance may not be available, it may be advantageous to have a design professional analyze the structures to determine whether they are capable of withstanding wind pressures without failure and to determine the implications to the attached buildings if attached structures collapse or are torn away. In addition, it is recommended that detached structures be analyzed by a professional to determine their ability to withstand windstorm events. This analysis should include a review of the anchoring of lightweight structures. The attention to the code guidelines for wind-resistant design is often neglected in these structures.

Some contractors may view the use of best practices that meet or exceed code minimums, such as the *AAF Guide to Aluminum Construction in High Wind Areas,* as an impediment due to a false perception of high costs associated with these engineering practices in the competitive arena of home contracting. However, some contractors understand that providing durable structures is a sound business practice that enhances their reputations and reduces their liabilities. Some measures to improve the survivability of aluminum structures are simple and inexpensive (e.g., strengthening the anchoring of corner posts and installing additional bracing). For this reason, they should be utilized by all aluminum contractors.

8.5 Architectural, Mechanical, and Electrical

To improve the performance of the building envelope and rooftop equipment, the following action items are recommended in addition to the code revisions identified previously.

- **Wind design guides.** Design guides need to be developed for gutters and downspouts, soffits, metal panel systems, continuous ridge vents (including means to provide secondary protection from water intrusion if the vent blows off), rooftop mechanical and electrical equipment, and lightning protection systems (LPSs). The guidance in FEMA *Hurricane Recovery Advisories No. 1* and *No. 2* (Appendix D) should be added to the *Residential Asphalt Roofing Manual* published by the Asphalt Roofing Manufacturer's Association) and to *The NRCA Steep-Slope Roofing Manual* published by the National Roofing Contractors Association (NRCA). The guidance in FEMA *Hurricane Recovery Advisory No. 3* (Appendix D) should be considered for incorporation into the *Concrete and Clay Tile Installation Manual* published by the Florida Roofing, Sheet Metal and Air Conditioning Contractors Association, Inc. (FRSA) and Roof Tile Institute (RTI).

- **Loads and attachment.** It is recommended that designers calculate loads on the building envelope and rooftop equipment and specify/detail adequate attachment to resist the loads. A minimum safety factor of 2 is typically recommended.

- **Roof coverings.** When re-roofing, tear-off rather than re-covering is recommended in areas where the basic wind speed is 110 mph or greater. This will allow inspection of the integrity and attachment of the roof sheathing. If the existing decking attachment does not comply with the loads derived from the current building code, installation of additional fasteners to meet the code loads is recommended; contractors are reminded that in-process inspections are required by many jurisdictions. Further, it provides access to the roof deck so secondary underlayments may be installed to improve the roof deck's resistance to water intrusion. Specific system/component recommendations are:

  Asphalt shingles. Guidance given in FEMA *Hurricane Recovery Advisories No. 1* and *No. 2* (Appendix D) is recommended. In addition, installers need to follow manufacturer's installation instructions with respect to starter strips and nail locations. Manufacturers should re-evaluate the attachment of factory-laminated tabs (Figure 5-27). Loss and blow-off of the tabs may be reduced if additional

quantities of adhesive, or a stronger adhesive, is used during the production of the shingles.

Metal panels. It is recommended that uplift resistance be based on ASTM E 1592. For panels with concealed clips, it is recommended that clip locations be chalk-lined to ensure that they are not excessively spaced or different from manufacturers' recommendations. It is also recommended that designers specify close spacing of fasteners at eaves, and hip and ridge flashings (e.g., spacing in the range of 3 to 6 inches on center, commensurate with the design wind loads).

Tiles: It is recommended that foam-set manufacturers re-evaluate their installation recommendations in order to simplify the number of options and to clarify the requirements. It is also recommended that they re-evaluate their training and certification programs, because it was evident that many foam-set roofs were installed improperly, most likely by inadequately trained workers. Guidance given in FEMA *Hurricane Recovery Advisory No. 3* (Appendix D) addresses both of these issues and should be implemented.

It is recommended that FRSA and RTI re-evaluate the use of a safety factor of 2 for mechanically attached systems. Field observations of some roofs indicated that tile blow-off occurred at wind speeds less than those predicted by the resistance tables in the *Concrete and Clay Tile Installation Manual*. This difference between predicted and actual performance may be due to the static test method used to evaluate wind resistance. However, tiles are dynamically loaded during hurricanes. With dynamic loading, minor oscillating of down-slope ends of the tiles may induce fatigue loading, which, during a hurricane, allows the oscillating tiles to jack the fasteners out of the deck, or allows the nail holes through the tiles to be enlarged enough to allow tiles to pull over the fasteners. Until a dynamic test method can be developed, the existing test method could be used with a higher safety factor (e.g., 3) applied to the ultimate resistance.

Similarly, it is recommended that the foam-set manufacturers re-evaluate the use of a safety factor of 2. With foam-set attachment, there is an opportunity for variation in size and placement of the foam paddies. Also, as discussed above, the static test method may over-predict actual performance. A higher safety factor (e.g., 4) may be a more appropriate value to use to account for these application and testing concerns.

Edge flashings, copings, and gutters. Successful performance of edge flashings, copings, and gutters is vital to avoid progressive lifting and peeling of roof membranes. For edge flashings and copings, compliance with 2003ANSI/SPRI ES-1 is recommended. However, because ES-1 does not incorporate a safety factor, it is recommended that a safety factor of 2 be applied to the ultimate resistance values obtained from testing (a safety factor of 3 is recommended for critical and essential facilities).

Further, to avoid progressive failure in the event of gutter, edge flashing or coping uplift, it is recommended that a bar be placed over the roof membrane near the edge flashing or coping (Figure 8-4). The purpose of the bar is to provide secondary protection against membrane lifting and peeling in the event that the edge flashing/coping fails. A robust bar specifically made for bar-over mechanically-attached single-ply systems is recommended. The bar needs to be very well anchored to the parapet or deck. Depending upon design wind loads, spacing between 4 and 12 inches on center is recommended for the bar anchors. A gap of a few inches should be left between each bar to allow for water flow across the membrane. After the bar is attached, it is stripped over with a stripping ply.

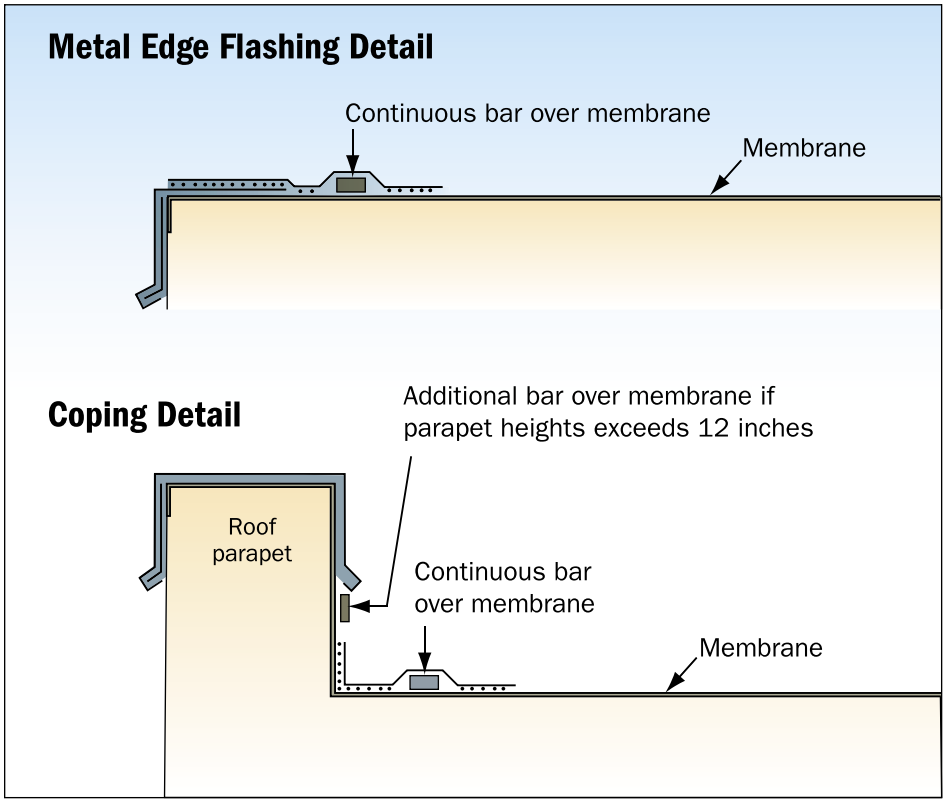

Figure 8-4. Continuous bar near the edge of edge flashing or coping. If the edge flashing or coping is blown off, the bar may prevent a catastrophic progressive failure.

SOURCE: FEMA 55, *COASTAL CONSTRUCTION MANUAL*, 2000

Design guidance and test methods are lacking for gutters. Therefore, it is recommended that designers exercise their professional judgment in specifying and detailing gutter uplift resistance.

- **Windows**. It is recommended that the window/curtain wall industry re-evaluate the test pressures that are currently used to assess resistance to wind-driven rain. Although this has not been an issue in the past, as building performance is improved and water infiltration due to failed envelopes is reduced, the damage due to wind-driven rain infiltration is becoming more pronounced. With incorporation of more realistic test pressures, development of more water-resistance assemblies is necessary.

- **Motorized shutters.** Motorized shutters should be manufactured with a manual override. This will allow deployment of the shutters prior to a hurricane, even if power has been lost. After a hurricane, they can be rolled up even if the electrical power has not been restored; this will facilitate drying the building if water infiltration has occurred and speed recovery.

- **Rooftop mechanical and electrical equipment.** For attachment of rooftop equipment, a minimum safety factor of 2 is recommended due to uncertainties pertaining to load and resistance in currently required codes. It is recommended that cowlings on exhaust fans be anchored with cables to curbs, and that access panels that are not securely attached by the manufacturer be field modified (guidance is provided in FEMA 424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds*). It is also recommended that special attention be given to attachment of LPSs, per guidance provided in FEMA 424.

- **Weatherstripping at exterior doors.** Specifying wind-driven rain-resistant weatherstripping at exterior doors is recommended. Although it has not been an issue in the past, as building performance is improved and water infiltration due to failed envelopes is reduced, the damage due to wind-driven rain infiltration at doors is becoming a more significant problem. FEMA 424 provides weatherstripping guidance.

  When the basic wind speed is greater than 120 mph, some leakage should be anticipated when design wind-speed conditions are approached. One approach to minimize infiltration damage would be to design a vestibule to provide more than one level of protection against rain water infiltration, in addition to robust weatherstripping. With this approach, both the inner and outer doors can be equipped with weatherstripping, and the vestibule itself can be designed to tolerate rain water intrusion.

8.6 Critical and Essential Facilities (Including Shelters)

Designers should be reminded that codes and standards recommend the minimum design requirements for facilities (even critical and essential facilities); thus, implementing known best practices for high-wind design above the required minimums is prudent. To achieve building performance that will not result in the loss of function of the facility, the following are recommended in addition to the proposed code revisions provided in Section 8.2.3.

- **Expand the use of the critical and essential facility designation.** ASCE 7 Table 1 defines which buildings are required to be classified as critical and essential facilities (i.e., Category III and IV buildings). However, building owners and their design professionals should not consider Categories III and IV to be an all-inclusive list. Other buildings may be vital in the response before and during, and recovery following a hurricane, or they may house functions that need to remain operational during an event. For example, a medical office building (MOB) is not a Category III or IV building, but the poor performance of a MOB could adversely affect the functioning of the hospital. Therefore, classifying MOBs that are integrated with hospitals as critical or essential is recommended. Similarly, nursing homes are not specially mentioned in ASCE 7 Table 1; however, health care facilities with 50 or more resident patients are classified as Category III. Although an independent living or assisted living facility would typically not be considered Category III, a skilled nursing or Alzheimer's facility (regardless of size) would benefit from being classified as Category III.
- **Prioritize the critical and essential facilities.** All critical and essential facilities are important, yet some are more critical than others. Because of the realities of funding limitations to mitigate wind effects for both new and existing buildings, building owners and their design professionals should prioritize their facilities. For example, 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 could also receive the highest priority for mitigation (retrofit) projects.
- **Siting.** New critical and essential facilities and, specifically, shelters should not be constructed below the 500-year flood elevations or within a designated storm surge inundation area. Evaluation of

existing shelters located in storm surge inundation zones that were opened during Hurricane Charley is an operational issue that was beyond the scope of this building-focused MAT report.

- **Detailing and notations on the building plans.** Designers should clearly indicate on the plans the area of the facility that was designed to function as a high-wind shelter or hardened area. Further, the designer should provide additional details of the portions of the building's structure and envelope elements to ensure that the construction requirements or differences for this portion of the building are clearly understood by the builder and the building official. Additional notes should also be provided that clearly indicate the design criteria used for this facility (or portion thereof) and maximum design pressures should be stated for the main wind force resisting system (MWFRS) and for components and cladding (C&C) systems. Specific references to design assumptions from ASCE 7 and FEMA 361, *Design and Construction Guidance for Community Shelters should be provided.*

- **Material selection.** Regardless of whether the FBC, ASCE 7, model building codes, or FEMA 361 is used to design the critical or essential facility, other design measures should be taken for design of the building's structural and envelope systems, and rooftop equipment. Structural systems that have a proven record of excellent high-wind performance include reinforced cast-in-place concrete structures (including insulated concrete forms), reinforced masonry structures with concrete or heavy metal decks, and steel frame systems with debris-resistant exteriors. Both FEMA 361 and FEMA 424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds,* provide detailed guidance on material selection for structural and building envelope systems. Although FEMA 361 was developed for shelter design and FEMA 424 was developed for schools, much of the information is applicable to other types of critical and essential facilities. Finally, a comprehensive design guide addressing retrofitting and mitigation of existing essential facilities should be developed. This guide would benefit many communities with older facilities.

- **Peer review process.** To improve the quality of design, contract drawings and specifications for new construction and remedial work on existing building envelopes and rooftop equipment should undergo rigorous peer review prior to permitting and construction. This would ensure important details are not overlooked or under-designed.

- **Construction contract administration.** For new construction and remedial work on existing building envelopes and rooftop

equipment, more rigorous submittal review and field observation (inspection) should occur than is the case with non-critical and essential buildings. This is imperative for maintaining the integrity of the building envelope.

- **Code requirements.** The only special criteria for critical and essential facilities in the FBC, ASCE 7, and the model building codes is the importance factor (I). The importance factor adjusts the mean recurrence interval to the facility type being designed. However, for these facilities, this adjustment will typically increase the loads by only 15 percent. Other criteria need to be added to the code and were presented in Section 8.2.
- **Maintenance and repair.** To protect from adverse facility degradation as they age, critical and essential facilities should be periodically inspected, maintained, and repaired. Emphasis should be on the building's envelope and rooftop equipment because these are the components most prone to degradation. The roof and rooftop equipment should be inspected twice a year. Windows, doors, and wall coverings should be inspected at 5-year intervals. In addition, special inspections of the entire facility (both building structural and envelope systems) should be conducted after storms with wind speeds in excess of 90 mph 3-second peak gust winds.

8.7 Design Guidance and Public Education

In order to reduce the damages caused by building structural and envelope failures, better guidance and public education needs to be developed and provided to design professionals, contractors, and the general public who design, construct, and live in hurricane-prone regions. The following items are provided for consideration:

8.7.1 Design and Construction Guidance

Design professionals are in need of additional guides to provide methodologies and best practices when code guidance is vague or unclear. For instance, it was common to see fasteners for roof coverings and wall cladding spaced too far apart, fasteners that were too small, and connections that were too weak. Enhanced details were seldom observed. Numerous examples of building envelope component failure were observed, especially when well-established basic construction practices were not implemented, such as compliance with minimum edge distance spacing for fasteners. Unless designers and contractors understand wind-resistance issues, envelope and equipment failures

will continue to occur. The following list identifies where improved design, construction, and testing guidance is needed so that code compliance can be better achieved.

- **Pre-engineered metal buildings.** The MAT observed numerous pre-engineered metal building failures due to corrosion of the main structural framing members. To improve the performance of these buildings, main framing members of all pre-engineered buildings that are 10 years of age and older should be inspected at 3-year intervals by a registered structural engineer. A report of the building's structural adequacy should be submitted to the building official and the building owner or manager. This type of evaluation could be combined with a building maintenance program to ensure the buildings will perform as originally designed.
- **Roof coverings, gutters, and downspouts.** A design guide, test method, and building code criteria need to be developed for gutters. The design guide should also address attachment of downspouts. Technically-based criteria need to be developed and codified for aggregate surfacing on built-up and sprayed polyurethane foam roofs. To decrease susceptibility of tiles to windborne debris damage and subsequent blow-off from the roof, development of tiles with improved ductility via internal or backside reinforcement or bonding film is recommended in hurricane-prone regions (i.e., development of a tile akin to laminated glass). Although it is currently a low priority, research is needed on wind resistance of roof walkway pads.
- **Rolling and sectional doors.** Because of their large size, high loads can be induced on frame fasteners. Designers and contractors should give special attention to fastener type, and size and spacing used to attach the frame. If the frame is attached to wood blocking, attention should also be given to the blocking attachment. If the fasteners are placed in concrete or masonry, adequate edge distances should be maintained.
- **Soffits.** Design guidance is needed for the attachment of soffits, including design of baffles or filter media to prevent wind-driven rain from entering attics.
- **Rooftop equipment.** Design guidance and building code criteria are needed for the attachment of condensers and rooftop mechanical equipment (including outside ductwork). Air conditioning condensers can be anchored to a secure mounting for little cost. Such anchoring would greatly reduce damage to the Freon and electrical connections to the compressors, thus decreasing the amount of time occupants would be without air conditioning.

Building owners and homeowners also need to be educated to inspect exterior connections and fasteners for wear, corrosion, and other deterioration that weakens the integrity and becomes breakable in a hurricane.

- **Other exterior devices and equipment.** Other exterior devices, such as pool equipment, gas heaters, and heat pumps, should be evaluated and secured as needed. These devices may already be anchored well enough by plumbing lines, and additional anchoring may not be necessary. However, property owners should be educated about performing an appropriate inspection of their homes to evaluate the need to secure objects, including children's swing sets, aboveground pools (not filled), barbeque grills, and storage sheds. Because of the number of roof-mounted solar water heater collectors that were torn off homes during hurricanes, it is recommended that their attachment to the roof be carefully inspected by a qualified professional to be sure they are secured well enough to withstand anticipated wind pressures.
- **Electrical and communications equipment.** Design guidance and code criteria are needed for attachment of LPSs, communications towers, and satellite dishes.
- **Test methods.** Some of the methods used to test building envelope assemblies are inadequate. Virtually all of them are static tests. Static testing is suitable for some assemblies, but other assemblies should be dynamically tested in order to obtain a more realistic measure of their wind resistance. For those assemblies where it would be prudent to test dynamically, but dynamic test methods are not currently available, higher safety factors should be used.
- **Manufacturers' instructions.** There were numerous instances of products being installed in a manner that was a significant deviation from manufacturers' installation instructions. This points to a need for better training of the workforce, establishing better quality control (i.e., contractors inspecting their work) and more frequent quality assurance (i.e., field observations by a qualified party other than the contractor, such as an engineer or building official).
- **Human intervention.** Building owners and homeowners need to be educated about pre-storm activities, such as installation of shutters (if glazing is not laminated), installation of removable stiffener bars at garage doors (where applicable), and tying down or removing loose items from roofs and yards. They should also be educated about post-storm activities, such as quickly removing wet materials from within buildings and drying out the buildings.

8.7.2 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, it is clear that many of the failures observed after Hurricane Charley were not caused by current code inadequacies, but caused by instead from the failure of designers, manufacturers, building officials, and contractors to implement the current state of knowledge with respect to buildings located in hurricane-prone regions. A renewed, state-wide comprehensive educational effort is needed to avoid the hurricane building damage cycle, wherein buildings are constructed, damaged, repaired, or rebuilt, and then damaged again in a future severe weather event. The following specific action items are recommended:

- **Building owners and homeowners.** Owners need to be educated in a number of areas:
  - The need to adequately budget for a construction project, so that appropriate mitigation measures can be implemented
  - The need to select a design and construction team that is knowledgeable about designing and constructing in hurricane-prone regions, and who will execute the work in a diligent and technically proficient manner utilizing state-of-the-art best practices
  - Preparations to be taken prior to hurricane landfall
  - Steps to be taken after the hurricane passes (e.g., having the building inspected for damage, having emergency repairs performed, and drying out the building)
  - If the building is damaged, having it rebuilt in a manner that protects against future damage
  - The need to periodically inspect exterior connections and fasteners for wear, corrosion, and other deterioration that weakens the integrity and becomes breakable in a hurricane

To facilitate these educational goals, pamphlets tailored to homeowners and commercial/governmental owners should be developed, along with strategies for distributing this information to owners (possibly during the sale of a home or business). Enlisting the assistance

of real-estate companies and organizations such as the Building Owners and Managers Association (BOMA) and providing public service notices to television programs at the start of each hurricane season should be pursued.

- **Architects/engineers/consultants.** From the damage observed to both old and new buildings, it is clear that some design professionals working in hurricane-prone regions still struggle with the design and detailing of hazard-resistant construction. Although it appears that in most cases the structural systems (MWFRS) are receiving proper attention, many design professionals falter and struggle with the design of building envelopes and rooftop equipment; this indicates a need for substantial improvement in their technical proficiency in this aspect of building design. A variety of educational tools could be used to assist the designers, including monographs, web-based tutorials, and seminars. Colleges and universities located in hurricane-prone regions should consider a curriculum that emphasizes hurricane-resistant design for current students and continuing education for design professionals.
- **Building officials.** Coastal area building officials, plan reviewers, and inspectors should be required to attend annual seminars specially designed to share "lessons learned" and to train the building officials to look for items that may cause failure of a structure or building components during hurricane events. These items include unbraced gable ends, missing truss bracing, truss anchorage, and anchorage of the windows and doors. Quality of construction also depends upon knowledge of the building officials and enforcement techniques of the building department.
- **Contractors.** Many contractors, particularly those involved in constructing building envelopes and installing rooftop equipment, could be better trained in the installation and use of fastening and anchoring systems. For construction trades, visual tools that use videos/DVDs and on-the-job or classroom mock-up training that highlights the failures that occur when simple anchoring techniques are not applied may be beneficial. Trade schools in hurricane-prone regions should include courses on hurricane-resistant construction in their curriculum.
- **Manufacturers.** Many manufacturers of building envelope materials and rooftop equipment are also in need of education regarding performance of their products during hurricanes. With increased knowledge, manufacturers will be better equipped to provide special guidance for use of their products in hurricane-prone regions and will be better equipped to develop improved products and systems for these areas. With a better educated manufacturing

sector, manufacturers could serve a vital educational role when they interface with designers and contractors.

- **Associations.** It is recommended that associations, institutes, and societies representing design professionals, contractors, and manufacturers take an active role in developing hurricane-resistant design and/or construction educational materials and promote them, along with educational materials developed by others, to their members.
- **Incentives.** 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 (Federal, state, and local) funding 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.
- **Public education on rain water damage.** To reduce property losses and the negative impact to business owners whose businesses and homeowners whose homes were damaged, business owners and homeowners should be educated on how rain water damage can occur to buildings. The purpose of the education would be to encourage all property owners to protect their businesses and homes from the entry of rain water. Key points to highlight include:
  - Prolonged rain falling on damaged buildings can result in significant water damage to their business or home.
  - It is not uncommon for wind-driven rain, sometimes traveling in excess of 100 mph, to wet all interior surfaces of a building.
  - Associated pressure differences across walls, windows, doors, soffits, etc., can lead to the entry of damaging amounts of rain water into a business or residence.
  - Wet or flooded buildings are unlikely to have electricity for several weeks; this can present long- and short-term problems for drying the building if auxiliary power is not available.
  - Basic ventilation and removal of water may not be possible if motorized shutters cannot be opened; there is typically no means for dehumidification without power.
  - High temperatures and high humidity are conducive to the growth of mold and odors.

Similarly, builders and remodelers might benefit from education related to best practices and methodologies to minimize rain water-entry issues. If they are aware of these issues, they may be encouraged to suggest to business owners and homeowners cost-effective measures to make buildings more water- and wind-resistant. Even though there are several relatively inexpensive means that can be taken to minimize rain water entry, most builders and remodelers are not aware of the vulnerabilities of buildings.