HURRICANE IKE IN TEXAS & LOUISIANA

7 Recommendations

The recommendations in this report are based on the observations and conclusions of the MAT.

These recommendations are intended to assist the States of Texas and Louisiana, communities, businesses, and individuals in the reconstruction process, and to help reduce future damage and impacts from flood and wind events similar to Hurricane Ike. The recommendations will also help FEMA assess the adequacy of building codes and standards as they relate to flood hazard mapping and floodplain management requirements, and determine whether changes are needed or additional guidance is required.

In addition to these recommendations, several of the recommendations in the MAT report on Hurricane Katrina (FEMA 549) are also applicable. Specifically, most of the public outreach recommendations apply equally to Hurricane Ike.

7.1 Residential

The recommendations that follow are based on the MAT observations discussed in Sections 3.1 and 3.2, and the conclusions presented in Section 6.1.

7.1.1 Flood

Scour Around Foundations. Unexpected levels of foundation scour were observed between Surfside Beach, TX, and Holly Beach, LA. The local scour around building foundations greatly exceeded the vertical and lateral extents indicated by current design guidance. Damage from the scour was significant and widespread. Also, linear scour features that were likely associated with barrier island canals and roads were observed by the MAT. Numerous houses were undoubtedly affected by linear scour features, suffering either damage or destruction.

> ***Recommendation #1:*** FEMA should assist engineers and standards-writing organizations in developing new design and building code guidance that incorporates scour knowledge gained following Hurricane Ike.
>
> ***Recommendation #2:*** Coastal land development guidance and practices should be revised to minimize potential linear scour (and associated building damage), and building design and construction practices should be modified to account for potential linear scour effects.
>
> ***Recommendation #3:*** FEMA should study foundation scour in more detail during future post-storm investigations.

Building Elevation Relative to Flood Level. Much of the damage observed by the Ike MAT resulted from buildings not being adequately elevated to escape Ike's storm surge, waves, and flood-borne debris. Specific observations and conclusions, with related recommendations, follow.

BFEs shown on Effective FIRMs should not be used for reconstruction purposes in Ike-affected communities unless communities can demonstrate that Effective BFEs are adequate. Thousands of residential buildings were damaged or destroyed by Ike's flooding, many of them constructed at or above the Effective BFEs. New flood studies are underway in Louisiana and Texas; preliminary flood maps have been produced in parts of Louisiana, but Texas preliminary maps are not expected before the end of 2009.

Widespread damage outside the SFHA was observed; the Ike MAT recommends taking flood mitigation measures in the areas beyond the landward limit of the Effective SFHA, where there are likely to be no flood-resistant design and construction requirements (i.e., beyond Zone A and within Zones B, C, shaded X, or X), and in Zone A, which could experience Coastal A Zone or even Zone V conditions during a base flood.

> ***Recommendation #4:*** Until new DFIRMs are available and adopted, the MAT recommends requiring the following freeboard above the currently Effective BFEs for new construction, substantial improvements, and repair

> **ADDING FREEBOARD TO NEW CONSTRUCTION**
>
> A comprehensive study of freeboard (American Institutes for Research, 2006) demonstrated that adding freeboard at the time of house construction is cost effective. Reduced flood damage yields a benefit-cost ratio greater than 1 over a wide range of scenarios, and flood insurance premium reductions make adding freeboard even more beneficial to the homeowner. Reduced flood insurance premiums will pay for the cost of incorporating freeboard in a Zone V house in 1 to 3 years; in a Zone A house, the payback period is approximately 6 years.

of substantial damage: freeboard specified by ASCE 24-05, plus 3 feet. Once new DFIRMs are available and adopted, the MAT recommends requiring new construction, substantial improvements, and repair of substantial damage to be elevated to or above the freeboard elevation specified by ASCE 24-05.

Recommendation #5: Enforce Zone A design and construction standards in the area between the Effective SFHA landward limit and a ground elevation equal to the adjacent Zone A Effective BFE plus freeboard. This recommendation should be implemented before and following the adoption of new DFIRMs.

Recommendation #6: Enforce ASCE 24-05's Coastal A Zone design and construction requirements in areas presently mapped as Zone A on the Effective FIRM. This recommendation should be implemented before the adoption of new DFIRMs; following adoption, Coastal A Zone requirements should be adopted in the area between the LiMWA and Zone V.

Recommendations #4, #5, and #6 are illustrated in Figure 7-1.

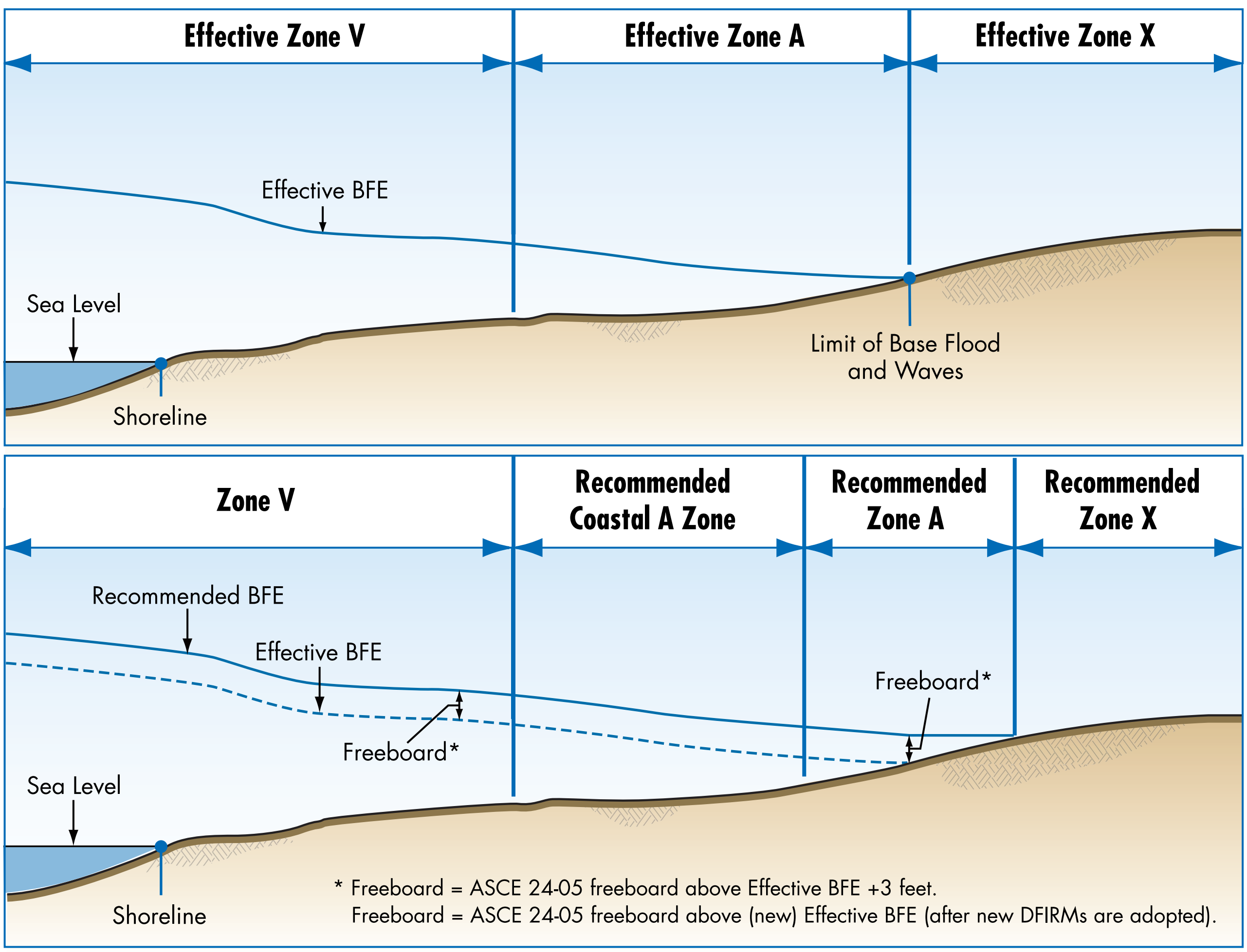

Figure 7-1. Comparison of Effective BFEs and flood hazard zones (upper figure), with MAT-recommended freeboard and flood hazard zones (lower figure)

Based on damage observed to NFIP-compliant buildings throughout the area affected by Ike, minimum floor elevation requirements in NFIP regulations (44 CFR section 60.3) are inadequate and allow flood damage in Zone A, particularly by allowing the top of the lowest floor to be set at the BFE.

> ***Recommendation #7:*** FEMA should revise its regulations to require the entire floor system to be set at or above the BFE, and should implement the minimum floor elevation recommendations contained in the NFIP Evaluation Study (American Institutes for Research, 2006).

Even when buildings are elevated and constructed to meet minimum requirements, they are still vulnerable to flood damage when flood levels exceed the BFE.

> ***Recommendation #8:*** Property owners should be encouraged to design new and reconstructed buildings for flood levels above the BFE.

Some houses that were advertised as enhanced-code construction and intended to withstand greater-than-design level flood events sustained flood damage during Ike. Even though these buildings were elevated above the BFE, the MAT observed instances where scour and erosion exceeded the ability of the pile/column foundation to remain vertical, and instances where lateral loads and bending moments exceeded the material properties of the foundation piles/columns—the piles/columns cracked or broke.

> ***Recommendation #9:*** Enhanced-code houses should be designed for erosion, scour, and flood loads associated with flood levels above the BFE, not just elevated above the BFE on otherwise minimally flood-compliant foundations. Entities certifying enhanced-code houses should review foundation calculations before granting enhanced-code status.

Flood damage to commercial buildings was, for the most part, similar to flood damage to residential buildings.

> ***Recommendation #10:*** The MAT recommends elevating commercial buildings to the same levels and on the same types of foundations as called for in residential recommendations #4, #5, and #6. See also Section 7.3, Future Studies and Standards Revisions, recommendation #33.

Parking Slabs. A wide range of parking slab performance was observed by the MAT: a) unreinforced, frangible parking slabs collapsed, as intended, with no apparent harm to elevated houses or their foundations; b) unintended failure of non-frangible parking slabs led to timber pile failures at elevated houses where broken slabs remained connected to foundation piles and transferred loads to the piles that the piles could not resist—racked foundations and broken piles resulted; and c) intact but undermined parking slabs sometimes contributed to foundation and building settlement, by increasing scour around the foundation (as water flowed between the bottom of the slab and the eroded ground) and by placing additional vertical load on the foundations.

Recommendations #11: Coastal house foundations subject to scour and erosion should be designed to resist all loads imposed during coastal storm events, where possible, without benefit of parking slabs and grade beams to provide stiffness. Unreinforced, frangible parking slabs should be constructed under these houses when parking slabs are desired by the owner.

Recommendations #12: Where tall foundations cannot be constructed under coastal houses without added stiffness, grade beams with frangible slabs are preferred over structural slabs. This will minimize the weight that must be supported by an undermined foundation and minimize the potential of unintended load transfer from failed slabs to the foundation.

Siting. The widespread destruction and damage to houses situated closest to shorelines during Ike reinforced the principle that siting of buildings is critical to their survival during hurricanes. Siting of buildings close to eroding shorelines puts those buildings at risk and often results in erosion and flood damage to those buildings.

Recommendation #13: The State and local governments of Texas and Louisiana should encourage siting away from eroding shorelines; employ coastal restoration, where justified, to mitigate erosion effects; and acquire erosion-damaged properties and prohibit reconstruction on those properties.

Breakaway Walls. One unintended consequence of elevating houses above the BFE has been taller and taller solid breakaway wall panels, which provide larger and larger floodborne debris elements when they break away.

Recommendation #14: Lattice or louvers should be used instead of solid breakaway walls. Louver and lattice wall panels will remain intact longer than solid breakaway walls, resulting in less debris and less repair cost to homeowners. If solid breakaway walls are used, designers and owners should consider installation of flood vents in those walls. This may help to delay the failure of the walls, reduce floodborne debris, and reduce repair costs.

Manufactured Homes. Destruction of manufactured housing occurred during Ike, either because the homes were not elevated to or above the BFE (this may have occurred through proper use of the 3-foot pier exemption permitted in existing manufactured home parks, or by misinterpretation of this exemption), or because homes had not been installed on flood- and wind-resistant foundations.

Recommendation #15: All new and replacement manufactured homes should be elevated to or above the BFE using wind- and flood-resistant foundations such as those specified in NFPA 225-09. Manufactured home installations should follow the guidance contained in FEMA 85. Please note that the 1985 edition of FEMA 85 is currently under revision and is tentatively scheduled to be released later in 2009.

7.1.2 Wind

In the areas observed by the MAT, Hurricane Ike was not a design wind event; wind speeds ranged from 90+ mph[1] from the west end of Galveston Island to 110 mph on Bolivar Peninsula, 94 mph in downtown Houston, and 90 mph or less in other inland areas of Texas, 80 mph at the Texas-Louisiana border, to less than 50 mph east of Vermilion Parish, LA.

Structural. Though major wind damage to building structures was seldom observed by the MAT, wind damage to roof overhangs and sheathing was seen. This type of damage, though not pervasive, was seen from Galveston County to the affected Louisiana Parishes, including some enhanced-code construction homes.

> ***Recommendation #16:*** Roof overhangs of widths up to 2 feet are routinely designed using prescriptive standards. Roof overhangs in excess of 2 feet should be designed to withstand wind pressures calculated using ASCE 7-05 guidelines.

Asphalt Shingles. The MAT observed a substantial amount of wind-damaged asphalt shingles. To achieve good wind performance, shingles with sufficient wind resistance should be installed. TDI currently allows 110-mph-rated asphalt shingles (i.e., Class F) for all wind zones in the Designated Catastrophe Area. Products are currently manufactured to meet ASTM D 7158, which provides for testing and classification of asphalt shingles to meet 120-mph (Class G) and 130-mph (Class H) wind resistance.

> ***Recommendation #17:*** When asphalt shingles are used, it is recommended that TDI require the use of shingles complying with ASTM D 7158 Class G shingles in Inland (I) and Inland (II) and Class H shingles in the Seaward Zone.

Non-Load Bearing Walls and Wall Coverings. An extensive amount of envelope wall covering, primarily vinyl siding and fiber cement siding, was damaged by Hurricane Ike.

> ***Recommendation #18:*** Municipalities with building code authorities, along with TDI and their inspection program, should require that the installed products are on the approved and tested list and are installed in accordance to industry and manufacturer's recommendations for high wind zone installations.

Doors, Windows, and Shutters. Few impact-resistant glazed window units were observed by the MAT in either Texas or Louisiana, with homeowners and builders opting to use shutters to provide debris impact protection of building openings. TDI currently requires only homes located in the Seaward Zone and the Inland (I) to be protected by impact-resistant glazing or shutters.

1 All estimated speeds in this chapter are peak gust, Exposure C at 33 feet taken from *Estimates of Maximum Wind Speed Produced by Hurricane Ike in Texas and Louisiana* (ARA, 2008).

Recommendation #19: It is recommended that opening protection by TDI include Inland (II [110 mph]) within 1 mile of the coastal mean high water line where the basic wind speed is equal to or greater than 110 mph, which is consistent with ASCE 7-05 and IRC 2003 recommendations.

Roof Soffits, Fascias, and Gable Vents. Vinyl soffits and roof ridge ventilation systems frequently failed, thereby allowing water infiltration into the homes, causing damage.

Recommendation #20: The TDI and Building Inspection Program should ensure that vinyl soffits are installed in accordance to industry and manufacturers' recommendations for high wind zone installations. Ridge ventilation systems frequently allow wind-driven rain to enter the attic space and should not be allowed in Designated Catastrophe Areas.

Exterior-Mounted Equipment. All observed HVAC units mounted on the outside of the homes were elevated, per the guidelines in FEMA 55.

Recommendation #21: It is recommended that where railings are installed around elevated units, the railings either be removable or adequate space be provided on the platform to allow servicing of the units.

7.2 Critical Facilities

Critical facilities apparently continue to be designed and constructed without sufficient consideration of the guidance documents written to make critical facilities more hazard resistant.

Recommendation #22: Critical facilities should be designed in keeping with available guidance (FEMA 424, 543, and 577). Existing critical facilities should be audited using FEMA 424, 543, and 577 and retrofitted where appropriate.

Recommendation #23: Update FEMA 424, 543, and 577: See Section 7.3, Future Studies and Standards Revisions.

FEMA GUIDANCE FOR CRITICAL FACILITIES

FEMA 424, *Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds*

FEMA 543, *Design Guide for Improving Critical Facility Safety from Flooding and High Winds: Providing Protection to People and Buildings*

FEMA 577, *Design Guide for Improving Hospital Safety in Earthquakes, Floods, and High Winds: Providing Protection to People and Buildings*

Mitigation Project Performance. Some critical facilities that had received Federal mitigation grant funds to address previous damage or known vulnerabilities were found to still be vulnerable, either to the hazard against which they had presumably been mitigated, or against other hazards.

Recommendation #24: Additional controls should be put in place by FEMA to ensure mitigation projects for critical facilities are properly designed and constructed/implemented.

7.2.1 Flood

Many of the critical facilities observed by the MAT were insufficiently elevated and vulnerable to flood damage. This was the case for most of the older buildings housing critical operations, but was also an issue for many recently constructed critical facilities.

Building Elevation Relative to Flood Level. New and replacement critical facilities continue to be located within the SFHA, and without freeboard.

> ***Recommendation #25:*** New and replacement critical facilities should be sited outside the 500-year floodplain, where possible; where not possible, the critical facilities should be elevated higher than the residential and commercial building elevations called for in Recommendations #4, #5, #6, and #10. At a minimum, critical facilities should be elevated above the 500-year flood level or the freeboard requirements of ASCE 24-05, whichever offers more protection to the facility.

Equipment and Utilities. The MAT continues to see critical facility equipment and utilities damaged by flooding as a result of insufficient elevation.

> ***Recommendation #26:*** Do not locate equipment and utilities in basements or ground levels of critical facilities. Locate these above the BFE-plus-freeboard elevation. If elevation of these components is not feasible for existing critical facilities in Zone A, evaluate dry-floodproofing of these areas to an elevation several feet above the BFE. If the building structure cannot accommodate flood loads associated with dry floodproofing to this elevation, consider relocating the critical facility or replacing with a new critical facility.

7.2.2 Wind

Most of the critical facilities observed by the MAT had wind vulnerabilities, some of which were quite significant. Vulnerable elements primarily pertained to building envelopes and emergency power, but for some facilities, the MWFRS were also susceptible to wind damage. The presence of large numbers of wind-vulnerable facilities has also been observed by MATs in other locations of the United States and its Territories. To avoid wind, windborne debris, and water infiltration damage that results in partial interruption of facility operations or entire evacuation of a facility after passage of a hurricane, the following are recommended:

> ***Recommendation #27:*** For existing facilities, perform a comprehensive vulnerability assessment of the MWFRS and building envelope. As part of the evaluation process, prioritize the identified vulnerabilities. FEMA 543 and 577 recommend such an evaluation regardless of building age for critical facilities located in hurricane-prone regions.
>
> The evaluation should also include assessing a facility's capability of coping with loss of municipal utilities (i.e., electrical power, water, sewer, and communications). FEMA 543 and 577 provide guidance on back-up systems and operations when loss of municipal utilities occurs, as well as guidance for performing remedial work on existing facilities.

If budget constraints prohibit timely evaluation of all critical facilities in a community, then the order of facility evaluation should be prioritized, commensurate with community needs and perceived vulnerability of the facilities. For example, EOCs, hospitals, and hurricane evacuation safe rooms are common high-priority facilities. These types of facilities would therefore normally be the type of facilities that would first be evaluated. However, if the local hospital was quite new and the community's fire or police stations were quite old, evaluation of the fire or police station would likely be of higher priority.

Upon completion of the evaluations of a community's facilities, the order in which remedial work will be scheduled should be prioritized.

Recommendation #28: The MAT recommends that design and construction of new critical facilities follow the guidance in FEMA 543 and 577 so that wind vulnerabilities are not built into new facilities. This approach is more cost effective than building to minimum codes and standards and then retrofitting a building in the future to decrease its wind vulnerability.

Emergency Equipment. The MAT observed critical facilities with significant wind vulnerabilities that were evacuated prior to hurricane landfall. However, in some instances (such as the fire station discussed in Section 4.3.4), equipment was not removed.

Recommendation #29: The MAT recommends that emergency supplies and equipment (such as fire trucks) also be evacuated, to the extent possible. Otherwise, building failure can damage supplies and equipment, thereby making them unavailable for post-storm response and recovery.

Mitigation Project Performance. As discussed in Sections 4.2.1, 4.3.2, 4.3.3, and 4.4.3, the MAT observed mitigation projects that were not sufficiently robust and/or were not sufficiently comprehensive.

Recommendation #30: Before a critical facility receives a grant from the HMGP or Pre-Disaster Mitigation Grant Program, it is recommended that a comprehensive vulnerability assessment be conducted. All significant wind vulnerabilities (including those related to interruption of municipal utilities) should be mitigated by the grant work, and for those that are not, the remaining residual risk should be recognized and documented.

Recommendation #31: It is recommended that the guidance in FEMA 577 be considered for healthcare facility mitigation projects, and that FEMA 543 be considered for all other critical facilities. Not all of the guidance is appropriate for all facilities, but if a recommendation is not implemented, that decision should be based on deliberation and consideration of residual risks.

Recommendation #32: It is recommended that a two-stage peer review be implemented for all projects. The first review should be made early in the design process to ensure that the scope and direction of the remedial work is fundamentally sound. The second review should be quite comprehensive, and should be conducted prior to bidding the construction work.

7.3 Further Studies and Standards Revisions

7.3.1 Flood

Observations by the Ike MAT revealed that additional studies, or implementation of existing study recommendations, will be required to improve design, construction, and siting practices for coastal buildings in the area affected by Ike.

> ***Recommendation #33:*** Determine the causes of and contributors to foundation scour observed by the MAT along the Gulf of Mexico shoreline between Surfside Beach, TX, and Holly Beach, LA. Incorporate any needed changes to foundation design and construction practice to minimize and counteract such scour.

> ***Recommendation #34:*** Gulf Coast States have ongoing shoreline erosion studies and coastal restoration initiatives (e.g., to characterize shoreline erosion, and to restore the habitat and storm buffer properties of marshes). Monitor the progress and review the findings of these studies and initiatives. Incorporate findings into flood hazard mapping procedures and into building siting, design, and construction requirements.

7.3.2 Wind

The Ike MAT expected to observe a high level of building and cladding performance, given that Ike's wind speeds were less than design levels. Though the MAT did not observe complete structural failure produced by Ike's winds, the poor performance of roofing materials and cladding systems are indicative of poor design, construction, and inspection practices.

Design, Construction, and Inspection for Disaster Resistance. Construction of buildings to meet the minimum disaster-resistance provisions of model building codes is necessary for sustainability of communities. Contractor knowledge of acceptable building practices, plan review and independent inspections are necessary to ensure disaster resistance. It is not clear that the current administrative processes for controlling building in unincorporated areas of Texas provide the same level of disaster resistance as building approaches taken by other States. A warranty to the owner of the building that it will perform well in future disasters provides little value in a future distant disaster event because of the lapse of time, change in owners, and builders being out of business.

> ***Recommendation #35:*** The State of Texas should evaluate its current approach in unincorporated areas and determine if it provides an acceptable level of disaster resistance and building quality.

Roof Systems. Based on Hurricane Ike observations, the MAT makes the following recommendations regarding aggregate surface roofs, asphalt shingles, and vegetative roofs.

Aggregate Surface Roofs. The MAT observed glazing that was damaged by windborne roof aggregate (Figures 5-25 and 5-26). In urban areas where there are mid- and high-rise buildings, the presence of aggregate surface roofs has great potential to cause a significant amount of glazing damage. Beginning with the 2006 edition, IBC prohibits aggregate surface roofs in hurricane-prone regions, but there are no requirements for removing existing aggregate. Therefore, the following are recommended in urban areas in hurricane-prone regions:

> Aggregate removal will normally necessitate replacement of the roof system. Consult with a qualified design professional or professional roofing contractor.

Recommendation #36: Remove existing aggregate from built-up and sprayed polyurethane foam roofs to avoid damage to other buildings from wind-blown aggregate.

Recommendation #37: For aggregate ballasted roofs, determine if the roof complies with the current edition of ANSI/SPRI RP-4 (available online at www.spri.org). If it does not, bring the roof into compliance with RP-4 or remove the aggregate.

Recommendation #38: It is recommended that criteria based on the two recommendations above be added to the ICC International Existing Building Code.

Asphalt Shingles. The MAT observed wind damage at several relatively new asphalt shingle roofs. However, because the labeling on the plastic strip on the underside of the shingles did not include wind resistance information, compliance with ASTM D 7158 could not be ascertained.

Recommendation #39: Asphalt shingle product standard ASTM D 3462 should be revised to require labeling the underside of each shingle with its wind resistance classification (i.e., D, G, or H as determined in accordance with D 7158). Doing so will facilitate future storm damage research by providing investigators information on the wind resistance rating of installed products.

Vegetative Roofs. The MAT observed three vegetative roof systems in downtown Houston. Although they were not damaged, nor did they cause damage to other buildings, they had the potential to do so.

Recommendation #40: The MAT recommends that a consensus wind design guideline and wind-related building code requirements be developed for vegetative roof systems. The following interim guidance is recommended: In hurricane-prone regions, trees and shrubs should not be planted more than approximately 30 feet above grade. (The higher the elevation, the greater the wind speed, and hence the greater potential for limb blow-off and damage to glazing.)

Non-Load-Bearing Walls and Wall Coverings. Based on Hurricane Ike observations, the MAT makes the following recommendations regarding non-load-bearing walls and wall coverings.

Recommendation #41: The TDI inspection program should ensure that cladding products are manufacturer-rated for the appropriate wind zones, and that the methods of installation are consistent with the manufacturer's recommendations. To improve the performance of the cladding system, as well as the overall strength of the house, it is recommended that TDI consider requiring that the exterior wall substrates of residences be fully clad with plywood or OSB sheathing so that the sheathing is capable of withstanding design wind pressures that produce both in-plane and out-of-plane loads. A fully sheathed house is more robust and resistant to water infiltration in the event of the loss of wall cladding or windborne debris impacts.

Windows and Shutters. The MAT observed interior water damage due to window leakage (Figure 7-2). The current minimum test pressures used to assess the resistance of windows to wind-driven rain are substantially below the design wind pressures. Hence, current minimum testing is inadequate to evaluate leakage potential during hurricanes.

Recommendation #42: 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.

Figure 7-2. Several windows at this house on Bolivar Peninsula leaked and wetted the carpet

The MAT observed a house under construction on Bolivar Peninsula (Figure 7-3) that had protected glazing in a breakaway wall. The breakaway walls and the window were destroyed by flooding. Currently, if a building is in a windborne debris region, ASCE 7, IBC, and IRC require protected glazing, including the glazing in breakaway walls. However, if the walls break away because of flooding, the windows will likely be destroyed as shown in the inset in Figure 7-3.

Recommendation #43: Because glazing in breakaway walls is far more susceptible to flood damage than windborne debris, it is recommended that an exception be added to ASCE 7, IBC, and IRC that would allow the glazing in breakaway walls to be unprotected. Such an exception would reduce the cost of providing protected glazing, yet would not significantly increase the risk of damage.

Figure 7-3.
The breakaway walls at this house were destroyed. The inset shows a window with laminated glazing that was washed away with the walls. Using protected glazing on the upper-level windows is logical, but protected glazing is of little value in breakaway walls.

7.3.3 Critical Facilities

Schools. The MAT observed schools in need of mitigation. FEMA 424 provides design guidance for new and existing schools, but the guidance is out of date.

> ***Recommendation #44:*** It is therefore recommended that the flood and wind chapters be updated to incorporate the applicable guidance in FEMA 543, as well as the new provisions presented in Recommendation #45 below.

Critical Facility Guidance. The MAT observed various types of critical facilities in need of mitigation. FEMA 543 and FEMA 577 provide guidance for new and existing facilities.

> ***Recommendation #45:*** Based on Hurricane Ike observations, it is recommended that the wind chapters in these two guidance documents be updated to incorporate the following conceptual guidance:
>
> **Roof Drainage.** Roof drains and scuppers have the potential to be blocked by leaves, tree limbs and other windborne debris during a hurricane. If primary and overflow drains/scuppers become blocked, development of deep ponding water may inundate base flashings and

cause leakage problems or lead to roof collapse. To avoid problems with blocked drains and scuppers, the following are recommended:

- *Scuppers* – Only a relatively small scupper is needed to drain a large roof area, provided the scupper opening is not blocked by debris. However, since small openings are more easily blocked than larger openings, it is recommended that scupper openings be much larger than normal. It is recommended that scupper openings be a minimum of 24 inches wide and 16 inches high. In addition, it is recommended that the distance between scuppers be such that, in the event a scupper becomes blocked, the adjacent scuppers have sufficient capacity to drain the roof.
- *Roof drains* – Avoiding blockage of drains is more problematic than avoiding blockage of scuppers. Drain lines need to be protected by domes to prevent debris from flowing into the lines and blocking them. For domes to be effective in protecting drain lines from blockage, the dome openings must be relatively small. To provide overflow protection, it is recommended that overflow scuppers be provided. Where drainage patterns necessitate that overflow protection be provided by overflow drains (rather than, or in addition to, overflow scuppers), it is recommended that additional overflow drains be installed. By doing so, if both a main drain and its nearby overflow drain become blocked, the additional overflow drain in the vicinity can provide drainage and avoid roof collapse.
- *Maintenance* – As part of pre-storm preparations, drains, scuppers, and gutters should be cleaned of debris in order to maximize their effectiveness in draining the roof and minimize the potential for their blockage during a hurricane.

Flexible Connectors. Flexible connectors between rooftop ductwork and fans may leak (as discussed in Section 4.2.3) if they are in a deteriorated condition prior to a storm or if they are punctured by windborne debris. FEMA 543 and 577 recommend placing mechanical equipment in a penthouse to avoid these types of problems. However, if equipment is exposed, the following are recommended:

- Because of their small size, the potential for a flexible connector to be punctured by windborne debris is typically very low. However, if site-specific conditions present an unusually high potential for debris damage, it is recommended that the flexible connectors be protected by equipment screens or a custom-designed shield.
- As part of annual roof inspections prior to hurricane season, it is recommended that all flexible connectors be inspected. Those found to be in a weathered condition (e.g., cracked, torn, or embrittled) should be immediately replaced.

Emergency Electrical Power. Hurricanes often cause widespread and prolonged interruptions of municipal power. Hence, because reliable power is essential to operating most critical facilities, they need emergency generators. Current codes and standards do not require emergency generators for all critical facilities and functions, nor are the requirements sufficient to ensure reliable power during prolonged power outages. In the aftermath of Hurricane Ike (as well as previous hurricanes), some critical facilities (including hospitals) had to be evacuated because of lack of power. It is for this reason that FEMA 543 and 577 provide a number of recommendations pertaining to generators.

Recommendation #46: Based on the Ike MAT's observations, FEMA 543 and 577 should be updated as follows:

- Currently, the guidance on electrical power does not differentiate between those critical facilities where power for some services cannot be interrupted (such as hospitals and EOCs) versus those where loss of power for several days is tolerable (for instance, a community center that serves to house emergency workers brought in after a storm). The current guidance to provide standby generator(s) in addition to the emergency generator(s), as well as devices to allow quick connection of portable generators, is overly conservative for facilities where loss of power for several days is tolerable. The current guidance to house generators in wind- and windborne debris-resistant enclosures is also overly conservative for facilities that can tolerate loss of power. The guidance should be differentiated based on the ramifications of loss of power to facility operations.
- The MAT observed several critical facilities that had generators fired by natural gas. One community had great success with this fuel source. Use of natural gas alleviates various potential problems associated with on-site storage of diesel fuel (such as adequate quantity of fuel for prolonged outages). However, at a facility observed by the MAT (discussed in Section 4.4.1), the natural gas supply was shut down by the gas supplier leaving the facility without power. Neither FEMA 543 nor 577 discuss natural gas-fired generators. It is recommended that this fuel type be added to the discussion, along with guidance regarding potential interruption of gas service (such as providing a diesel fuel back-up generator).
- Guidance should be developed to determine what loads need to be supplied with emergency or standby power to enable facilities to provide services needed for operations during and/or after a hurricane.

SELF-AUDIT

A self-audit of a critical facility can help identify equipment that is essential to facility operations, but vulnerable to disruption by a natural hazard. The emergency plan should be reviewed periodically and revised as necessary.

When completing this audit for electrical power, the building owner should:

1. Determine possible restoration times for municipal power during a natural disaster (restoration times will be significantly longer than those caused by more common causes of power disruption)
2. Determine emergency power and fuel source based on restoration time
3. Determine how electrical equipment that is vulnerable to flood, wind, or windborne debris damage should be modified or relocated
4. Determine what other equipment (not currently on emergency circuits) might be needed when restoration times are longer
5. Consider how portable emergency generators and switchgear will be connected if/when required

Supplemental Emergency Power Recommendations. Many generators that are used for meeting the power demands from outages are intended to provide power for a relatively short duration. These standby generators are typically designed to supply power for a minimum of a few hours to a maximum of several days, not durations of a few weeks that often follow a hurricane. Standby generators often lack redundant control systems, redundant ancillary systems like fuel filters, adequate on-site fuel storage, and redundant capacity in their cooling systems. These limitations don't significantly affect generator reliability if generators are run for short periods of time, but can greatly affect reliability if the generators are required to operate for several weeks.

Prime-power generators, on the other hand, are designed to operate indefinitely. Their nameplate ratings are typically 15 to 20 percent lower than standby units (e.g., a 1,000 KVA standby generator will have a prime-source capacity of around 800 KVA). With prime-source units, more attention is given to maintenance under load and typically at least two units are specified to allow periodic shut-downs for maintenance. This additional capacity helps alleviate overheating and improves reliability. Redundant ancillary systems (like fuel pumps and filters) allow some components of the on-site power systems to be serviced while the system is operating; this type of maintenance can greatly increase system reliability. FEMA 543 and 577 recommend the use of prime-power generators.

Power Quality. The quality of electrical power provided by on-site generation can also be a concern. While this is generally not a problem with larger fixed generators, power quality can be problematic for smaller generators (particularly smaller generators operated near their capacity) and for portable units. Voltage control and frequency control are particularly critical.

Sizing and Vulnerability. To be effective, all emergency power systems must be properly sized and be less vulnerable than the utility power system. Generators, transfer switches, fuel supplies, and control equipment should be protected from wind, windborne debris, and flooding, as recommended in FEMA 543 and 577. Generator sizing should take into account all loads required for the critical facility to function. While not required from a life-safety standpoint, mechanical equipment for temperature and humidity control should be considered critical equipment. In many hurricane-prone regions, temperature and humidity levels can increase rapidly to the point that they severely limit or prevent the delivery of critical functions. In new or renovated facilities, energy efficient equipment, such as high efficiency lighting, can be specified to reduce loads on emergency power sources. Alternative power sources, such as wind turbines or photovoltaic cells, should not be relied upon unless they are designed to resist high winds, windborne debris, and flooding.

Temporary Generators. Temporary generators may be appropriate options for supplying power during prolonged power outages for those facilities that can tolerate loss of power until the temporary generator becomes operational. Temporary generators have the benefit of not requiring the capital expense of on-site emergency generators. If temporary generators are selected to provide power, the following issues should be considered:

- *Availability of generators* – Arrangements must be made before the event to ensure adequately sized generators are available when needed.

- *Off-loading requirements* – When generators are not trailer mounted, provisions must be available to off-load the generators on site.
- *Fuel availability* – Large generators require great amounts of fuel. Facilities need to ensure that adequate amounts of fuel are available.
- *Connection to the facility* – Methods to connect temporary generators to the facility should be installed before the event. Quick disconnects with manual transfer switches (often referred to as cam locks) should be installed. The connection point should be close to the generator location to reduce voltage drop that can result from long cables.
- *Capacity and quality of power* – The generators must be large enough to serve the requirement loads (i.e., they must be large enough to start the largest motor when operating all other loads) and the quality of the power must be sufficient to prevent damaging facility equipment.

Operation and Maintenance Staff. Temporary generators require maintenance and periodic testing and monitoring. Knowledgeable staff must be available to provide those services.