CHAPTER 2

Identifying the Risks and Desired Level of Protection

To better understand the wind-related risk to a house from hurricanes, it is important to know how wind hazards are defined. Further, to understand the level of protection provided by a house before and after implementing a retrofit project, homeowners should understand or try to identify the code to which their house was constructed and the methods and materials used during construction.

This chapter discusses wind hazards in coastal regions and summarizes how and when building codes and standards started to address these hazards. Also included is a discussion on the level of protection provided by houses, and the level of protection or performance that is reasonable to expect after implementing a wind mitigation project.

2.1 Wind Hazards in the Hurricane-Prone Region

High-wind natural hazards affecting the hurricane-prone region include hurricanes, tropical storms, typhoons, nor'easters, and tornadoes. The retrofits outlined in this Guide are specific to protecting existing houses from hurricane damage. Although most common in coastal areas, the damaging effects of hurricane-force winds are not limited to coastal counties. The American Society of Civil Engineers (ASCE) 7-05, *Minimum Design Loads for Buildings and Other Structures,* defines the hurricane-prone region as the U.S. Atlantic Ocean and Gulf of Mexico coasts where the design wind speed is greater 90 miles per hour (mph), as well as Hawaii, Puerto Rico, Guam, Virgin Islands, and American Samoa.

> Unless otherwise stated, all wind speeds used in this Guide are ASCE 7-05 3-second gust wind speeds and correspond to design requirements set forth in that document and the 2006 and 2009 editions of the International Residential Code (IRC). Due to changes in the development of the ASCE 7-10 wind speed map, it is not appropriate to use the ASCE 7-10 wind speed map in combination with the provisions of ASCE 7-05 and the older codes.

Figure 2-1 shows the hurricane-prone region of the United States mainland. The map shows the hurricane-prone region as defined in both the 2005 and 2010 editions of ASCE 7. ASCE 7-05 defines the windborne debris region as areas within 1 mile of the coastal mean high water line where the basic wind speed is equal to or greater than 110 mph (and in Hawaii) and in areas where the basic wind speed is equal to or greater than 120 mph (130 mph

> **THE APPLIED TECHNOLOGY COUNCIL (ATC) WIND SPEED WEB SITE**
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> Products that help determine the applicable wind speed for a given location can provide a valuable service. One such product is ATC's wind speed Web site (www.atcouncil.org/windspeed.html). ATC is a nonprofit corporation that develops applications for hazard mitigation.

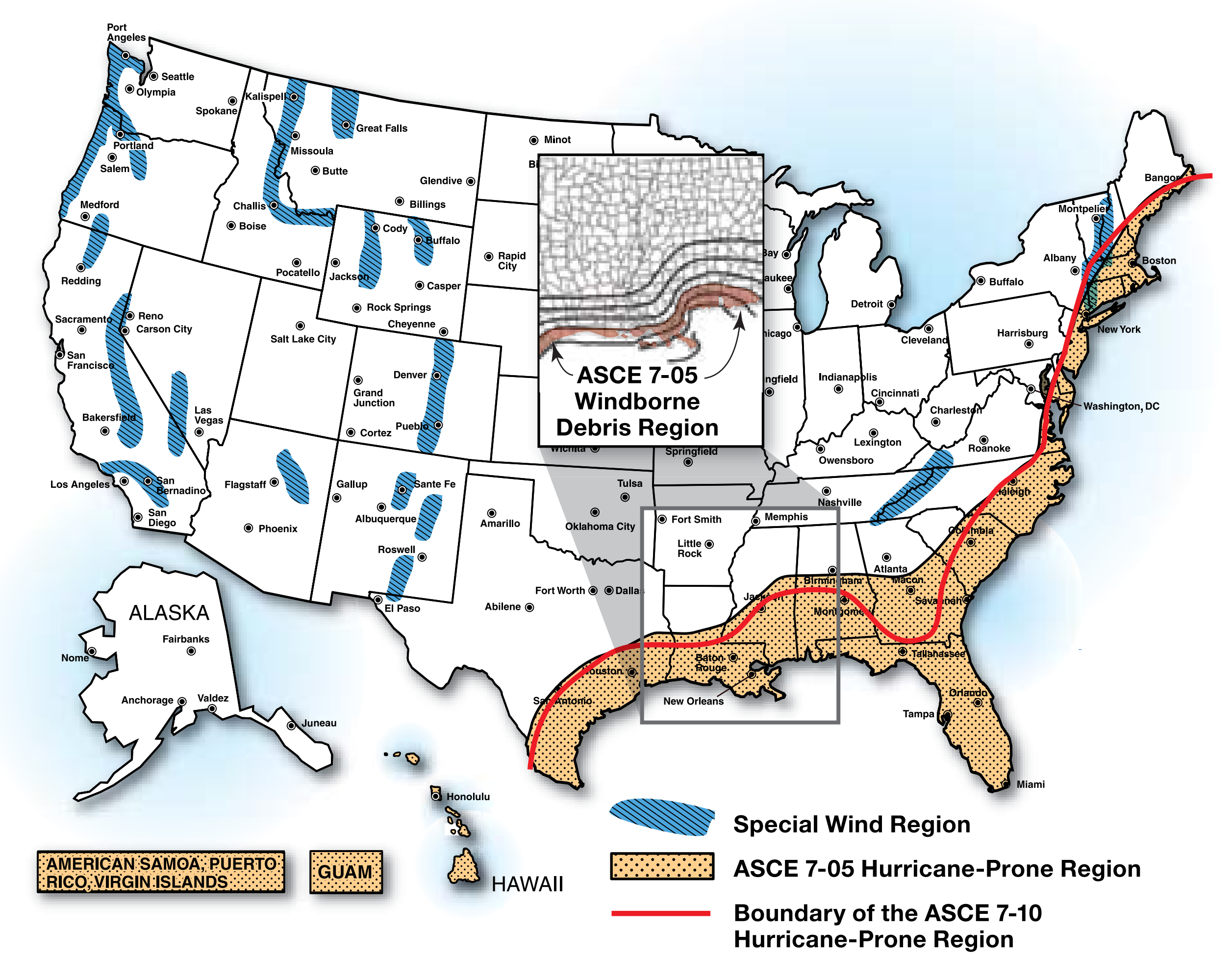

FIGURE 2-1:
Illustration of the hurricane-prone region of the United States

and 140 mph in ASCE 7-10, respectively). Note that the map is for illustration purposes only and should not be used to determine (basic) design wind speed.

ASCE 7 also defines exposure categories that reflect the terrain roughness for the building site (see text box). As the terrain becomes more open, there is more potential for wind damage. Conversely, areas that are densely populated or otherwise have a lot of potential windborne debris can be prone to other types of wind-related damage. In addition to the wind speed and location within the hurricane-prone region, the exposure category is also an important component in identifying a building's vulnerability to wind-related damage.

> **EXPOSURE CATEGORIES FROM ASCE 7-05**
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> **B:** Urban, suburban, wooded
>
> **C:** Open terrain (includes shoreline in hurricane-prone regions)
>
> **D:** Flat, unobstructed; exposed to wind flowing over open water at least 1 mile, but outside of the hurricane-prone region

Houses in hurricane-prone regions can be damaged by high wind pressures and wind-driven rain, as well as windborne debris. This last hazard requires special attention in the windborne debris region. High winds can produce large amounts of debris that may become windborne and perforate the building envelope and openings. Once a building is perforated, wind-driven rain can enter the building, causing water damage to the interior and contents. A broken window or glass door may also allow wind pressures to increase within the house, leading to structural damage. As such, building codes require that new homes constructed in windborne debris regions protect glazing (windows and glass doors) against damage and impacts from windborne debris. Homeowners should consider adding protection to the openings in their existing home to mitigate this risk. The inset of Figure 2-1 illustrates the windborne debris region for several Gulf Coast States. Homeowners should consult their local building department for a final determination regarding their home's location within the windborne debris region. Homeowners should understand their potential risk based on their location to determine which retrofit package is right for their house (see Chapter 3).

2.2 Levels of Protection

Over the past few decades, building codes have progressed toward addressing design and construction practices that will result in buildings that are more resistant to high winds. However, much of the existing building stock in hurricane-prone regions was designed and constructed to codes and standards that required far less than current codes to mitigate wind damage—or constructed to no codes at all. It is important for homeowners to be aware of the limits of the building code used to construct their house, the existing level of risk, and how and to what extent the risks can be mitigated.

Properly designing and constructing a building to locally adopted building codes provides the minimum level of protection for the wind hazard at a particular site for *new* construction. However, older houses may not be wind resistant when compared to today's codes and standards, even if constructed to adopted building codes at the time they were built. This Guide describes retrofits for those older buildings and for newer structures that were not designed to hazard resistant codes. Residential buildings can suffer extensive wind damage when wind speeds exceed the design levels or when they are improperly designed and constructed. For example, even though Hurricane Ike's wind speeds were below the design wind speeds for much of the impacted area, many residential

FIGURE 2-2:
Roof structure failure on a house (Galveston, TX, 2008)
(SOURCE: FEMA P-757)

buildings suffered wind damage, some of which was disproportionate to the reported wind speeds. During Hurricane Ike, the house in Figure 2-2 sustained structural damage from wind speeds estimated at 93 mph, which was below the design wind speed.

2.2.1 Wind Hazards and Building Codes

Many States and communities now regulate the construction of buildings by adopting and enforcing building codes. Most locally adopted building codes in the United States are based on model building codes. Examples of model building codes promulgated by the International Code Council (ICC) include:

- *International Building Code* (IBC) (ICC, 2009a)
- *International Residential Code for One- and Two-Family Dwellings* (IRC) (ICC, 2009b)
- *International Existing Building Code* (IEBC) (ICC, 2009c)

The approaches to wind design in these model codes are based on modern wind engineering provisions of ASCE 7, as well as acceptable methods for enhancing wind hazard resistance. The IRC also incorporates, by reference, industry standards in addition to ASCE 7 that are specifically recognized as accepted engineering practice for one- and two-family dwellings in high-wind regions. These standards include:

- American Forest and Paper Association (AF&PA) *Wood Frame Construction Manual for One- and Two-Family Dwellings* ([WFCM], 2001)
- ICC *Standard for Residential Construction in High-Wind Regions* (ICC-600, 2008a)
- American Iron and Steel Institute (AISI) *Standard for Cold-Formed Steel Framing—Prescriptive Method for One- and Two-Family Dwellings* (AISI S230, 2007)

While compliance with codes and standards for new construction is not the subject of this Guide, construction methods within those documents may serve as additional guidance for improving resistance to high winds.

FIGURE 2-3:
Building built to the 2001 Florida Building Code (FBC) standards with no structural damage after Hurricane Charley (North Captiva Island, 2004)
(SOURCE: FEMA 488)

Building codes and standards are typically refined to incorporate lessons learned after natural disasters. Buildings like the one shown in Figure 2-3, built using modern wind engineering provisions incorporated in codes after Hurricane Andrew, performed better than older buildings during the 2004 hurricane season. The lack of a locally adopted code, or use of older codes, will likely increase the vulnerability of homes to wind damage.

As hurricanes continued to affect coastlines, more States, including Florida in 2001–2002, began adopting and mandating the use of nationally recognized codes and standards. Prior to Hurricane Katrina in 2005, Louisiana communities had varying building and residential codes, and in many communities, no established building codes at all. This lack of building codes, or use of older codes, is often an indicator that the houses in the area were designed and constructed without the modern hazard-resistance techniques that have been incorporated into newer building codes. To ensure that new buildings would perform better in future hurricanes, Louisiana mandated the use of the 2003 IRC and IBC, with State-specific amendments in 2007. This action was consistent with the recommendations in FEMA's 2006 MAT report, FEMA 549, *Hurricane Katrina in the Gulf Coast* (FEMA, 2006a).

2.2.2 Recommended Protection and Best Practices

Many mitigation or retrofit projects may be implemented to improve the performance of residential buildings in coastal regions, especially those buildings built to older codes. Section 2.2.1 discussed wind hazards and the building codes and standards that have been implemented over the years to help ensure that buildings perform adequately in their environment. As our knowledge of wind hazards has grown, our understanding of building performance has also changed, and so has the level of protection provided by a "code-compliant" building.

> Based on observations from previous post-disaster investigations FEMA has conducted, it is highly unlikely that a single retrofit measure alone will provide improved protection and risk reduction from a wind event. This Guide presents groups of retrofit measures in "packages" for a more comprehensive solution to risk reduction. The Mitigation Packages are presented in Chapter 4.

To improve the performance of a building in hurricane-prone regions, post-disaster investigations of impacted areas are conducted by FEMA, the building industry, and the insurance industry. Both independently and collaboratively, these groups have identified performance issues in older buildings. In general, the buildings that performed poorly did not have:

- Roof and wall coverings capable of resisting high winds
- Protection for openings (windows, doors, garage doors, soffits, and vents) to resist high winds, windborne debris, and wind-driven rain
- Structural systems providing a continuous path for all loads (gravity, uplift, and lateral) to be passed from the building exterior surfaces to the ground through the foundation

This Guide presents Mitigation Packages that, if implemented correctly, will reduce the risks of damage to a residential building from a wind event. However, there are several factors to consider in the decision-making process to implement wind retrofit measures, such as:

- Whether the house is a good candidate for a wind retrofit project
- What Mitigation Packages are cost-effective for a house's desired level of protection
- How much risk of wind-related damage is acceptable to the homeowner

These factors and others are discussed in further detail in Chapters 3 and 4 of this Guide. It is important to understand that although the individual retrofit measures of the Mitigation Packages are based on design methods in current building codes and standards, not all of the design elements required by modern building codes for wind hazard resistance will be included in the retrofit project. Therefore, depending on the Mitigation Package(s) implemented, residual risk will likely still exist, even though some of the strengthened elements of the implemented retrofits may meet or exceed local building code requirements. More information on residual risk and addressing other hazards can be found in Section 5.3.

Implementing mitigation measures to reduce risk is a personal decision for homeowners to protect their house and property. Having made the decision to pursue a wind retrofit project, the homeowner will also have to decide what level of protection is desired. A homeowner's decision regarding the desired level of protection will likely involve weighing the wind hazard risk with the cost of mitigating that risk. The FEMA BCA Tool can be used as a reference point for determining whether the mitigation measures being considered are cost-effective. Use of this software is required when submitting a grant application to one of FEMA's HMA programs (refer to Chapter 5 and Appendix C). It should not, however, be the only factor used to make decisions regarding the wind retrofit project.

DETERMINING COST EFFECTIVENESS

The FEMA BCA Tool determines that a project is cost-effective when the benefit-cost ratio (BCR) is 1 or above. The software, along with resource documents to guide users through the BCA process, can be downloaded from www.bchelpline.com.

Appendix C provides a step-by-step guide on using the FEMA BCA Tool with the wind retrofit packages presented in this Guide.

Each individual house is unique and exposed to risks that may be specific to a particular site or region. For example, implementing the Basic Mitigation Package may reduce risk, but may also leave too much residual risk; in this case, a homeowner may decide the additional cost of implementing the Intermediate Mitigation Package is more acceptable. Another cost consideration homeowners may face is the need to make improvements to their house *before* the Basic Mitigation Package described in this Guide can be implemented. Some houses may be previously damaged or may be undergoing improvements (addition or renovation). These houses may be candidates for a wind retrofit project, as components that are normally difficult to access may already be exposed. However, such conditions may also trigger substantial improvement/substantial damage (SI/SD) provisions of governing building codes, requiring further work on the house outside the scope of the wind retrofit project type. See Section 5.2.1 for more information.

The wind retrofit Mitigation Packages described in this Guide are meant to improve the wind resistance of existing residential buildings. Retrofits described in this Guide should not be construed as providing protection comparable to that provided by safe rooms designed and constructed in accordance with FEMA 320, *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business* (Third Edition, 2008a) and FEMA 361, *Design and Construction Guidance for Community Safe Rooms* (Second Edition, 2008b). Even where Mitigation Packages described in this Guide are implemented, evacuating hurricane-prone regions is still the best way to protect against injuries or loss of life during a hurricane event. Homeowners should always evacuate when told to do so by local or State authorities. If a homeowner's ultimate goal of implementing a wind retrofit project is to protect building occupants from injury or death, FEMA recommends building a safe room. For additional information on safe rooms, see FEMA 320 and FEMA 361.

SAFE ROOMS: NEAR-ABSOLUTE PROTECTION

The level of occupant protection provided by a safe room is much greater than the protection provided by buildings that comply with the minimum requirements of most building codes or any level of protection detailed in this Guide. Safe rooms offer near-absolute protection (a very high probability of being protected from injury or death). FEMA 320, *Taking Shelter from the Storm: Building a Safe Room for Your Home or Small Business* (Third Edition, 2008a), includes prescriptive designs that provide homeowners and their builders/contractors with information on how to construct a safe room for a house. For solutions not covered by FEMA 320, FEMA 361, *Design and Construction Guidance for Community Safe Rooms* (Second Edition, 2008b), contains design criteria for custom residential safe rooms.

Construction of a safe room in an existing house can be cost-effective when the house undergoes a wind retrofit project, even though construction of a safe room during new construction is typically more cost-effective. Because safe rooms must have heavy, debris-impact-resistant walls (constructed of reinforced concrete, reinforced masonry, or wood with steel or masonry infill) that are secured to the foundation, they are more difficult to construct in an existing house. However, during a wind retrofit project for which walls, roofing systems, and load path connections are being retrofitted, constructing a safe room can be cost-effective. These retrofits are likely to occur while the homeowner is attempting to achieve an Advanced Mitigation Package designation. Installing a safe room during a retrofit helps to economize the design staff, labor, and materials already under contract and on site. For example, implementing the Advanced Mitigation Package described in Chapter 4 typically requires consultation with an engineer. If a homeowner is also considering adding a safe room to an existing structure, it would be cost-effective to include the safe room in the engineering consultation, whether or not the consultation is required by local building codes.

FEMA continues to advocate for the design and construction of residential safe rooms as evidenced by its continuing support of safe room initiatives through several grant programs. Since the initiation of its safe room program, FEMA has provided support for over 20,000 residential safe rooms with Federal funds totaling more than $75,000,000 (as of FY 2010). A growing number of these safe rooms have already saved lives in actual events. There have been no reported failures of any safe room constructed to FEMA criteria.