Testimony to the

State of Texas

Texas Senate Subcommittee on Flooding and Evacuations

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Testimony Regarding

Mitigating Damage to Residential Structures from Hurricanes & Coastal Windstorms

Testimony of

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from Hurricanes & Coastal Windstorms
by Larry J. Tanner, P.E.

Introduction

Thank you Mr. Chairman and committee members.

My name is Larry Tanner. I am an engineering researcher with the Wind Science and Engineering Research Center at Texas Tech University. I have documented 12 storms, tornadoes and hurricanes, in the last ten years, including the devastating Oklahoma/Kansas Outbreak of 1999, Hurricane Katrina in 2005, and Hurricane Ike in 2008. I was also a member of the FEMA Mitigation Assessment Teams for those storms. My CV is appended to this testimony.

Subcommittee Charge:

1. **Methods of mitigating hurricane damage to existing residential structures.**
2. **Methods of mitigating hurricane damage to new residential structures.**
3. **Comparable costs of these methods.**
4. **Recommendations relating to cost effective options to either retrofit or require new building structures to be built as shelters for use during evacuations.**

Background

According to the U.S. Census Bureau, as of July 1, 2007, 35.3 million people lived in areas of the United States most threatened by Hurricanes.[1] These areas are defined as the coastal portions of Texas through North Carolina and represent approximately 12% of the U.S. population.[2] Disaster losses paint a compelling picture of our economic and societal vulnerability to windstorms. From 1987 to 2006 the inflation-adjusted, insured losses break down as follows:[3]

- $297.3 billion - Total Disaster Losses
- $137.7 billion (46.3%) Tropical Cyclone Losses
- $77.3 billion (26%) Tornadoes
- $19.1 billion (6.4%) Earthquakes

Vulnerability will continue to increase due to a variety of economic and other factors, including the aging of our built environment, the percentage of the built environment constructed without use of model building codes, the increased cost of new construction, and the increase in coastal population.

Hurricane Hazards

The hazards of hurricanes and coastal storms include the following:

- Erosion of barrier sand dunes and foundation structures
- Coastal flooding, wave action, and storm surges
- High winds

Homes in Velocity Zones (National Flood Insurance Program - NFIP V Zones and Coastal A Zones) are vulnerable to wave action and storm surges if not elevated to or above the Base Flood Elevation (BFE) and properly constructed on an open and elevated foundation (piles), see **Figure 1**. The loss or alteration of the dune structures and vegetation can lead to erosion produced by wave and surge forces that can scour foundation piles and undermine the structure's stability. Although not subjected to wave and velocity surges, inland area homes in NFIP mapped Special Flood Hazard Areas (SFHA) should have appropriate foundation structures and their first floor elevated to or above the NFIP or jurisdictional Base Flood Elevation (BFE), shown in **Figure 2**.

Tropical storms and hurricanes produce winds far in excess of normal winds in inland and interior land areas. The wind forces will produce inward pressures on the windward face, outward pressures on the sides and leeward face, and depending upon the roof slope, outward pressures on the roof surfaces, see **Figures 1&2**. .

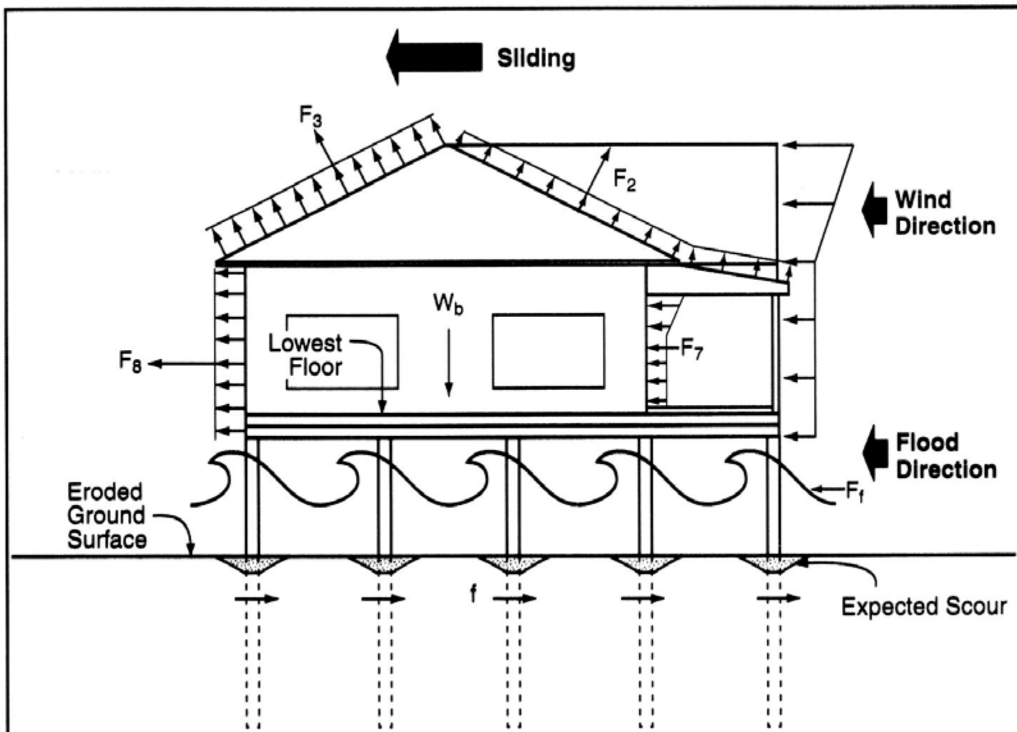
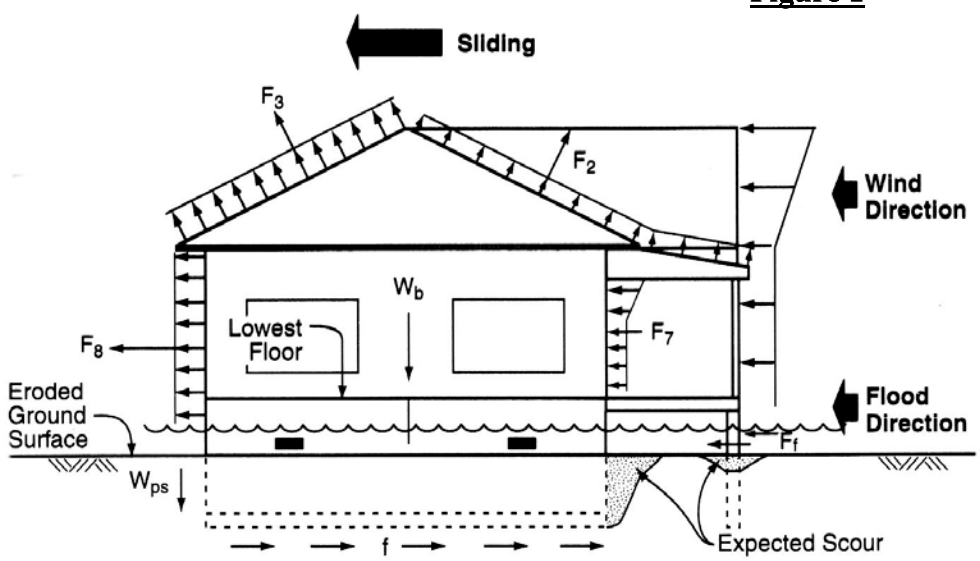


Figure 1



F = Wind Force

F_f = Flood Force

W_b = Building Weight (Including Foundation)

W_{ps}= Passive Soil Pressure

f = Frictional Resistance

Figure 2

Figures 1 & 2. Wind and water forces on coastal construction[4]

Construction Guidelines

Numerous surveys have been conducted over the years to determine the primary causes of building failures in hurricanes. Differences in building performance are routinely observed in adjacent structures. Initially, these differences were assumed to be the result of some anomaly in wind forces and water loads. However, post storm inspections and documentation routinely reveal this disparity to be the result of design and construction differences. In general, those homes that are better connected from roof top to foundation (load path) are more resistant to hurricane forces. **Figure 3** illustrates the concept of Load Path.

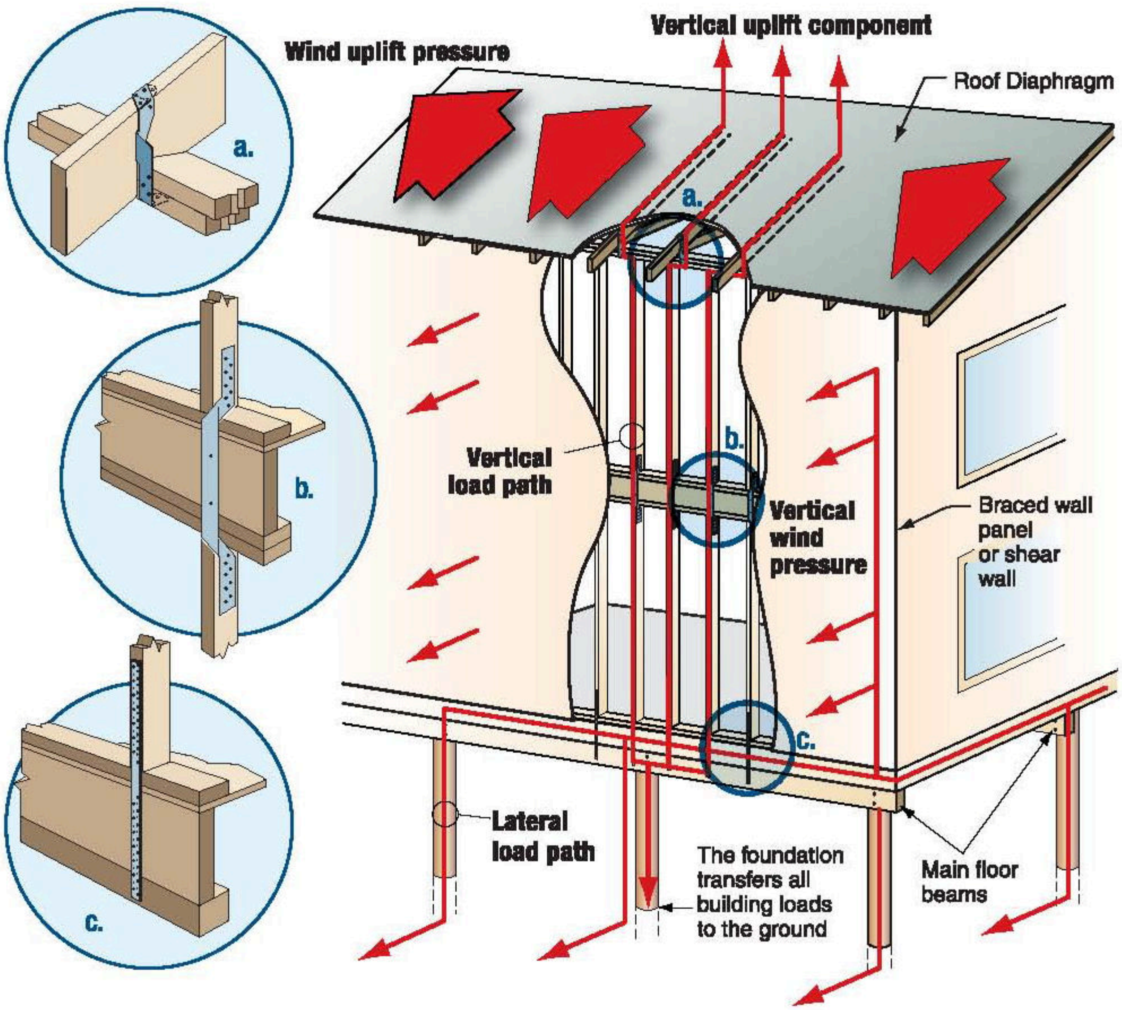


Figure 3. Building Load Path[5]

Building codes are written to provide a minimum design and construction standards, to diminish this divergence in building performance. Prominent building codes, standards and guidelines relevant to hurricane resistant construction include:

- *2006 International Building Code* [6]
- *2006 International Residential Code* [7]
- *Minimum Design Loads for Buildings and Other Structures,* ASCE 7-05[8]
- *Flood Resistant Design and Construction,* ASCE 24-05[9]
- *Standard for Hurricane Resistant Residential Construction,* SBCCI SSTD 10-99[10]
- *Guidelines for Hurricane Resistant Residential Construction,* IBHS[11]
- *Coastal Construction Manual*, FEMA 55[4]
- *Florida Building Code*[12]
- The Texas Department of Insurance – Windstorm Program[13]

<u>Retrofitting Existing Homes to Diminish Hurricane Damage</u>

Hurricane Katrina, Hurrican Rita, and Hurricane Ike produced surge and flooding that exceeded the mapped the National Flood Insurance Program (NFIP) Base Flood Elevations (BFE). Thus, many homes were destroyed or severely damaged by these storms, including: 1) older homes constructed at or near grade; 2) homes constructed to the BFE; and 3) homes constructed outside the Special Flood Hazard Area (SFHA, shown on the Flood Insurance Rate MapsI and without regard to flood resistance. Short of moving or raising homes, very little can be done to improve the flood resistance of homes that are built at/or below the BFE, or just outside the SFHA.

Many recent hurricanes have resulted in significant amouts of wind damage to homes, despite having wind speeds below the Design Code speeds. Typical hurricane wind damage includes roof and siding damage, and wind propelled debris damage to doors and windows. Improper use of non-hurricane wind-zone materials, or the poor installation of rated materials, account for most of the observed wind damage. Unless a home has been gutted by a storm, the installation of “wind clips” and similar hidden metal connectors is virtually unreasonable:

Flood

1. For an elevated home with non-breakaway walls, install one 8”x16” flood vents per every 150 sf of enclosed space.
2. For an elevated home, remove and replace all visible corroded metal connectors and bolts.
3. Provide additional elevation of a home elevated at/or below the current BFEs. The lowest floor elevation should be equal to the Effective (i.e., shown on the currently adopted NIFP Map) BFE + 3-feet (Freeboard), see **Figure 6.** Homes in all flood hazard zones would qualify for a flood insurance premium reduction; however, unlike the case of new construction where freeboard costs are recovered quickly, the time to recover elevation costs through flood premium savings for existing homes (payback time) can be many years.

Wind

1. Improve and/or replace observable connections of elevated structures, overhangs, and porches.
2. Where gable ends are accessible from attics, provide wind bracing to prevent hinging of the gable end.
3. When re-roofing, the existing decking should be re-nailed to ensure a positive connection.
4. When re-roofing, the installed asphalt shingles should comply with ASTM D 7158, with Class G (120 mph) installed in Inland Zone I & II, and Class H (130 mph) installed in the Seaward Zone.

<u>Hurricane Mitigation in New Residential Construction</u>

New construction affords the builder/developer/owner to site, elevate, connect, and clad the home to be less affected by the hurricane forces of water, waves, and wind. Building location is a sustainable issue requiring extensive studies by affected communities and counties, as well as the State. Guidance on this issue is provided in the FEMA Mitigation Assessment Team Report, *Hurricane Ike in Texas and Louisiana, FEMA 757*.[14]. Resistance to water and erosion is a function of foundation depth and type (**Figure 4**), whereas wave resistance is a function of elevation (**Figure 5**). Resistance to hurricane wind forces is a function of good connections (**Load Path, Figure 3**), proper installation of hurricane rated roofing and cladding systems, and the protection of building openings with shutters or impact resistant glazing, see **Figures 4 & 5**.

Figure 4. Erosion along the Galveston Island shoreline, west of the seawall
(Oct. 17, 2008, photo C.P. Jones)

Figure 5. Bolivar Peninsula house on left sustained minor flood damage (to access stairs and below-BFE enclosures) during Ike, while the house on the right was severely damaged. The house on the left was constructed 5.5 ft above the BFE, the house on the right was estimated to be at the BFE (Oct. 18, 2008, photo C.P. Jones).

Flood

1. The only protection from waves and water is through sufficiently elevating the structure on a strong foundation. Many homes built to the current BFEs were damaged or destroyed by Ike. Until new Digital Flood Insurance Rate Maps (DFIRMs) are developed and adopted, a Freeboard of three feet should be added to the current Effective BFEs as shown in **Figure 6.** Though each foot of freeboard will cost more than the at-BFE construction cost, flood insurance premiums will be reduced. A V-Zone home should have a 1-3 year payback and an A-Zone home should have a payback period of approximately 6 years. [14]

2. Elevated homes frequently have parking slabs constructed below the home. Reinforced and stiffened concrete parking slabs should not be allowed under and around the residential structures, since they can become eroded and can transfer extreme wave and water loads onto the structure's foundation system. Parking slabs should be un-reinforced frangible slabs that will break-up under the water forces. Frangible slabs cost less than reinforced slabs.

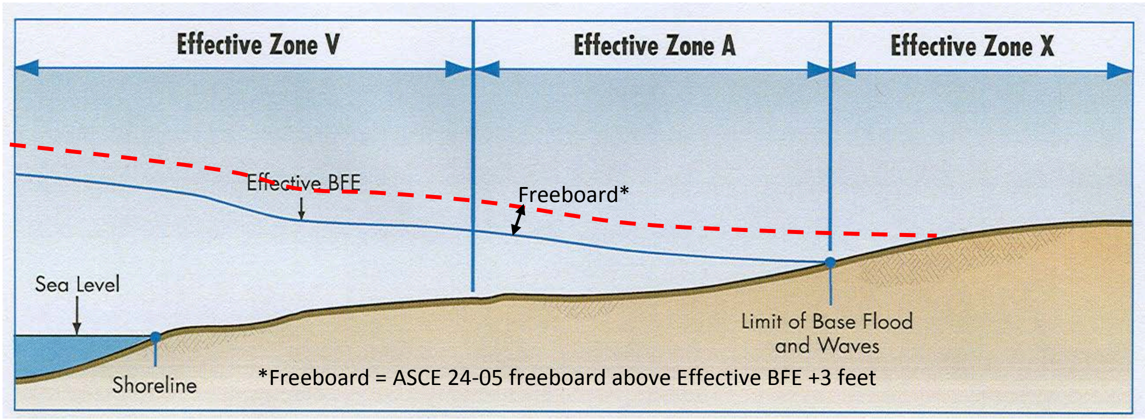


Figure 6. Comparison of Effective BFEs, flood hazard zones, and recommended Freeboard.

3. Below-BFE walls constructed of lattice or louvers are preferred over solid breakaway walls and will reduce flood insurance premiums by a couple of thousand dollars per year in V Zones.
4. Breakaway walls get taller as homes are elevated higher. Though breakaway walls normally perform as intended, they become large floating debris that produce damage to nearby structures. The installation of flood vents in solid breakaway walls can alleviate unbalanced water pressures, thereby delaying the damage and loss of breakaway walls, which are not covered by the standard flood insurance policy (repair or replacements costs must be borne by the owner)..
5. Tall breakaway wall sizes can be reduced by constructing breakaway joints at mid-height. This type of installation will reduce the size of floating debris and will reduce repair or replacement costs, should the upper section survive the storm.

Wind

1. Roof structures and roofing elements are particularly vulnerable to hurricane winds. Roof gable and shed roof ends must be braced to resist wind forces as recommended in the cited publications. Hip-style roofs are more wind resistant and normally perform better than other styles in hurricanes.
2. Asphalt roof shingles are the predominant roofing material found in coastal areas. The Texas Department of Insurance (TDI) currently allows Class F shingles, rated to 110 mph by the old ASTM D 3161 Standard, to be installed in all three Designated Catastrophe Areas (**Figure 7**). The Seaward Zone and the Inland I Zone are respectively 130 mph and 120 mph wind zones.

Products meeting the newer ASTM D 7158 Standard are available that meet the wind zone requirements. The Class F shingle should only be allowed in the Inland II, 110 mph Zone. The D 7158 shingle, though more expensive than the D 3161, Class F shingle, it is tested to meet the higher wind speeds in the Seaward Zone (Class H shingle) and in the Inland I Zone (Class G shingle).

3. Building felts are nailed to the roof decking to form a secondary moisture barrier below the shingles. Storm damage observations reveal that the building felts are routinely blown off the decking, along with the shingles. Taping of the joints formed by the overlapping felts had disappointing results in Hurricane Ike. It is therefore recommended that the secondary moisture barrier consist of either mopped felts or a self-adhesive membrane. Damage to home contents from water intrusion represents a large percentage of insurance claims.

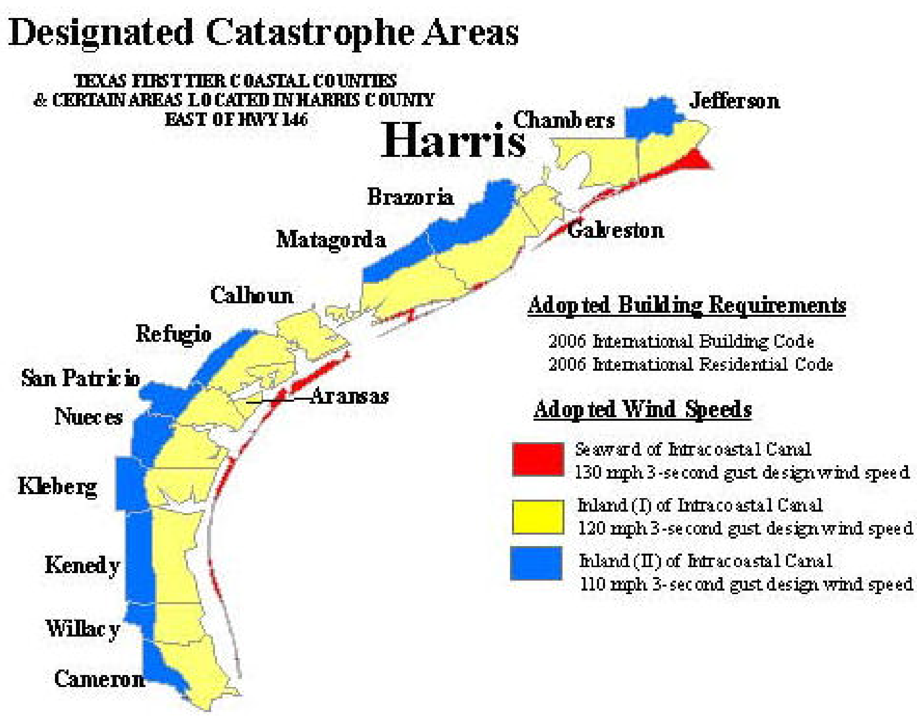


Figure 7. Texas Windstorm Designated Catastrophe Areas

4. Wall cladding materials are vulnerable to hurricane winds, and have been observed to fail when subject to less the “Code Design” winds. Cladding failure is normally associated with installation of “Non-High Wind Zone” products or with installation methods not consistent with manufacturer recommendations for high wind zones. This is a code compliance issue and not a cost issue.
5. Protection of openings is required by TDI in the Seaward and Inland I Zones. The opening protection of choice by most homeowners is plywood. Though

effective, it is difficult and dangerous to install over high windows and is frequently omitted on the non-seaward side of the dwelling. Plywood or shutters should be installed over all openings to protect the home from damage by wind pressures and rain. Though expensive, permanently mounted shutters could be installed over inaccessible or difficult to access openings. Costs for permanent shutters vary by quantity, size, and shutter selected. A less expensive alternative to shuttering inaccessible windows is to install windows with hurricane impact resistant glazing.

Summary of Mitigation Costs

NC	No Cost	MC	Moderate Cost
LC	Low Cost	HC	High Cost

Retrofitting Existing Homes		
1	Install flood vents in non-breakaway walls	LC
2	Install flood vents in solid breakaway walls	LC
3	Improve and replace observable metal connectors and connections	LC
4	Provide additional elevation to home (BFE + 3-ft. Freeboard)	HC**
5	Provide gable end bracing	MC
6	When re-roofing, re-nail decking	LC
7	When re-roofing, tape felt underlayment joints	LC
8	When re-roofing, additional cost for Class G shingles (120 mph)	MC*
9	When re-roofing, additional cost for Class H shingles (130 mph)	MC*
New Home Construction		
1	Elevate homes to BFE + 3-ft. Freeboard*	MC**
2	Install frangible parking slabs instead of reinforced concrete slabs	NC
3	Install flood vents in solid breakaway walls	LC
4	Construct tall breakaway wall in two horizontal breakaway sections	LC
5	Up charge to install Class G shingles (120 mph) over Class F (110 mph)	MC*
6	Up charge to install Class H shingles (130 mph) over Class F (110 mph)	MC*
7	Up charge to install substantial secondary roofing moisture barrier	MC*
8	Install hurricane windows in inaccessible locations	MC*

*Cost as compared to traditional construction or as indicated.
**Anticipated flood insurance premium reduction.

Hurricane Evacuation Shelters[15]

"The Texas coastal area population has grown more rapidly than the capacity of transportation facilities, resulting in congestion or even entrapment, thus creating hazards greater than the one prompting the evacuation. Evacuations are expensive for individuals and communities. Business interruptions are among the greatest of evacuation costs. Many options are available in safe rooms and in building design to improve safety and to reduce economic loss from extreme winds."[15]

The design of "Safer Areas of Refuge" and hardened safe rooms is contingent upon the perils anticipated. Tornadoes represent perils of extreme wind speeds, rain, and hail. Though hurricanes frequently spawn lower speed tornadoes, the greatest perils include high wind speeds, torrential rains, and flooding. Examples of building envelope hurricane resistance standards include those of TDI, Florida, and South Carolina. These standards address protection of building contents from extreme water intrusion, but do not address life safety. In 1997 the State of Florida enacted legislation requiring state university, college, and public school facilities be upgraded to serve as "Enhanced Protection Areas" for hurricane evacuees. The designated locations were selected based upon their perceived envelope resistance. The enhanced areas have generally performed well during recent hurricanes; however a few experienced problems that resulted in relocation of evacuees to other locations.

In 2000, FEMA published the first edition of *FEMA 361, Design and Construction Guidance for the Design of Community Safe Rooms.*[16] In 2008, the *ICC-500 Standard for the Design and Construction of Storm Shelters* was adopted for the *2009 International Building Code* to provide guidance for the construction of tornado and hurricane residential and community safe rooms.[17] Under this standard, community safe rooms were further identified as tornado, tornado/hurricane, or hurricane, and were based upon the differing wind speed and impact criteria. The FEMA 361 publication was updated in 2008 to specifically include hurricane safe rooms and identify parallels and comparisons between it and the ICC-500 Standard.[18] Both standards utilize the same wind speed criteria, but somewhat differ in impact criteria, with the FEMA 361 missile speed being slightly higher. Both standards provide sufficient hardening against wind forces and debris impacts specifically related to the intended peril to provide life safety protection.

Currently the State of Texas has a Hazard Mitigation Program funded by FEMA to provide grant assistance for safe room construction, most of which have been residential.[19] It is recommended that the State encourage the construction of FEMA/ICC-500 Hurricane Safe Rooms in the coastal areas when new schools and community structures are being planned. The incorporation of safe rooms in a host building, such as a school, represents approximately 6%-8% up-charge over traditional construction, whereas stand-alone community safe rooms can cost as much as $200-$300 per square foot. Although more costly to construct, stand-alone community safe rooms are frequently multi-use spaces, small gyms, community centers, etc.

Summary

Low cost to moderate cost measures can be implemented to improve existing home performance subjected to hurricane winds. However, little can be done to protect the home from water and waves if the home is built too low. For new construction, reasonable hurricane resistant construction codes, standards and guidelines currently exist and have proven to be effective. Constructing new homes to elevations that include freeboard, represent a modest increase over current coastal construction costs and provides the homeowner the benefit of a lower flood insurance premium.

It should be understood that codes and standards represent design/construction minimums and too often these minimums are compromised by poor construction practices and a lack of code enforcement. In essence, hurricane resistance is a function of better educated designers and constructors; and improved inspection. It should be also noted that new homes constructed outside of code enforcing jurisdictions are seldom inspected.

With the population growth of the Texas coastal areas, wholesale evacuation will soon not be an option. The lower Rio Grande Valley region is especially vulnerable to loss of life from hurricanes because large numbers of people are unable to evacuate due to personal limitations. The transportation infrastructure in this area is also inadequate to support such a massive evacuation. The State of Florida has already identified "Non-Evacuation Zones" outside of flood prone areas. Minimally and similarly to Florida, Texas should identify "Enhanced Protection Areas" to house those that must evacuate. However, given the life safety concerns for housing masses of people in non-hardened protection areas, it is recommended that the State encourage and support the construction of hardened community safe rooms that meet the FEMA/ICC-500 standards.

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Curriculum Vitae

Larry J. Tanner

Registered Professional Engineer/ State of Texas
Registered Architect / States of Texas, Oklahoma & Pennsylvania
Graduate Texas Tech University, 1971, Architectural Engineering

Larry Tanner spent 20 years in the private sector in the practice of architecture and structural engineering. His public sector work includes nine years as the Director of Facility Planning and Construction at Texas Tech managing campus design and construction.

Currently, Larry Tanner is an adjunct professor and a research associate in the Wind Science and Engineering Research Center (WISE) and manager of the WISE Debris Impact Test Facility. His fields of research include storm protection utilizing above ground in-residence shelters and building performance during extreme storms. His storm investigations and documentation include the following:

- Spencer, South Dakota Tornado in 1998
- Oklahoma and Kansas 1998 Tornadoes (member of FEMA MAT Team)
- Tuscaloosa, Alabama 2000 Tornado
- Happy, Texas 2002 Tornado
- Ohio 2002 Tornadoes
- Southwest Missouri and Oklahoma City Tornadoes - May, 2003
- Hurricane Ivan, Pensacola, Florida - September, 2004
- Hurricane Katrina, 2005 (member of FEMA MAT Team)
- Evansville, Indiana 2005 Tornado
- Central Florida Tornadoes, 2007
- The Super Tuesday Outbreak - Tennessee Tornadoes, 2008
- Hurricane Ike, Texas and Louisiana, 2008

His reports and written contributions to storm research include documentation of the listed storms and collaboration with FEMA in the writing of FEMA 320, *"Taking Shelter from the Storm;,"* FEMA 361, *"Design and Construction Guidance for Community Shelters;"* FEMA 342, *"Building Performance Assessment Report of Midwest Tornadoes of May 3, 199;"*authorship of the Evansville Tornado Report, "A Focus on the Eastbrook Mobile Home Park;" co-authorship of FEMA Publication 549, "*Hurricane Katrina in the Gulf Coast, Observations, Recommendations, and Technical Guidance;*" the *"Central Florida Tornadoes Damage Documentation of 2007 Using the Enhanced Fujita Scale;"* and co-authorship of the 2008 revisions of FEMA 320 and 361; and co-authorship of FEMA Publication 757, *Hurricane Ike in Texas and Louisiana*.