Texas Senate Subcommittee on Flooding and Evacuations
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Testimony Regarding Design and Retrofit of Commercial/Public Structures for Hurricane Evacuation Shelters

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Mr. Chairman and Committee Members, thank you for inviting me to speak to you today. Recent hurricanes along the Gulf Coast have highlighted the need and importance of hurricane evacuation shelters. Several national standards have been adopted over the past ten years that govern to the design of hurricane evacuation shelters. I would like to discuss these design standards briefly today and provide an indication of the costs of designing or retrofitting commercial and public structures to meet these standards.

The American Red Cross was among the first organizations to develop guidelines for selecting hurricane evacuation shelters [1]. These guidelines address acceptable locations for shelters, structural design criteria, risks due to hazardous materials, and space recommendations for each shelter resident. These guidelines alone are not sufficient to design or retrofit a hurricane shelter, but they summarize the lessons learned during Hurricane Andrew in Florida in 1992. For example, many large public or commercial buildings in the immediate hurricane impact area are not viable emergency shelters because they are located within the storm surge inundation zone for a Category 4 hurricane, located within the 100-yr floodplain, located on a barrier island, constructed before modern structural design codes were adopted in the community, or constructed from unreinforced masonry or other structural material that is susceptible to wind damage during extreme storms.

Shortly after Hurricane Andrew, the State of Florida began a program to increase the number of hurricane evacuation shelters throughout the state [2]. In addition to adopting higher design wind speeds than the national standards [3] in several high-risk areas, the 2007 Florida Building Code [4] includes provisions that portions of new public school buildings must be designed as enhanced hurricane protection areas. These enhanced hurricane protection areas provide at least 20 ft^2 for each evacuee and are designed to provide emergency shelter and protection for up to 8 hours. Specific design requirements for enhanced hurricane protection areas include:

- The minimum floor elevation must be above the maximum storm surge inundation elevation associated with a Category 4 hurricane.
- Wind design loads are 15% higher than those for buildings with regular occupancy. (The enhanced hurricane protection areas must be designed as essential facilities in accordance with national design standards [3].)
- All door, window, and roof openings must be designed for impact caused by wind-borne debris.
- All roof systems must be rain resistant and anchored against wind uplift.
- Emergency overflow scuppers on the roof must be sized for 6 hours of rainfall associated with the design hurricane.

- At least one emergency vehicle access route must be above the 100-yr floodplain.
- Parking for evacuees must be at least 50 ft from the building to reduce the risk of rollover hazards.
- Landscaping around the building must not represent a laydown or impact hazard for the building envelope.
- A standby emergency electrical power system must be provided.

In addition to the design guidelines, special inspection of the enhanced hurricane protection areas is also required:

- Inspection of the building and emergency electrical systems is required during construction.
- All shutter systems, roofs, overflow scuppers, structural systems, and emergency power systems must be inspected before the hurricane season begins each year and after each major hurricane.
- All structural systems must be inspected and recertified for compliance every five years by a professional engineer.

The Florida Division of Emergency Management develops an annual report to document their progress toward increasing the number of hurricane evacuation shelters. The 2007 report [5] notes that buildings designed and constructed before the mid-1980s rarely meet the structural criteria in the American Red Cross guidelines [1] and typically require major structural renovations to serve as hurricane evacuation shelters. In most cases, renovation of these older buildings was not considered to be cost-effective.

Using the Florida Building Code, buildings constructed in accordance with the modern, national standards for wind loads [3] (buildings constructed since the late 1980s) can often be retrofit by installing window protection or reinforced doors [6] to address shelter requirements for debris impact. The average cost of retrofitting buildings in this category was approximately $150 per evacuee space (in 2007 dollars) [5]. The cost of complying with the Florida Building Code provisions for enhanced hurricane protection areas for new construction was estimated as increasing the cost of constructing a new school building by 3 to 6% [5].

In spite of the design standards for enhanced hurricane protection areas, significant structural damage (Figure 1) was observed at a modern, hurricane evacuation center in Arcadia, Florida during Hurricane Charley in 2004 [7, 8]. Approximately 1,400 evacuees were housed in the building at the time of that the roof and exterior walls began to collapse. After the hurricane, it was determined that the building had not yet been evaluated for compliance with the enhanced hurricane protection areas design requirements [7], raising the possibility that this shelter had not been designed in accordance with the Florida provisions. Wind damage to roofs, cladding, and gutters led to rainwater intrusion was observed in several other shelters, however [7, 9].

Figure 1: Turner Agri-Civic Center Damage Caused by Hurricane Charley [7]

More recently, two national standards have been developed that specifically address the design of hurricane and tornado shelters. The ICC 500 [10] provisions for community hurricane shelters are more stringent than the Florida Building Code [4] provisions for enhanced hurricane protection areas. For example, the design wind speeds are higher, design loads corresponding to debris missiles are considerably higher, and the minimum floor elevation must be above both the 500-yr floodplain and the maximum storm surge inundation elevation associated with a Category 5 hurricane.

The FEMA 361 provisions [11] for safe rooms are even more conservative than those in ICC 500 and are intended to provide "near-absolute protection" to the occupants. Because most residents are able to evacuate the immediate impact area before a hurricane, the FEMA 361 provisions are intended only for first responders and individuals who are physically unable to leave the immediate impact area [11].

The recent development of ICC 500 [10] and FEMA 361 [11] provides specific guidance regarding the design and construction of hurricane shelters and safe rooms. The 2009 edition of the International Building Code [12] adopts ICC 500 by reference. Therefore, these provisions will govern the design of hurricane shelters once communities in Texas adopt the 2009 IBC.

FEMA 361 [11] provides cost data from recent community safe room projects. Assuming a basic wind speed from the model building code of 140 mph, the incremental cost of hardening a portion of a new building to create a safe room with a 250-mph design wind speed is estimated to be 5 to 7% [11], based on the area of the safe room. The basic wind speed along the Texas Gulf Coast ranges from 130 to 140 mph [3]; therefore, these costs are considered to be representative of new construction in Texas, and are similar to the reported costs in Florida [5].

It is important to note, however, that observed damage during hurricanes is often attributed to minor changes from the original design [13]. Therefore, it is important that if Texas adopts a

policy of constructing hurricane evacuation shelters, the requirements for periodic inspection of be adopted as well.

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